A text-book of the science and art of bread-making : including the chemistry and analytic and practical testing of wheat, flour, and other materials employed in baking / by William Jago.

Contributors

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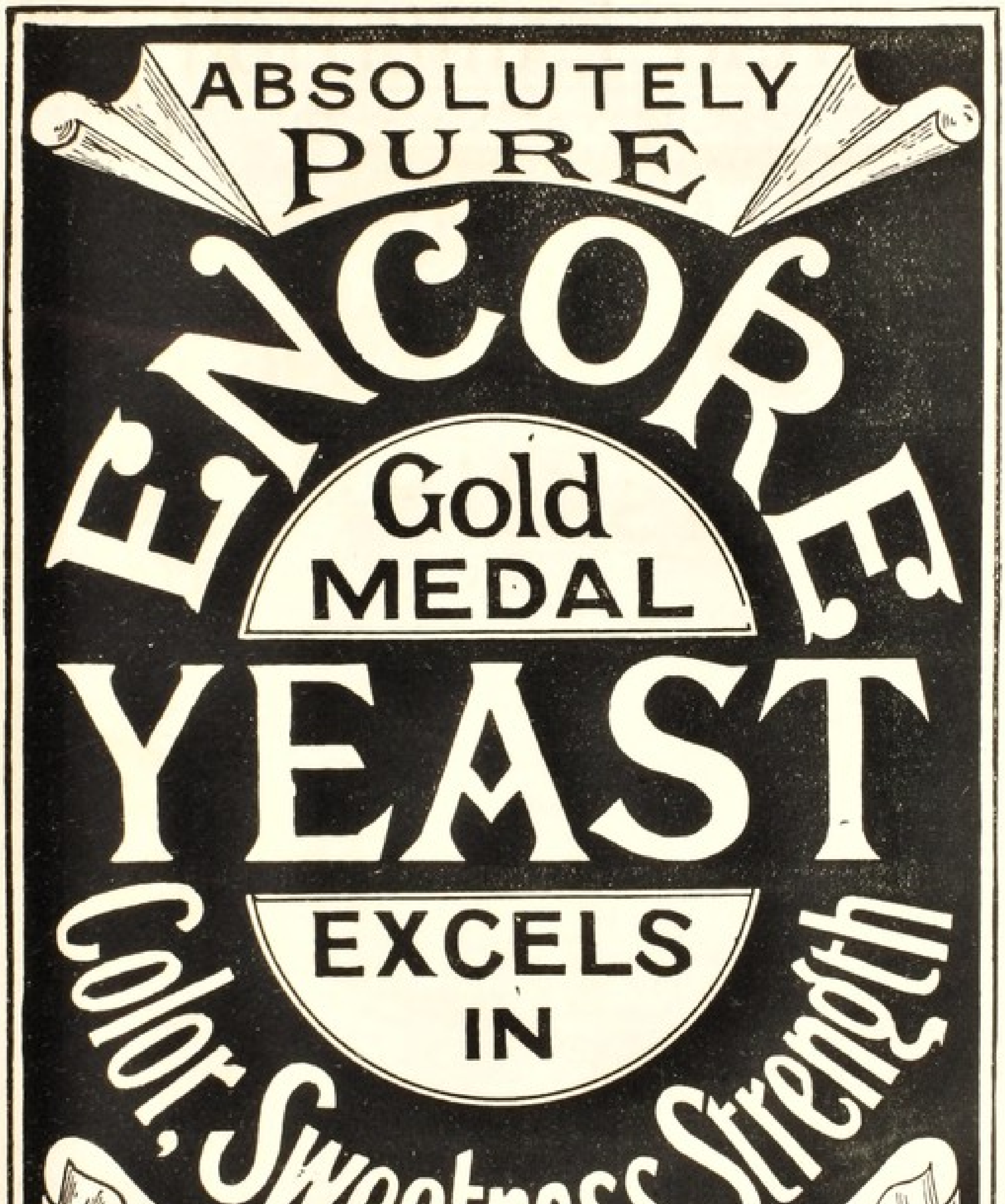
MADE WITH ENCORE YEAST
ONE OF THE 'ENCORE' YEAST FACTORIES.
FISHER



FINEST

M.B.D. Hungarian Flour. M.B.D.

ALL THE HIGHEST AWARDS

for Vienna Bread and French Pastry at the Exhibition were obtained by users of this Brand, viz., Messrs. T. WATT & SON, Silver Medal and Diploma for London made Vienna Bread; CLARK'S BREAD FACTORY, Silver Medal and Diploma for country-made Vienna Bread; FIETTA BROS., Medal and Diploma for Continental Pastry.

Used in all his Mixtures by Mr. HENRY CARTWRIGHT, who was so Highly Successful.

Also the Two Only Medals for Vienna Bread in Indoor Competition.

Awarded the only Gold Medal for Flour at the International Health Exhibition, London, 1884.

Mr. W. JAGO, F.C.S., F.I.C., reports as follows:—

"32, Clarendon Villas,
"Brighton, 19th April, 1895.

"I have received from Mr. C. Waydelin a sample of his well-known brand of Hungarian Patent Flour, M.B.D.O., for purposes of Analysis and Baking Tests. Employing the methods described in my work on Bread-making, the following results were obtained:—

Gluten,	Wet, ...	32·60	per cent.
	Dry, ...	10·69	„
	'True,'	9·20	„
Moisture,		9·50	„
Water Absorption by Viscometer, Quarts per Sack,		78·0	„
Colour on Pékarised Flour,		0·90 Yellow + 0·35 Red.	

A Baking Test was made with the following quantities:—

Flour, 560 grams; Water, 390 grams = 78 Quarts per Sack.

The Fermented Dough weighed 942 grams = 107·5 Quarterns to the Sack; weighed in at 4 lb. 6 oz.

The weight of the Baked Loaf, 12 hours old, was 821 grams = 102·6 Quarterns to the Sack.

The bloom of the baked bread was exceedingly good, its colour registering 1·5 Yellow + 0·5 Red. The volume was fair, texture good, pile good. The flavour was very sweet, and the loaf pleasantly moist.

"I have been acquainted with the M.B.D. Flour for at least ten years, and can speak in the highest terms of its general uniformity and excellence. It belongs to the highest class of Hungarian flours, and can with confidence be recommended to the favourable attention of bakers of highest class bread.

"(Signed) WILLIAM JAGO."

M.B.D. SOLE AGENT— **M.B.D.**

CHARLES WAYDELIN,

45, Borough High Street, LONDON, E.C.

NATIONAL ASSOCIATION

OF

Master Bakers & Confectioners

OF

GREAT BRITAIN AND IRELAND.

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Annual Subscription of Half-a-Guinea,

every member is entitled to the following three of many advantages:—

1. The official "Review" of the Association, published post free to members every month.
2. A £500 Free Insurance Policy against Fatal Injury by Train, Tram, or Bus.
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General Objects of the Association.

The general objects of the Association are to concentrate and bind together the influence, experience and power of the members of the trade; to protect its members and the trade from vexatious restrictions and impositions; to secure the repeal of all laws that harass the trade; to establish a benevolent fund for distressed members; to educate bakers and confectioners in the science and art of their calling, by promoting lectures, competitive examinations, and other available means; generally to promote good fellowship; to raise the status of the trade; to take all steps deemed advisable in the interests of bakers and confectioners; and to publish to every member a monthly journal entitled "The National Association Review."

Secretary—A. W. LAST, 23, Burlington Chambers, Birmingham.

Names and Addresses of Millers whose Flours are described in the body of this Work.

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VERNON, WILLIAM, & SONS, The Atlantic, Brunswick Street, Liverpool,	550
WASHBURN CROSBY CO., Minneapolis, Minn., U.S.A.,	550

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THE
SCIENCE AND ART
OF
BREAD-MAKING.

BY THE SAME AUTHOR.

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A TEXT-BOOK
OF THE
SCIENCE AND ART
OF
BREAD-MAKING;
INCLUDING
THE CHEMISTRY
AND
ANALYTIC AND PRACTICAL TESTING
OF
WHEAT, FLOUR, AND OTHER MATERIALS
EMPLOYED IN BAKING.

BY
WILLIAM JAGO, F.I.C., F.C.S.,
CHEMIST TO THE NATIONAL ASSOCIATION OF MASTER BAKERS AND CONFECTIONERS
OF GREAT BRITAIN AND IRELAND;
HONORARY CONSULTATIVE EXAMINER IN BREAD-MAKING
TO THE CITY AND GUILDS OF LONDON INSTITUTE FOR THE ADVANCEMENT OF
TECHNICAL EDUCATION;
CANTOR LECTURER ON "MODERN DEVELOPMENTS OF BREAD-MAKING"
TO THE SOCIETY OF ARTS, LONDON, ETC.

LONDON:
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1895.

10822

LESLIE, PRINTER, PERTH.

PREFACE.

As indicated by the title, the subject matter of the present work is essentially that of the Science and Art of Bread-making. The mode of treatment is described in the opening paragraph of the introductory chapter, but some further few words of explanation of its object may appropriately be given here.

Among the classes to whom the book appeals there are many whose scientific library is somewhat scanty; and still more to whom it is at least a great convenience to have their scientific explanations self-contained in the one treatise. In deference therefore to the representations of those best fitted to speak on behalf of the practical baker, the work commences with a brief description of elementary chemistry and physics in so far as they apply to bread-making. For the same reason, explanations of many other matters are written more fully than necessary for scientific readers, who it is hoped will not be inconvenienced by the presence of these details, which are likely to prove of material assistance to the baker-student.

In the more purely scientific section of the book, the aim has been to discuss fully and exhaustively all that has a bearing on Chemistry and Fermentation in their application to Bread-making. No pains have been spared to render the matter absolutely authentic, and to embody the results of the most recent researches on these subjects. Prominent among such are the investigations of O'Sullivan, Brown, Heron, Morris, and Moritz on the Carbohydrates. The exhaustive researches of Osborne and Voorhees on the Proteids of Wheat are also included, as likewise are those of Hansen and Jörgensen on Fermentation and Yeast. The author himself contributes the results of researches on Diastase and Malt Extracts generally in their relation to Bread-making.

As a subject of considerable interest to the miller, the physiology of grain life, together with the chemical composition of wheat, flour, and other milling products, is somewhat fully discussed.

In the practical section of the work, the principles of modern bread-making, together with their application to the manufacture of different varieties of bread, are extensively described. A very complete summary of various contributions to the literature of Sour Bread is given, concluding with a description of recent investigations by the author. The subject of Bakehouse Design is treated systematically, being illustrated by a number of typical plans prepared by the author, and reproduced as plates. (The descriptive matter of these is partly derived from a lecture by the writer on Bakehouse Design, delivered some years ago at the Heriot-Watt College, Edinburgh, and partly from some original articles contributed by him to the *British Baker and Confectioner*, the well-known standard monthly trade journal.) There follows a detailed account of the nature and method of management of the motive power, and various machines employed in a bakery. It is hoped that these chapters may be of special service to master-bakers, foremen, and others having charge of bakeries, and particularly modern machine plants and ovens.

The work also comprises a description of the methods of analytic, baking and other tests on wheat, flour, yeast, and other materials employed by the baker. The examination of flour is in particular treated very fully; included in this section are tabulated results of the examination of large numbers of flours specially obtained for the purpose of this work. It is hoped that these will be of value not only to bakers as buyers of flour, but also to all millers and flour merchants, who are interested in a record of the quality and character of typical and standard flours.

In the preparation of the present book, the author has been primarily guided by the object of providing a work of service to every Baker and Miller who wishes to know as much as possible about wheat, flour, and bread-making. But he also hopes to have furnished information that will be of value to Yeast Brewers and Manufacturers, Engineers, Farmers, and others who are more or less directly connected with milling and baking industries.

The writer also feels that his subject appeals strongly to members of his own profession, and trusts that as a specialised work of reference on the Chemistry and Analysis (commercial and otherwise) of flour, bread, and yeast, the book will prove of service to Chemists.

He further ventures to express the opinion that to members of the Medical Profession generally, all of whom are interested in food and dietetics, and particularly to Medical Officers of Health, the work should prove of value. To those who, as medical superintendents and officers of asylums, prisons, work-houses, hospitals, and other public institutions, have the responsibility of seeing that provision is made for the healthy, efficient, and economical manufacture of bread, he believes it will continually be of great assistance. The author can at least claim that in writing the book, he has throughout studied to meet the requirements and difficulties of those here indicated.

The writing a preface affords one the opportunity of thanking those to whom he is indebted for help received in scientific work. It is with great pleasure that the author in the first place acknowledges the kindly and courteous reception given to his previous works on the same subject, by the whole Press, both technical and scientific. Many of the various suggestions and recommendations of his critics have borne fruit in the present book, and in every case they have received the most careful attention and consideration of the writer.

It is almost impossible to acknowledge the whole of the kindness received from fellow scientists while engaged in work of this description. The author wishes, however, to specially thank the following:—

Drs. Morris and Moritz, authors of *A Text Book of the Science of Brewing*, and Messrs. Spon, publishers of the same, for having placed at his disposal various Plates from that work which are reproduced as Plates III., IV., and V. of the present book.

Dr. Alfred Jörgensen, Director of the Laboratory of the Physiology and Technology of Fermentation at Copenhagen, author of *Micro-organisms and Fermentation*, and Mr. F. W. Lyons of Eastcheap Buildings, E.C., publishers of the same, for the loan of blocks for Figures 10, 11, 12, 14, and 15.

Dr. S. H. Vines, author of *Lectures on the Physiology of Plants*, for the loan of block for Figure 40.

Among books to which the author wishes to express his special acknowledgments are Morris and Moritz's *Science of Brewing*, Jörgensen's *Micro-organisms and Fermentation*, and Halliburton's *Chemical Physiology and Pathology;* the previous existence of these works has materially lightened the author's labours (always sufficiently heavy) in the direction of reading and comparing original memoirs and papers. He also thanks Mr. Voller for having freely placed at his disposal the subject matter of his excellent work on *Modern Milling;* to this he is indebted for the Dictionary of Wheat given on pages 296-7.

To Mr. S. A. Vasey, F.C.S., the author is indebted for a number of references in connexion with researches on the proteids. His thanks are also due to his pupils, Messrs. W. Chitty, of Dover, and W. T. Callard, of Torquay; and also his assistants, Messrs. Stamp and Fuller, for much help rendered in making the various analytic and baking tests recorded in this book, and in the preparation of the drawings for the various illustrations and plates.

In conclusion, the writer would say that no effort of his has been spared to put the very best work of which he is capable into the present treatise. In this spirit he commends the book to the favourable consideration of those classes of readers to whom it specially appeals.

WILLIAM JAGO.

London, E.C.,
Cornwall House, 35, Queen Victoria Street,
and Brighton,
May, 1895.

CONTENTS.

THE SCIENCE AND ART

OF

BREAD-MAKING.

CHAPTER I.

INTRODUCTORY.

1. General Scope of Work.—The object of the present Work is to deal, in the first place, with those branches of knowledge which together constitute the scientific foundations of Bread-making as a science in itself. Paramount among these is—

Chemistry.

With which is closely associated—

Heat and its properties.
Fermentation and the Biology of Micro-organisms.
Vegetable Physiology in its relation to the Wheat Plant.
Microscopy.

Next, viewing Bread-making as an Art or Industry, the design of Bakeries and adaptation of Machinery for various purposes is fully discussed. Following on this is a description of the various processes and operations involved in the Commercial Manufacture of Bread, together with an investigation of the many important practical problems connected therewith.

The more purely analytical section of the Work includes detailed directions for the commercial testing and valuation of flour, yeast, and other bread-making materials; in addition to which there are also given approved methods for the commercial and complete chemical analysis of such substances. The results of a number of original chemical researches are also embodied, and are here for the first time made public.

It is not proposed to adhere to any very rigid classification, but to so arrange the subject matter as seems most likely to meet the requirements of the majority of readers.

2. Matter.—The bodies with which we are surrounded present an almost endless diversity of colour, appearance, and other characteristics.

One property they however all possess in common, and that is the property of *weight*. All bodies are attracted by the earth, and any substance is said to be heavy because of the resistance which it offers to this earth-attraction or gravitation. Not only are solid bodies, such as iron and wood, possessed of weight, but so likewise are liquids, such as water and oil, and also gases, such as, for example, common air, or coal-gas. It is convenient to have one name for all bodies which possess weight, and for this purpose, in English, the term *Matter* is employed. **Matter, then, is anything which possesses weight (i.e., is acted on by gravitation), and exists in three distinct forms, namely, as solids, liquids, and gases.**

3. Force.—The definition of matter just given would seem at first sight sufficiently comprehensive to embrace everything of which we can take cognisance, but yet a moment's reflection shows the existence of other things beside matter. An illustration best demonstrates this fact—A hammer-head is known to consist of matter because it possesses weight; but if with this hammer-head you give a series of blows to a small piece of nail-rod, you have given the nail-rod something which is not matter. The hammer-head is not lighter, nor is the nail-rod heavier—still the blows are something, as otherwise they could produce no effect. For one thing, the nail-rod will have been flattened and altered in shape; further, and which is of far more present importance, it will have become hot to the touch. Again, to make use of another illustration, if a dry brick be carefully weighed and then made red hot in a furnace, it will be found to weigh when hot precisely the same as it did when cold. Further, this brick, if allowed to become cold, imparts heat to surrounding objects, and nevertheless remains unaltered in weight. Here, then, is something very definite which a body can receive and again yield, and which is not matter. This something has, however, a very direct relation to matter; in the first illustration the blows were struck by the moving hammer-head, which consists of matter in motion. The more rapid the motion, the more violent would be the blows; in fact the force of the blow depends both on the quantity of matter and the rapidity of its motion. A number of considerations lead to the belief that the hot iron of the nail-rod and also the hot brick differ from the same substances in the cold state, in that their component particles are in a state of movement; as these substances cool, the particles once more enter into a condition of comparative rest. This something beyond matter is closely associated with motion, and is termed force. **Force is defined as that which is capable of setting matter in motion, or of altering the direction or velocity of matter already in motion.** The motion of bodies may be divided into two classes: there is, first, that of the body as a whole, as in the case of the moving hammer-head; second, the internal movements of the particles of a body, as when it becomes hot.

ELEMENTS OF HEAT.

4. Heat, its Nature and Effects.—Among generally observed facts with regard to heat, one of the first and most important is that it induces the sensation of warmth. According to the character and degree of this sensation, a body is said to be cold, warm, or hot. The conditions which produce this sensation of warmth also cause other well-marked changes in the physical condition of substances. The general effects of heat are to cause bodies as they get hot to expand in volume; further, solids are reduced to the liquid state; and, with still further increments of heat, liquids are converted into gases. The opposite series of changes occur as heat is abstracted from bodies. From the explanation of Force given in the preceding paragraph, it will be understood that these changes are not accompanied by any addition or diminution of weight. On the contrary, **Heat is viewed as a form of Force, and is regarded as a mode or variety of internal motion of the particles of bodies—the hotter they are, the more violent and energetic is this motion.**

5. Measurement of Heat: Temperature.—The earliest and most accessible measure to be applied to heat is that of the sensation of warmth before referred to, and according to whether a body to the touch is hot or cold, it is said to be of high or low temperature. Temperature is, in fact, the measure of what is popularly termed "how hot a body is;" it will be seen on consideration that this depends on the power the body has of imparting heat to another body. Thus, if when the hand is thrust into water, the water is able to yield heat to the hand, it is said to be "hot," while if it robs the hand of heat it is said to be "cold." The measure of this power is termed temperature, and is more exactly embodied in the following definition:—**The temperature of a body is a measure of the intensity of its heat, and is further defined as the thermal state of a body considered with reference to its power of communicating heat to other bodies.**

6. The Thermometer.—For scientific, and also for most technical purposes, the sensations are not sufficiently accurate methods of measuring temperature; accordingly temperature is usually measured by certain of the effects which heat produces: the most convenient for this purpose is the expansion of liquids with an elevation of temperature. For the general purposes of temperature measurement, the metal mercury is the most convenient substance. This liquid, enclosed in a suitable vessel, constitutes the temperature-measuring instrument termed a thermometer. In constructing a thermometer, a bulb is blown at one end of a glass tube of very narrow bore; the bulb and tube are next filled with carefully purified mercury; this is boiled, and thus all air and moisture are driven out of the tube; the open end is then hermetically sealed by fusing the glass itself. At this stage the bulb and a portion of the tube are filled with mercury, the remainder of the tube being a vacuum, save for the presence of a minute quantity of mercury vapour. On heating the bulb of this instrument, the mercury expands and rises considerably in the stem. Throughout any body, or series of bodies in contact with each other, heat has a tendency to so distribute itself that the whole series shall be at the same temperature; consequently if the thermometer be placed in contact with the body whose temperature it is desired to measure, a redistribution of heat occurs, until the two are at the same temperature. That is to say, if the body be the hotter, it yields heat to the thermometer; and if it be colder, it receives heat from the thermometer, until the temperature of both is the same. The two being in efficient contact, this stage is indicated by the mercury becoming stationary in the thermometer. Now, the volume of mercury is constant for any one temperature; therefore, to register temperature, it is only necessary to have further a scale, or series of graduations, attached to the stem of the instrument, by which the temperature may always be read.

7. Thermometric Scales.—Subject to certain precautions, the temperatures of melting ice and of steam in contact with boiling water are constant. The height at which the mercury stands when immersed in each of these is marked on most thermometers; for the registration of other temperatures some system of graduation must be devised. The one most commonly employed in this country is that of Fahrenheit, while for scientific purposes that of Celsius, or the Centigrade Scale, is almost universally adopted. Fahrenheit divided the distance between the melting and boiling points of his thermometer into 180 degrees; degrees of the same value were also set off on either side of these limits. At 32 degrees below the melting point he fixed an arbitrary zero of temperature, from which he reckoned. On his thermometric scale, the melting point is 32°, while the boiling point is $32 + 180 = 212°$. Degrees below the zero are reckoned as – (minus) degrees, thus $-8°$ means 8 degrees below zero, or 40 degrees below the melting point; degrees above 212 simply reckon upwards, 213, 214° F., &c.

The Centigrade Scale is much simpler, the melting point is taken as 0° or zero, and the boiling point as 100°, temperatures below the melting point are reckoned as – degrees.

The conversion from one to the other of the Centigrade and Fahrenheit Scales may be easily performed.

180 Fahrenheit degrees = 100 Centigrade degrees.
9 ,, ,, = 5 ,, ,,
1 ,, degree = $\frac{5}{9}$,, degree.
$\frac{9}{5}$,, ,, = 1 ,, ,,

There is this important difference between the two scales—Centigrade degrees count from the melting point, while Fahrenheit degrees are reckoned from 32 below the melting point.

$$30° \text{ C.} = 30 \times \tfrac{9}{5} = 54 \text{ Fahrenheit degrees.}$$

Therefore 30° C. are equivalent to 54 Fahrenheit degrees above the melting point, but as the melting point is 32, that number must be added on to 54; the temperature Fahrenheit equal to 30° C. is 86°. By the reverse operation, Fahrenheit degrees are converted into degrees Centigrade. The following formulæ represent the two operations:—

$$\frac{C° \times 9}{5} + 32 = F°. \qquad \frac{(F° - 32) \times 5}{9} = C°.$$

The following table gives the equivalent readings on the two thermometric scales for some of the most important temperatures:—

−40° C. = −40° F.
−17·7 ,, = 0 ,,
0 ,, = 32 ,,
15 ,, = 59 ,,
15·5 ,, = 60 ,,
20 ,, = 68 ,,
21·1 ,, = 70 ,,
25 ,, = 77 ,,
26·6 ,, = 80 ,,
30 ,, = 86 ,,
35 ,, = 95 ,,
40 ,, = 104 ,,
45 ,, = 113 ,,
50 ,, = 122 ,,
55 ,, = 131 ,,
60 ,, = 140 ,,
65 ,, = 149 ,,

70° C. = 158° F.
75 ,, = 167 ,,
80 ,, = 176 ,,
85 ,, = 185 ,,
90 ,, = 194 ,,
95 ,, = 203 ,,
100 ,, = 212 ,,
150 ,, = 302 ,,
200 ,, = 392 ,,
232·2 ,, = 450 ,,
250 ,, = 482 ,,
260 ,, = 500 ,,
287·7 ,, = 550 ,,
300 ,, = 572 ,,
316·6 ,, = 600 ,,
350 ,, = 662 ,,
400 ,, = 752 ,,

8. Quantity of Heat.—Temperature is not a measure of quantity of heat, for a thermometer would indicate the same temperature both in a vessel containing a pint, and one containing a gallon of boiling water, although it is evident that one must contain eight times as much heat as the other; further, to raise the gallon of water to the boiling point, eight times the amount of heat necesary to similarly raise the pint is required. This leads to the mode of measuring and registering *quantity* of heat. **Quantity of heat is measured by the amount necessary to raise a certain weight of some body from one to another fixed temperature. The amount of heat necessary to raise 1 gram of water from 0° to 1° C. is termed a Unit of Heat.** From this it follows that to raise 2 grams of water from 0° to 1° C. will require 2 Units of heat, or 2 H.U. Between the freezing and the boiling points, *approximately* the same amount of heat is necessary to raise 1 gram of water through any 1 degree of temperature, so that to raise 1 gram through 2 degrees will require approximately 2 H.U. For practically all purposes, it may be taken that the weight of water in grams × degrees of temperature through which it must be raised = the number of H.U. required.

9. Specific Heat.—The quantity of heat necessary to raise the same weight of different substances through 1 degree of temperature varies very considerably. **The quantity of heat necessary to raise 1 gram of any substance through 1 degree of temperature is termed its Specific Heat.** From this definition it follows that the specific heat of water at 0° C. is 1·00, or unity. The following table gives the specific heat of various substances:—

Substance,	Specific Heat.
Water,	1·00000
Alcohol,	0·61500
Glass,	0·19768
Iron,	0·11379
Copper,	0·09391
Mercury,	0·03332

If equal weights of water at different temperatures are mixed together, the result is a mixture having a temperature the mean of the two; thus a gallon of water at 20° C. mixed with a gallon at 50° C. will produce a mixture at the temperature of 35° C. But if equal weights of two substances of different specific heats be thus mixed, the temperature of the mixture of the two will not be a mean of those of the substances, but will be nearer that of the substance having the higher specific heat. The most important mixture with which the baker has to do is that of flour with water, as the temperature of the resultant dough is a matter of vital concern to him. The results are complicated by the presence of other ingredients, as salt and yeast, and also in practice by loss of heat through absorption by the surroundings of the dough, and heat generated by chemical action among the ingredients. The following are the results of laboratory experiments made by mixing together flour and water only, and carefully taking the temperatures, but not allowing for loss of heat absorbed by containing vessels:—

					Specific Heat.
500	grams of	flour at	67° F.	= 1000 at 118° F.	0·53
500	,,	water at	145° F.		
500	,,	flour at	67° F.	= 1000 at 93° F.	0·42
500	,,	water at	104° F.		
500	,,	flour at	67° F.	= 1000 at 80·5° F.	0·40
500	,,	water at	86° F.		

The specific heats are calculated from the above experiments in the following manner:—in the first experiment, 500 grams of water have fallen from 145° to 118°, that is 27°, during which they must have afforded 500 × 27 = 13,500 H.U. At the same time 500 grams of flour have been raised from 67° to 118°, that is through 51°, which is equal to 500 × 51 = 25,500 grams through 1°, and to do this 13,500 H.U. have been utilised; then to raise 1 gram through 1° there has been taken

$$\frac{13{,}500}{25{,}500} = 0{\cdot}53 \text{ H.U.}$$

therefore 0·53 is the specific heat of flour as derived from this experiment.

A number of observations have also been made on the temperatures of mixtures made in the bakehouse on the large scale for manufacturing purposes. The doughs were machine-mixed, and no allowance is made for the salt and compressed yeast, quantities of which were the same in all cases. The quantities, temperatures, and calculated specific heats are given in the following table:—

WATER.			FLOUR.		DOUGH.	FLOUR.
Quarts.	Llbs.	Temp.	Lbs.	Temp.	Temp.	Specific Heat
53	132·5	95°	205	52·5°	79·0°	0·39
51	127·5	90°	205	50·0°	77·0°	0·30
51	127·5	90°	205	50·0°	77·0°	0·30
53	132·5	98°	205	53·0°	79·0°	0·45
53	132·5	89°	205	53·0°	76·0°	0·36
53	132·5	89°	205	53·0°	76·0°	0·36

The whole of these figures, it must be remembered, are those obtained in experiments made under conditions such as hold in the bakehouse, and represent rather the result of actual working, than theoretic specific heats with all disturbing causes eliminated. In the case of the mixtures made at the higher temperatures, there is naturally a greater loss of heat, and this causes an increase in the corresponding apparent specific heats. In consequence of this, the No. 1 Laboratory Experiment gives a remarkably high figure; but the whole of the others lie fairly closely together. Comparing those above given with a large number of observations on the manufacturing scale since made, practically all the specific heat results range between 0·36 and 0·45, with a mean of 0·40, to which the majority approach most closely. Taking 0·40 as the working specific heat of flour, 1 unit by weight of water in falling through 1° raises 2·5 units by weight of flour through the same increment of temperature

10. Sources of Heat.—Directly or indirectly all available terrestrial heat is practically derived from the sun: its immediate source, however, for manufacturing operations is the combustion of different kinds of fuel; these give out different amounts of heat according to their composition. The following table gives the number of heat units evolved by the combination of one gram of each substance in oxygen:—

HEAT DEVELOPED DURING COMBINATION.

Substance.	Formula.	Heat Units.
Hydrogen,	H_2	34,462
Carbon,	C	8,080
Carbon Monoxide,	CO	2,634
Marsh Gas,	CH_4	13,063
Olefiant Gas,	C_2H_4	11,942
Alcohol,	C_2H_5HO	6,909
Welsh Coal,		about 8,241
Newcastle Coal,		,, 8,220
Derbyshire Coal,		,, 7,773
Coke,		,, 7,000
Wood (dried in air),		,, 3,547

11. Expansion by Heat.—It has already been mentioned that in most cases bodies expand under the influence of heat. Solids expand the least, and at a definite rate for each particular solid: liquids have a higher rate of expansion, each still having its own special rate; while gases expand at a far higher rate than either liquids or solids. The following table gives what are termed the

COEFFICIENTS OF LINEAR EXPANSIONS FOR 1° BETWEEN 0° AND 100° C.

Glass,	0·000008613	Brass,	0·000018782
Platinum,	0·000008842	Lead,	0·000028575
Iron,	0·000012204	Zinc,	0·000029417

These figures mean that each of these substances expands at the rate expressed by its own coefficient: thus 1 foot of glass at 0° C. becomes 1·000008613 foot long at 1° C., and so for each degree rise in temperature. When a body is heated, its whole three dimensions of course increase, and the coefficients of cubical expansion of solids may be taken as three times their coefficients of linear expansion.

The apparent expansion of liquids is not so great as the real, because the vessels in which they are contained also expand. The following table gives the

TOTAL APPARENT EXPANSIONS OF LIQUIDS BETWEEN 0° AND 100° C.

Mercury,	0·01543	Fixed Oils,	0·08
Distilled Water,	0·0466	Alcohol,	0·116

The coefficient of apparent expansion for 1° C. is obtained by dividing these numbers by 100, thus that for mercury is 0·0001543. Mercury expands at a practically constant rate from − 36° to 100° C.; water, however, contracts in rising from 0° to 4°, and then expands from 4° to 100° C.

12. Expansion and Contraction of Gases.—There are certain reasons which lead us to suppose that at a temperature of − 273° C. bodies would be entirely devoid of heat. **This point − 273° C. is therefore often termed the absolute zero of temperature; and temperature reckoned therefrom is termed "absolute temperature."** The absolute temperature of a body is its temperature in degrees C. + 273. All gases expand with increase, and contract with diminution, of temperature. The amount of expansion and contraction is the same for all gases between the same limits of temperature, provided the temperature is considerably higher than that at which they condense to liquids. **The volume of all gases is directly proportional to their absolute temperature.** Because of this variation with temperature **it is necessary to fix a temperature which shall be considered as a standard in expressing the volume of gas: 0° C. is commonly adopted for this purpose.**

Knowing the volume of a gas at any one temperature, its volume at any other may be easily calculated; thus, a vessel was found to contain 750 c.c. of air at 15° C.; it is required to find its volume at the standard temperature.

15° C. + 273 = 288° Absolute Temperature.
0° C. + 273 = 273° ,,

As 288 : 273 :: 750 : 711 c.c. of gas at standard temperature.

13. Relation of Pressure and Volume of Gases.—It is convenient here to note that the volume of a gas is also affected by the pressure to which it is subjected: this variation is governed by what is called Boyle and Marriotte's Law—**The volume of any gas is inversely proportional to the pressure to which it is subjected.** The most important variations of pressure to which gases are liable are those resulting from the changes in pressure of the atmosphere. The height of the mercury column of the barometer is a direct measure of the pressure of the atmosphere, therefore that pressure is commonly expressed in the number of millimetres (m.m.) which that column is high. **For purposes of comparison it is also necessary to reduce all pressures to one standard; that selected is an atmospheric pressure which causes the barometer to stand at 760 millimetres.**

The temperature and pressure quoted as standards for gas measurement, 0° C. and 760 m.m. are often termed **normal temperature and pressure**; for this expression the abbreviation, "N. T. P." is frequently used.

14. Transmission of Heat.—It is well known that when one part of a body or place is heated, the other parts also become hot more or less quickly. Some explanation of how such transmission is effected must now be given. **There are three methods by which heat can be transmitted from one point to another, which are termed respectively Convection, Conduction, and Radiation.**

15. Convection.—As the word convection implies, a place or mass is heated by the heated matter being *conveyed* from one place to another. This kind of heating can only occur in liquids or gases where the particles of matter can move freely. One of the best illustrations of convection is the heating of an ordinary vessel of water by the placing of a fire underneath; the layer of water at the bottom first gets hot, and consequently expands and becomes of lower specific gravity. As a result of being lighter, it therefore rises to the surface, and its place is taken by other water which is colder and denser. This in its turn is heated and rises; continuous currents of warm water ascend through the liquid, and colder water descends to take its place. In this way the whole mass is gradually made hot. The heating of the water in a supply cistern on the top of a building by currents through flow and return pipes from a small boiler in the basement is due to convection. So, too, the ventilation of a building is naturally caused in the same way—heated air ascends and makes its way through exits at the highest point, while cold air enters through the joints of doors and windows or apertures specially provided for the purpose. It will be seen that **convection is a mode of distributing heat through a mass of either liquid or gas by means of moving currents, such currents being usually produced by differences in density due to expansion caused by the source of heat itself.**

16. Conduction.—Instances are well known in which the application of heat to any one point of a solid causes the whole mass to become hot. Thus, if the end of a bar of iron be placed in the fire, the other end gradually increases in temperature. This cannot be due to convection, but is due to the heating effect which the hot particles of the body have on the contiguous particles. In these cases the heat is said to be transmitted by conduction. **Conduction is that method of transmitting heat in which the heat passes from the hotter particles of a body to the colder ones lying in contact with them, and so throughout the whole body.**

There are wide differences in the power of conducting heat displayed by various substances; thus, if a bar of copper be heated in the same way as suggested for the iron, the further end becomes hot far more rapidly. If, instead, a rod of glass or porcelain be heated, the outer end gets hot only with extreme slowness. It must therefore be remembered that **some substances conduct heat much more rapidly than others.** The metals as a class are good conductors, although there are great differences between them. Porcelain, tiles, glass, and earthy substances are generally bad conductors, so also are most bodies of animal or vegetable origin, as, for example, felt, wool, and wood. Water is a bad conductor, and so are the gases. Air is one of the worst heat conductors known, consequently porous masses, as slag wool and fossil earth, conduct very badly, not only from their own non-conducting power, but because of the air retained in their interstices. Owing to their very slight conducting properties, wool, glass, bricks, and similar bodies are frequently termed non-conductors. The following table gives the comparative conducting power of a few substances, silver being taken as 100.

COMPARATIVE POWERS OF CONDUCTIVITY.

Silver,	100
Copper,	75
Iron,	10
Lead,	8
Marble	about 2
Porcelain,	,, 1
Brick Earth,	,, 1

17. Radiation.—It has been already explained that when a substance is hot, its particles are in a state of motion: under circumstances in which transmission of heat by convection and conduction is impossible, one body may yet be heated by another. The explanation now generally accepted is, that all space is permeated by a highly elastic imponderable body to which the name of *ether* has been given, which is capable of being set in undulatory motion by appropriate agitation. The violently moving particles of a hot body in the act of vibration strike against this ether, setting up in it a series of waves. These waves spread in all directions, and on impinging against a cold body, cause its particles also to assume a state of vibration—that is, they make the substance hot. **In this way heat passes from one body to the other, not, however, as hot matter, but as a peculiar wave-like motion in the substance called ether. This is known as "Radiation" of Heat, and is independent of the temperature of the medium through which radiation occurs.**

Radiation occurs in straight lines in all directions from the body which is evolving heat, and follows the same general laws of reflection as those which govern light. At the same temperature different bodies radiate heat at different rates. The rate of radiation is affected both by the nature of the radiating material and also the condition of its surface, whether rough or smooth. Highly polished surfaces radiate less rapidly than those which are roughened. Being maintained at the same temperature, the following table gives the comparative radiating power of different bodies:—

COMPARATIVE POWER OF RADIATION.

Lampblack (Soot),	100
White Lead,	100
Tarnished Lead,	45
Polished Iron,	15
Burnished Silver,	2·5

When hot, surfaces of clay and brick are good radiators of heat, so also are those of flannel and other like substances.

In order that bodies may be heated by radiant heat, it is necessary that they possess the power of absorbing such heat—like radiation, this power of absorption also varies with different bodies. Those which are good radiators of heat are good absorbents, and practically the table showing power of radiation equally applies to power of absorption.

18. Mechanical Equivalent of Heat.—It has already been stated that heat is produced when mechanical work is absorbed by friction or percussion, as when nail-rod is heated by repeated blows of the hammer. Careful measurements have shown that **the work done by 1 lb. falling through 772 feet (or 772 ft.-lbs.), is capable of raising the temperature of 1 lb. of water 1° F.: this amount is therefore termed the Mechanical Equivalent of Heat.** From this the value in degrees Centigrade is easily calculated, being $\frac{9}{5}$ of $772 = 1390$ ft.-lbs. of work to raise 1 lb. of water through 1° Centigrade.

INTRODUCTORY CHEMICAL PRINCIPLES.

19. Definition of Chemistry.—Chemistry has well been defined as that science which treats of the composition of matter, of changes produced therein by certain natural forces, and of the action and reaction of different kinds of matter on each other. It follows that the **Chemistry of Wheat, Flour, and Bread may be defined as that branch of the science which treats of the composition of these bodies, of the changes they undergo when subjected to the action of certain natural forces, and of the action and reaction of these and other kinds of matter on each other.**

20. Introductory Study necessary.—An elementary course of study of the general principles of chemistry must precede that of any particular branch of the applied science. Such a course should include the preparation and properties of the commoner elements and their compounds, the principles of qualitative analysis, and the simpler laws governing chemical action and combination. For this purpose, "Jago's Elementary Chemistry, Theoretical and Practical," published by Messrs. Longmans & Co., may be employed. For convenience of reference, a short description follows of the most important chemical laws, and also of such elements and compounds as are closely connected with the chemistry of wheat, flour, and bread. This brief account must not, however, be accepted as a substitute for a systematic course of study of elementary chemistry.

21. Indestructibility of Matter.—Chemical changes are often accompanied by very great alterations in the appearance and properties of the bodies involved; for example, when a candle is burned it almost entirely disappears, but although it no longer remains in the solid state, all its constituents exist as gases, and these weigh exactly the same as did the candle, *plus* the oxygen of the air with which they have combined. **Matter is indestructible, and, consequently, the same weight of material remains after any and every chemical change as there was before its commencement.**

22. Preliminary Definitions.—It is important that at the outset accurate and concise ideas are gained of the meaning of various chemical terms. Although matter assumes so many diversified forms, yet all bodies, on being subjected to chemical analysis, are found to consist of one or more of a class of between sixty and seventy substances, which are termed "elements."

An Element is a substance which has never been separated into two or more dissimilar substances.

While the letters of the alphabet are few, the number of words which can be formed from them is practically infinite; so, in a somewhat similar fashion, from the comparatively small number of elements which constitute the "alphabet" of chemistry, there may be built up an immense number of chemical compounds.

A compound is a body produced by the union of two or more elements in definite proportions, and, consequently, is a substance which can be separated into two or more dissimilar bodies. Compounds differ in appearance and characteristics from their constituent elements.

The term "Mixture" is applied to a substance produced by the mere blending of two or more bodies, elements or compounds, in any proportion, without union. Each component of a mixture still retains its own properties, and separation may be effected by mechanical means.

23. List of Elements.—The following is a list of some of the more important elements, together with their symbols and other particulars:—

Name.	Symbol.	Combining or Atomic Weight.		Atomicity or Quantivalence.
		Old.	New.	
Aluminium, -	Al	27	27·3	IV
Barium, - - -	Ba	137	136·8	II
BORON, - - -	B	11	11·0	III
BROMINE, - - -	Br	80	79·75	I
Calcium, - - -	Ca	40	39·9	II
CARBON, - - -	C	12	11·97	IV
CHLORINE, - -	Cl	35·5	35·37	I
Chromium, - -	Cr	52·5	52·4	VI
Copper (Cuprum), -	Cu	63	63·0	II
FLUORINE, - - -	F	19	19·1	I
HYDROGEN, - -	H	1	1·0	I
IODINE, - - -	I	127	126·53	I
Iron (Ferrum), - -	Fe	56	55·9	VI
Lead (Plumbum), -	Pb	206	206·4	IV
Magnesium, - -	Mg	24	23·94	II
Manganese, - -	Mn	55	54·8	VI
Mercury (Hydrargyrum),	Hg	200	199·8	II
NITROGEN, - -	N	14	14·01	V
OXYGEN, - - -	O	16	15·96	II
PHOSPHORUS, - -	P	31	30·96	V
Platinum, - - -	Pt	197	196·7	IV
Potassium, - -	K	39	39·04	I

Name.	Symbol.	Combining or Atomic Weight Old.	 New.	Atomicity or Quantivalence.
Silver (Argentum), -	Ag	108	107·66	I
SILICON, - - -	Si	28	28·0	IV
Sodium (Natrium), -	Na	23	22·99	I
SULPHUR, - - -	S	32	31·98	VI
Tin (Stannum), - -	Sn	118	117·8	IV
Zinc, - - - -	Zn	65	64·9	II

24. Metals and Metalloids.—The elements are divided into two groups, termed respectively "Metals," and "Metalloids" or non-metals. The non-metals are distinguished in the foregoing table by being printed in small capitals. The line of division between the two classes is not very marked, the one group gradually merging into the other. The metals, as a class, are opaque bodies, having a peculiar lustre known as metallic; they are usually good conductors of heat and electricity. Two of the elements, mercury and bromine, are liquid at ordinary temperatures, while hydrogen, oxygen, nitrogen, and chlorine are gaseous.

25. Symbols and Formulæ.—The symbols are abbreviations of the names of the elements, and, where practicable, consist of the first letter of the Latin names. When two or more elements have names commencing with the same letter, it becomes necessary to distinguish them from each other by restricting the initial letter to the most important element, and selecting two letters as the symbol of each of the others. Thus, carbon and chlorine each commence with "C," that letter is chosen as the symbol of carbon, while that of chlorine is Cl.

As all compound bodies consist of elements united together, they may be conveniently expressed symbolically by placing side by side the symbols of the constituent elements: the symbol of a compound is termed its **formula.** Thus, common salt consists of chlorine and sodium; its formula is accordingly written, NaCl.

26. Further uses of Symbols and Formulæ: law of chemical combination by weight.—Simply as abbreviations of the full names, symbols and formulæ are of great service; this, however, is but a small part of their significance and value to the chemist. Their further use may best be explained by reference to certain information gained by experiment, to which careful attention is requested. On analysis, it is found that 36·5 ounces of the substance known as hydrochloric acid consist of 1 ounce of hydrogen, combined with 35·5 ounces of chlorine; also, that in 58·5 ounces of common salt there are 35·5 ounces of chlorine to 23 of sodium. Taking water as another instance of a hydrogen compound, analysis shows that its composition may be expressed by the statement, that 18 ounces of water consist of 2 ounces of hydrogen combined with 16 ounces of oxygen. In the table given on page 12 there is a column, headed "Combining or Atomic Weight;" on referring to this it will be found that the numbers opposite hydrogen, chlorine, sodium, and oxygen, are, respectively, 1, 35·5, 23, and 16, being (with one exception) identical with those that have just been given as the numbers obtained by analysis of the compounds under consideration. **It is possible to assign to every element a number, which**

number, or its multiple, shall represent the proportionate quantity by weight of that element which enters into any chemical compound. These numbers are termed the "Combining or Atomic Weights" of the elements, and are deduced from results obtained on actual analysis. In addition to its use as an abbreviated title of any element, **the symbol represents the quantity of the element indicated by its combining weight;** where multiples of that quantity exist in a compound, the fact is expressed by placing a small figure after the symbol and slightly below the line. In the table of elements there are two columns of combining weights given, headed respectively "Old" and "New;" the second column gives those obtained by Stas as a result of recent researches. For most purposes the weights given in the first column are sufficiently accurate.

As previously stated, the formula of sodium chloride is $NaCl$, and it contains 23 of sodium to 35·5 of chlorine. The formula of hydrochloric acid is HCl, and it contains 1 of hydrogen to 35·5 parts of chlorine. Water consists of 2 parts of hydrogen to 16 of oxygen; the fact that it contains twice the combining weight of hydrogen is expressed by writing the formula, H_2O. Again, ammonia contains 3 parts by weight of hydrogen to 14 parts of nitrogen, consequently it has the formula, NH_3: the substance commonly termed carbonic acid gas consists of 32 parts, or twice the combining weight, of oxygen to 12 by weight of carbon, the formula is consequently CO_2. **The quantity of an element represented by its combining weight is termed "one combining proportion" of that element.**

27. Constitutional Formulæ.—In addition to simply showing the number of atoms of each element present, formulæ are frequently so written as to show the probable constitution of the molecule; such formulæ are termed "Constitutional Formulæ."

28. Chemical Equations.—Chemical changes are most conveniently expressed by what are termed "chemical equations:" these consist of the symbols and formulæ of the bodies participating, placed before the sign =, while those of the resultant bodies follow. As an instance it may be mentioned that, when a solution of potassium iodide is added to one of mercury chloride, potassium chloride and mercury iodide are produced. The equation representing this chemical action is written thus:—

$$\underset{\text{Potassium Iodide.}}{2KI} + \underset{\text{Mercury Chloride.}}{HgCl_2} = \underset{\text{Potassium Chloride.}}{2KCl} + \underset{\text{Mercury Iodide.}}{HgI_2}.$$

Having access to a table of combining weights, the chemist learns from this equation that two parts of potassium iodide, each containing one combining proportion of potassium weighing 39, and one of iodine weighing 127, together with one part of mercury chloride, containing one combining proportion of mercury weighing 200, and two of chlorine each weighing 35·5; together yield or produce two parts of potassium chloride, each consisting of one combining proportion of potassium weighing 39, and one of chlorine weighing 35·5; and one part of mercury iodide, containing one combining proportion of mercury weighing 200, and two combining proportions of iodine each weighing 127. As no chemical change affects the weight of matter, the weight of the quantity of a compound, represented by its formula, must be the sum of that of the constituent elements: so, too, the weight of the bodies resulting from a chemical change must be the same as that of the bodies before the change, whatever it may be, had occurred. Although from a chemical equation and table of combining weights, it is possible to state what relative weight of each element is concerned in any chemical action, it must never be forgotten that **the combining weights were first determined by experiment and then the table compiled therefrom.** The statement of premise and deduction is, that hydrogen and chlorine have respectively the combining weights of 1 and 35·5 assigned to them, because analysis shows that they combine in those proportions: **not** that hydrogen and chlorine have as combining weights 1 and 35·5, and therefore they must combine in those proportions. The combining weights are simply a tabular expression of results obtained by practical analytic investigation. This cannot be too strongly insisted on; ask many a young chemical student how it is known that hydrochloric acid consists of 1 by weight of hydrogen and 35·5 of chlorine, and he will answer "because those are the combining weights of the elements." Ask him how it is known that 1 and 35·5 are the combining weights of hydrogen and chlorine, and he will not have the slightest idea that they are simply deductions from experimentally obtained results. For this state of things many of the older text-books are largely responsible.

29. Atoms and Molecules.—The fact that the quantity of every element which enters into combination is either a certain definite and unchangeable weight, or a multiple of that weight, led chemists to feel that this weight of a combining proportion of an element is in some way associated with its physical nature. The first step toward the explanation of this question is due to Dalton, who enunciated what is termed the Atomic Theory. He assumed that all matter is built up of extremely small particles, which are indivisible, and that when elements combine, it is between these particles that the act of union occurs. These ultimate particles of matter are termed "Atoms." The name "atom" is derived from the Greek, and signifies that which is indivisible. Atoms of the same element are supposed to be of the same size and weight. With the absolute weight of atoms the chemical student has but little to do: the principal point of importance for him is their relative weights compared with each other. For chemical purposes, **an atom may be defined as the smallest particle of an element which enters into, or is expelled from, a chemical compound. For the phrase, "combining proportion," hitherto used, the term "Atom" may be substituted; the combining weight then becomes the relative weight of the atom of each element compared with that of hydrogen, which, being the lightest, is taken as unity.** Though the atomic theory does not admit of absolute proof, yet it so amply and consistently explains all the phenomena of chemistry that its essential principles are universally recognised.

The little group of atoms represented by the formula of a compound is termed a "molecule." **A molecule is the smallest possible par-**

ticle of a substance which can exist alone. In the case of chemical compounds, the molecule cannot be further subdivided, except by separation into the atoms of its constituent elements, or into two or more molecules of some simpler chemical compound or compounds. When elements are in the free or uncombined state, their atoms usually combine together to form elementary molecules: thus with oxygen, two atoms unite to form a molecule of oxygen; the formula of the oxygen molecule is written, O_2.

The molecules of the following elements contain two atoms:—hydrogen, chlorine, oxygen, sulphur, and nitrogen.

As all elements normally exist in the molecular state, it is advisable to always use equations in which the lowest quantity of any element present is a molecule. Thus, $H_2 + Cl_2 = 2HCl$, should be written as the equation representing the combination of hydrogen and chlorine, rather than $H + Cl = HCl$.

30. Avogadro's Law.—The fact that all gases, whether elementary or compound, expand and contract at exactly the same rate, when subjected to variations of temperature and pressure, has an important bearing on their probable molecular constitution. Their similarity in this respect has led to the assumption expressed in the "Law of Avogadro":—"**Under similar conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules.**" From this it follows, that at the same temperature and under the same pressure, the volume of any gaseous molecule is the same whatever may be the nature and composition of the gas. The density of a gas being known, its molecular weight is easily calculated. The density of a gas is the weight of any volume, compared with that of the same volume of hydrogen, measured at the same temperature and pressure, and taken as unity. It has already been stated that the molecule of hydrogen contains two atoms; its molecular weight, expressed in terms of its atomic weight, is consequently 2. **The molecular weight of any gas is the weight of that volume which occupies the same space as does two parts by weight of hydrogen**; or is identical with the number obtained by doubling the density. Similar conditions of temperature and pressure are always understood in speaking of the comparative weights of gases. Conversely, as the molecular weight is the sum of the weights of the constituent atoms, the density of a gas may be determined from its formula. Thus, carbon dioxide gas has as its formula, CO_2; its molecular weight is $12 + (16 \times 2 =)32 = 44$: the density is $\frac{44}{2} = 22$. Here again it must be remembered that the molecular weight is primarily determined from the density, and not the density from the molecular weight.

31. Absolute weight of Hydrogen.—As hydrogen is taken as the unit of comparison for other gases, it is necessary that its absolute weight be determined with the greatest exactitude. Experiment has shown that **1 litre of hydrogen, at normal temperature and pressure, weighs 0·0896 gram; or 11·2 litres weigh 1 gram.**

The student must make up his mind to remember this figure; to quote Hofmann, the fact that at 0° C. and 760 m.m. pressure, 1 litre of hydrogen weighs 0·0896 gram, should be impressed "as it were with a graving tool on the memory." **The weight in grams of a litre of any gas is its density × 0·0896.** Thus, the density of carbon dioxide gas is 22; the weight of a litre is 22 × 0·0896 = 1·9712 grams.

32. Laws of Chemical Combination by volume.—Not only does chemical combination follow definite laws, so far as weight is concerned, but also equally definite laws govern the proportions by volume in the case of gaseous bodies. For example, experiment shows that one volume of hydrogen unites with one volume of chlorine to form two volumes of hydrochloric acid gas. So, too, two volumes of hydrogen unite with one volume of oxygen to form two volumes of water-gas (steam). Again, ammonia consists of three volumes of hydrogen, united with one of nitrogen, to form two volumes of ammonia. The reactions are expressed in the following equations:—

$$\underset{\text{Hydrogen.}}{H_2} + \underset{\text{Chlorine.}}{Cl_2} = \underset{\text{Hydrochloric Acid.}}{2HCl.}$$

$$\underset{\text{Hydrogen.}}{2H_2} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Water.}}{2H_2O.}$$

$$\underset{\text{Hydrogen.}}{3H_2} + \underset{\text{Nitrogen.}}{N_2} = \underset{\text{Ammonia.}}{2NH_3.}$$

It will be observed that in the first equation one molecule of hydrogen unites with one molecule of chlorine to form two molecules of hydrochloric acid: the application of Avogadro's Law, therefore, teaches that these elements will unite in equal quantities of one volume to form two volumes of hydrochloric acid. In the same way, **the proportions by volume in which chemical changes occur between gaseous bodies are always expressed in the equation, it being remembered that all gaseous molecules occupy the same space when measured at the same temperature and pressure.** The following is a useful method of writing such equations, when the object is to show the proportions by volume in a chemical change in which any gaseous body is involved.

$$\underset{\text{1 volume.}}{H_2} + \underset{\text{1 volume.}}{Cl_2} = \underset{\text{2 volumes.}}{2HCl.}$$

$$\underset{\text{2 volumes.}}{2H_2} + \underset{\text{1 volume.}}{O_2} = \underset{\text{2 volumes.}}{2H_2O.}$$

$$\underset{\text{3 volumes.}}{3H_2} + \underset{\text{1 volume.}}{N_2} = \underset{\text{2 volumes.}}{2NH_3.}$$

33. Acids, Bases, and Salts.—The name acid is a familiar one, because it is continually applied in every day parlance to anything which is sour. A number of bodies possess this distinction in common; to the chemist, the sourness of an acid is but an accidental property, as, according to his definition of these bodies, substances are included as acids that are not sour to the taste. **An acid may be defined as a body which contains hydrogen, which hydrogen may be replaced by a metal (or group of elements equivalent to a metal), when presented to the acid in the form of an oxide or hydrate.** As a class, the acids are sour; they are also active chemical agents;

most acids are characterised by the property of changing the colour of a solution of litmus, a naturally blue body, to a red tint. Oxygen is a constituent of most acids. These are termed "oxy-acids." A few in which it is absent are termed "hydracids." Hydrochloric acid, HCl, is an example of these bodies. Most of the oxy-acids are produced by the union of water with an oxide—thus, oxide of sulphur and water form sulphuric acid :—

$$\underset{\text{Sulphur Trioxide.}}{SO_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Sulphuric Acid.}}{H_2SO_4.}$$

The oxides, which by union with water form acids, are termed anhydrides, or anhydrous acids. They are in most cases non-metallic oxides, but sometimes consist of metals combined with a comparatively large number of atoms of oxygen.

A Base is a compound, usually an oxide or hydrate, of a metal (or group of elements equivalent to a metal), which metal (or group of elements) is capable of replacing the hydrogen of an acid, when the two are placed in contact. The greater number of metallic oxides are bases. Bases, as well as acids, differ considerably in their chemical activity. Certain bases are characterised by being soluble in water, to which they impart a peculiar soapy feel. These bases are termed "alkalies," and possess the property of restoring the blue colour to reddened litmus. The most important alkalies are sodium hydrate, NaHO, and potassium hydrate, KHO. The bases, lime, CaO, baryta, BaO, and magnesia, MgO, are more or less soluble in water, and also turn reddened litmus blue. They, with SrO, constitute the group known as the "Alkaline Earths." Hydrates are compounds of oxides with water, thus :—

$$\underset{\text{Sodium Oxide.}}{Na_2O} + \underset{\text{Water.}}{H_2O} = \underset{\text{Sodium Hydrate.}}{2NaHO.}$$

When an acid and base react on each other, the body, produced by the replacement of the hydrogen of the acid by the metal of the base, is termed a Salt. Water is also produced during the reaction. Most salts have no action on litmus—that is, they do not affect the colour, whether it be red or blue. The action of acid and base on each other is illustrated in the following equation :—

$$\underset{\text{Acid.}}{HCl} + \underset{\text{Base.}}{NaHO} = \underset{\text{Salt.}}{NaCl} + \underset{\text{Water.}}{H_2O.}$$

34. Compound Radicals.—At times a group of elements enters into the composition of a body, and performs functions very similar to those of an atom of an element. Such groups are not only found to form numbers of very definite compounds, but may be even transferred from one compound to another without undergoing decomposition. **Groups of atoms of different elements which possess a distinct individuality throughout a series of compounds, and behave therein as though they were elementary bodies, are termed "Compound Radicals."**

35. Quantivalence or Atomicity.—Referring back to the three compounds of hydrogen mentioned in paragraph 32, it will be observed that one atom each of chlorine, oxygen, and nitrogen, combines respectively with one, two, and three atoms of hydrogen. If chlorine and oxygen compounds be classified and compared, it is found that oxygen in almost every instance combines with just double the number of atoms of the other element as does chlorine. **The atom-combining power of elements varies—Quantivalence of Atomicity is the measure of that combining power.** Among the elements, hydrogen, sodium, and chlorine are characterised by the fact that one atom of each rarely combines with more than one atom of any other element. Their atomicity is unity, and as every other element forms a chemical compound with one or more of these, the atomicity of any element can usually be determined by observing with how many atoms of one of these three elements an atom of the element in question enters into combination. The atomicity of the different elements is given in the table included in paragraph 23. Elements with an atomicity of one are termed monads; of two, dyads; three, triads; four, tetrads; five, pentads; and of six, hexads. It is often convenient to express the atomicity of an element graphically. This is done by attaching a series of lines to the atom, according to its atomicity. These lines may be viewed as indicating the number of links or bonds with which the particular atom can combine with other atoms. Of the actual nature of the force which holds atoms together in chemical compounds, nothing is known: the bonds must only be viewed as indications of the number of such units of atom-combining power. The following are examples of these graphic symbols:—

$H-$	$Cl-$	$-O-$	$-B=$	$=C=$
Hydrogen.	Chlorine.	Oxygen.	Boron.	Carbon.

The same two elements often form a series of two or more compounds with each other; under these circumstances the atomicity must vary. In the great majority of such compounds, the atomicity increases or diminishes by intervals of two—that is, the atomicity is either even or odd for an element throughout all its compounds. This is accounted for by the supposition that two of the bonds of an element may, by their union, mutually satisfy each other. This is not, however, invariably the case, as certain well-marked exceptions to this rule are known. The highest known atomicity of an element is termed its "absolute" atomicity; the atomicity in any particular compound is the "active" atomicity; the absolute, less the active, atomicity is the "latent" atomicity.

36. Basicity of Acids.—In order to form salts, different acids require different quantities of a base: the measure of this quantity is termed the "basicity" of the acid. **The basicity of an acid depends on the number of atoms of hydrogen it contains that may be replaced by the metal of a base.** In forming salts, one atom of hydrogen is replaced by one atom of a monad metal, two atoms of hydrogen by an atom of a dyad, and so on. In the case of acids which contain more than one atom of replaceable hydrogen, salts are sometimes formed in which a part only of the hydrogen is replaced; such salts are termed "acid" salts, while those in which the whole of the hydrogen is replaced are termed "normal" salts. The following are typical examples of acids and the corresponding salts:—

MONOBASIC ACID.	DIBASIC ACID.	TRIBASIC ACID.
HNO_3. Nitric Acid.	H_2SO_4. Sulphuric Acid.	H_3PO_4. Phosphoric Acid.
$NaNO_3$. Sodium Nitrate.	Na_2SO_4. Sodium Sulphate.	Na_3PO_4. Sodium Phosphate.
	$HNaSO_4$. Acid Sodium Sulphate.	Na_2HPO_4. Disodic Hydrogen Phosphate.
$Ca(NO_3)_2$. Calcium Nitrate.	$CaSO_4$. Calcium Sulphate.	$Ca_3(PO_4)_2$. Calcium Phosphate.

It is often convenient to view the acids in the light of their being compounds of the anhydrides with water: the corresponding salts may then be written as compounds of the bases with the anhydrides. This method is almost invariably employed when calculating the relative quantities of metals and acids in bodies when subjected to analysis. Subjoined are the formulæ, written in this manner, of the acids and salts previously given as examples:—

H_2O, N_2O_5. Two Molecules of Nitric Acid.	H_2O, SO_3. Sulphuric Acid.	$(H_2O)_3, P_2O_5$. Two Molecules of Phosphoric Acid.
Na_2O, N_2O_5. Two Molecules of Sodium Nitrate.	Na_2O, SO_3. Sodium Sulphate.	$(Na_2O)_3, P_2O_5$. Two Molecules of Sodium Phosphate
	$NaHO, SO_3$. Acid Sodium Sulphate.	$(Na_2O)_2\ H_2O, P_2O_5$. Two Molecules of Disodic Hydrogen Phosphate.
CaO, N_2O_5. One Molecule of Calcium Nitrate.	CaO, SO_3 Calcium Sulphate.	$(CaO)_3, P_2O_5$. One Molecule of Calcium Phosphate.

37. Chemical Calculations.—Most of the chemical calculations necessary in analytic work may be readily made by the help of chemical formulæ and equations, together with a table of combining weights. The following are illustrations of some of the most important of these calculations.

38. Percentage Composition from Formula.—Chemists usually express the results of analysis of a substance in parts per cent., so that in the case of a chemical compound it is often necessary to be able to calculate its chemical formula from the percentage composition, or conversely, the percentage composition from the formula. The latter operation, as being the simpler, shall be first explained. It is possible from the formula of any body to arrive at the molecular weight of the compound, and the relative weight present of each element. Thus, to find the percentage composition of acid sodium sulphate:—

The formula is

$$\begin{array}{ccccccc} Na & & H & & S & & O_4 \\ 23 & + & 1 & + & 32 & + & (16 \times 4 =)\ 64 = 120. \end{array}$$

From the combining weights, given beneath each element, with their sum at the end, it is seen that the molecule weighs 120, and contains 23 parts of sodium. Knowing that 120 parts contain 23, it is exceedingly easy to calculate the number of parts per 100, as the problem resolves itself into one of simple proportion:—

As 120 : 100 :: 23 : 19·17 per cent. of sodium.
As 120 : 100 :: 1 : 0·83 ,, ,, hydrogen.
As 120 : 100 :: 32 : 26·66 ,, ,, sulphur.
As 120 : 100 :: 64 : 53·33 ,, ,, oxygen.

99·99

Precisely the same method of calculation has been applied to the determination of the percentages of hydrogen, sulphur, and oxygen. As the results seldom work out to a terminated decimal, the added percentages usually amount to only 99·99; but by continuing the calculation, any additional number of 9's could be obtained, and as 0·9 recurring is equal to 1·0, so 99·9 recurring is equivalent to 100·00. As another example, let it be required to determine the percentage of base and anhydrous acid respectively in calcium phosphate. This salt is represented by

$$\underbrace{\begin{matrix}(\mathrm{Ca} \quad \mathrm{O}\ )_3\\ (40+16=)56\times 3\end{matrix}}_{168} + \underbrace{\begin{matrix}\mathrm{P}_2\ \ \mathrm{O}_5\\ 62+80\end{matrix}}_{142} = 310$$

The molecule, which weighs 310, contains 168 of lime (CaO), and 142 of phosphoric anhydride (P_2O_5), consequently

As 310 : 100 :: 168 : 54·19 per cent. of lime.
As 310 : 100 :: 142 : 45·81 ,, ,, phosphoric anhydride.

100·00

39. Formula from percentage composition.—Let the following represent the results of analysis of a body:—

Sodium, ...	16·79 per cent.
Nitrogen, ...	10·22 ,,
Hydrogen, ...	3·65 ,,
Phosphorus, ...	22·63 ,,
Oxygen, ...	46·71 ,,
	100·00

As a first step toward obtaining the formula, divide the percentage of each element by its atomic weight, the result will be a series of numbers in the ratio of the number of atoms of each element—

$$\frac{16·79}{23} = 0·73 \text{ of Sodium.}$$

$$\frac{10·22}{14} = 0·73 \text{ of Nitrogen.}$$

$$\frac{3·65}{1} = 3·65 \text{ of Hydrogen.}$$

$$\frac{22·63}{31} = 0·73 \text{ of Phosphorus.}$$

$$\frac{46·71}{16} = 2·92 \text{ of Oxygen.}$$

It is next necessary to find the lowest series of whole numbers that correspond to these; such a series may be obtained by dividing each number by the lowest one of the series:—

$$\frac{0{\cdot}73}{0{\cdot}73} = 1 \text{ atom of Sodium.}$$

$$\frac{0{\cdot}73}{0{\cdot}73} = 1 \text{ atom of Nitrogen.}$$

$$\frac{3{\cdot}65}{0{\cdot}73} = 5 \text{ atoms of Hydrogen.}$$

$$\frac{0{\cdot}73}{0{\cdot}73} = 1 \text{ atom of Phosphorus.}$$

$$\frac{2{\cdot}92}{0{\cdot}73} = 4 \text{ atoms of Oxygen.}$$

The formula of the compound is, therefore, $NaNH_5PO_4$; its name is "hydrogen ammonium sodium phosphate." The formula obtained in this way is the simplest possible for the body in question: it is evident that the percentage composition would be the same if they were double or any other multiple of the number of atoms of each element in the molecule. Other considerations are taken into account in determining whether the correct molecular formula is really the simplest thus obtained, by calculation, from the percentage composition, or a multiple of the same. **Such simplest possible formula is termed an Empirical Formula.**

40. Calculations of Quantities.—An exceedingly common type of calculation is that in which it is required to know the quantities of one or more substances required to produce a certain quantity of another body. Thus, hydrogen is commonly obtained by the action of zinc on sulphuric acid; suppose that 10 grams of hydrogen are required for some operation: what weights respectively of zinc and sulphuric acid are necessary for the purpose? Here, again, the equation gives the relative weights of each element and compound participating in the reaction. In every such calculation it is absolutely necessary that the equation and combining weights be known; but granted these, no other difficulties arise beyond those which can be readily overcome by an intelligent application of the principles of proportion.

In the case in question the equation is:—

$$\begin{array}{ccccccc} \text{Zn} & + & \text{H}_2\ \text{S}\ \text{O}_4 & = & \text{Zn}\ \text{S}\ \text{O}_4 & + & \text{H}_2. \\ 65 & & \underbrace{2+32+64}_{98} & & \underbrace{65+32+64}_{161} & & 2. \\ \text{Zinc.} & & \text{Sulphuric Acid} & & \text{Zinc Sulphate.} & & \text{Hydrogen.} \end{array}$$

To produce two parts by weight of hydrogen, 65 of zinc and 98 of sulphuric acid are required, then—

As 2 : 10 :: 65 : 325 grams of zinc required
As 2 : 10 :: 98 : 490 ,, sulphuric acid required.

Another instance may be given, in which not only weights but also volumes of gases have to be calculated. It is required to know how much carbon dioxide gas in cubic centimetres and in cubic inches is evolved by the fermentation of 28·35 grams (= 1 ounce) of pure cane sugar, the gas being measured at a temperature of 20° C. and 765 millimetres pressure; it being assumed that the whole of the sugar is resolved into alcohol and carbon dioxide. The chemical changes involved in this process may be represented by the following equations—

$$\begin{array}{ccccc} C_{12}\;H_{22}\;O_{11} & + & H_2\;O & = & 2C_6\;H_{12}\;O_6. \\ \underbrace{144+22+176}_{342} & & \underbrace{2+16}_{18} & & \underbrace{72+12+96}_{2\times180=360} \\ \text{Cane Sugar.} & & \text{Water.} & & \text{Glucose.} \end{array}$$

In the first place one molecule, equalling 342 parts by weight of cane sugar, is converted into two molecules of glucose, each weighing 180, or the two weighing 360.

$$\begin{array}{ccccc} 2C_6\;H_{12}\;O_6 & = & 4C_2\;H_5\;H\;\;O & + & 4C\;\;O_2. \\ \underbrace{72+12+96}_{2\times180=360} & & \underbrace{24+5+1+16}_{4\times46=184} & & \underbrace{12+32}_{4\times44=176} \\ \text{Glucose.} & & \text{Alcohol.} & & \text{Carbon dioxide.} \end{array}$$

The two molecules of glucose, weighing 360, are next decomposed into four molecules of alcohol, having a total weight of 184; and four molecules of carbon dioxide, each weighing 44, and the whole 176. From 342 parts by weight of cane sugar, 176 parts by weight of carbon dioxide are produced; then—

As 342 : 28·35 :: 176 : 14·59 grams of carbon dioxide, yielded by 28·35 grams of cane sugar.

The next step is to determine what is the volume of 14·59 grams of carbon dioxide at N.T.P. The molecular weight of carbon dioxide being 44, its density must be 22: one litre of hydrogen weighs 0·0896 grams, and therefore 1 litre of carbon dioxide must weigh 0·0896 × 22 = 1·9712 grams; then—

$$\frac{14{\cdot}59}{1{\cdot}9712} = 7{\cdot}401 \text{ litres at N.T.P.}$$

Applying the laws previously given by which the relations between the volume and temperature and pressure of a gas are governed; then—

$$\left.\begin{array}{r} \text{As } 273 : 293 :: 7{\cdot}401 \\ 765 : 760 \end{array}\right\} = \frac{293 \times 760 \times 7{\cdot}401}{273 \times 765}$$

= 7·891 litres at 20° C. and 765 m.m. pressure = 7891 cubic centimetres.

As 16·39 c.c. = 1 cubic inch, then

$$\frac{7891}{16{\cdot}39} = 481{\cdot}7 \text{ cubic inches.}$$

28·35 grams or one ounce of cane sugar would yield, according to the question given, 7891 c c or 481·7 cubic inches of carbon dioxide gas at 20° C. and 765 m.m. pressure.

The weight of sugar necessary to yield a certain volume of gas would be calculated on the same principles; as an illustration, the reverse of the calculation just made is appended. Required to know the weight of cane sugar necessary to produce 481·7 cubic inches or 7891 cubic centimetres of carbon dioxide gas at 20° C. and 765 m.m. pressure.

$$\frac{273 \times 765 \times 7891}{293 \times 760} = 7401 \text{ c.c at N.T.P.} = 7{\cdot}401 \text{ litres.}$$

$$7{\cdot}401 \times 1{\cdot}9712 = 14{\cdot}59 \text{ grams of } CO_2.$$

As 176 : 14·59 : : 342 : 28·35 grams of cane sugar required.

41. Gaseous Diffusion.—It is a well-known fact that gases mix with each other with remarkable readiness. For instance, if in a large room a jar of chlorine is opened at the level of the floor, the presence of the gas may be detected by its powerful odour, within a few seconds, in every part of the room. The natural process by which the chlorine is thus disseminated through the air is termed "gaseous diffusion;" it takes place between gases, even though the heavier is at first at the lower level. In other words, a heavy gas will diffuse up into a superincumbent light gas, while the light gas will make its way downwards and mix with the heavier one. In this way different gases, when placed in the same space, rapidly produce of themselves an uniform mixture. This process of diffusion will also go on through a porous membrane, as, for example, a thin diaphragm of plaster of Paris or porous earthenware. Thus, if a vessel be divided into two parts by a thin partition of porous material, and the one half be filled with one gas and the other with another, they will be found after some time to have become thoroughly intermixed with each other. The rate of diffusion of all gases through such a diaphragm is not the same, but depends on their densities. **The rate of diffusion of gases is inversely as the square root of their density.** Thus, hydrogen and oxygen have respectively densities of 1 and 16; hydrogen diffuses four times as rapidly as does oxygen.

42. Osmose and Dialysis.—Liquids which are miscible with each other—(*i.e.*, readily mix when placed together)—also undergo diffusion more or less rapidly. The laws governing diffusion of liquids are more complex than those affecting the diffusion of gases: not only gases, but also **liquids, are capable of diffusion through a porous diaphragm; such diffusion is termed "Osmose."** Some of the most remarkable and important phenomena of liquid diffusion are those exhibited by aqueous solutions of different substances. Thus, let a sort of drum head be made by stretching and fastening a piece of bullock's bladder, or either animal parchment or vegetable parchment paper, over a cylinder of some impervious material, as glass or gutta percha. Float this in a vessel of pure water, and pour inside it a strong solution of common salt. The brine and the pure water will only be separated from each other by the thin membrane of bladder or other similar material. After the lapse of some hours it will be found that the solution of salt will have diffused out through the membrane until the liquid both outside and inside the floating vessel has the same strength. By repeatedly changing the water in the outer vessel, the whole of the salt might be removed from the solution within the cylinder. On the other hand, if a solution of gum were placed within the parchment drum, and subjected to precisely the same treatment, the gum would be found incapable of diffusion through the membrane. If a mixture of brine and gum were placed in the cylinder with parchment bottom, and then floated on the surface of water, the salt would diffuse out and the gum remain behind: in this manner a complete separation of the two might be effected. **The separation of bodies by their respective ability or inability, when dissolved, to diffuse through a porous membrane, is termed "Dialysis."**

43. Crystalloids and Colloids.—All bodies are capable of being divided into two great classes, known respectively as "crystalloids" and "colloids." **Crystalloids are substances which, on changing from the liquid to the solid state, assume a crystalline form. Bodies are said to be crystalline when they consist of crystals, and for chemical purposes a crystal may be defined as matter which has spontaneously assumed during the act of solidification a definite geometric form. In crystals there is also a definite internal molecular arrangement related to the crystalline form by certain determinate laws.** Solutions of crystalline bodies are usually, but not invariably, free from any marked viscosity. Crystalline bodies are only soluble to a definite extent in water, the quantity dissolved depending more or less on the temperature: thus, 100 parts of water dissolve about 36 parts of salt. If more salt than this be added to water, it simply remains undissolved. **Jelly-like substances, as gum and gelatin, are termed "Colloids," and do not acquire a crystalline form when assuming the solid state.** The colloids form, when treated with water, sirupy, viscous, or jelly-like solutions. They may be said to be soluble in water in all proportions. Thus, if a few drops of water be added to a piece of dry gelatin, the water will be absorbed by the gelatin, and after a time will be uniformly diffused throughout the whole mass. Successive portions of water may thus be absorbed by the gelatin, which will become gradually softer, assuming the consistency of a jelly; further addition of water produces a solution with more or less viscosity, depending on the degree of concentration. **Crystalloids are especially susceptible of dialysis; colloids exhibit under similar treatment very little tendency to pass through a porous membrane.** The membranes used for dialysis consist of colloid substances: gelatin in the jelly-like form at times is a very convenient dialysing agent. The apparatus used for the purpose of effecting dialysis is termed a dialyser. The phenomena of liquid diffusion have an exceedingly important bearing on many chemical changes which occur during bread-making.

44. Measures of Weight and Volume.—It will be convenient to here furnish a statement of the different systems of weights and measures usually employed for scientific purposes. The chemist, as a rule, prefers the metric system, as in common use in France, to the very complicated system of weights and measures employed in this country. One reason is that the metric system is extremely simple; another, that the measures of weight and volume are directly connected with each other. If the writer simply followed his own predilections, metric weights and measures only would be used throughout this work, but it having been strongly represented to him that the introduction of the English equivalents of the different weights employed would be a help to some of his readers, they also have been, in most cases, given. The writer is conscious that the result of this intermixture is often incongruous, but to those familiar with the metric system this will present no difficulty, while to those who are unacquainted with it, it will be an assistance. It is nevertheless urged that the metric system be mastered; this may be easily done in a quarter of an hour, much time will then be saved which otherwise would have to be spent in making calculations.

45. The Metric System.—The unit of the metric system is a "metre," which is the length of a rod of platinum that is deposited in the archives of France. The metre measures 39·37 English inches. The higher and lower measures are obtained by multiplying and dividing by 10, thus:—

Kilometre = 1000 metres = 39370 inches.
Hectometre = 100 ,, = 3937 ,,
Decametre = 10 ,, = 393·7 ,,
Metre = 39·37 ,,
Decimetre = 0·1 metre = 3·937 ,,
Centimetre = 0·01 ,, = 0·3937 inch.
Millimetre = 0·001 ,, = 0·03937 ,,

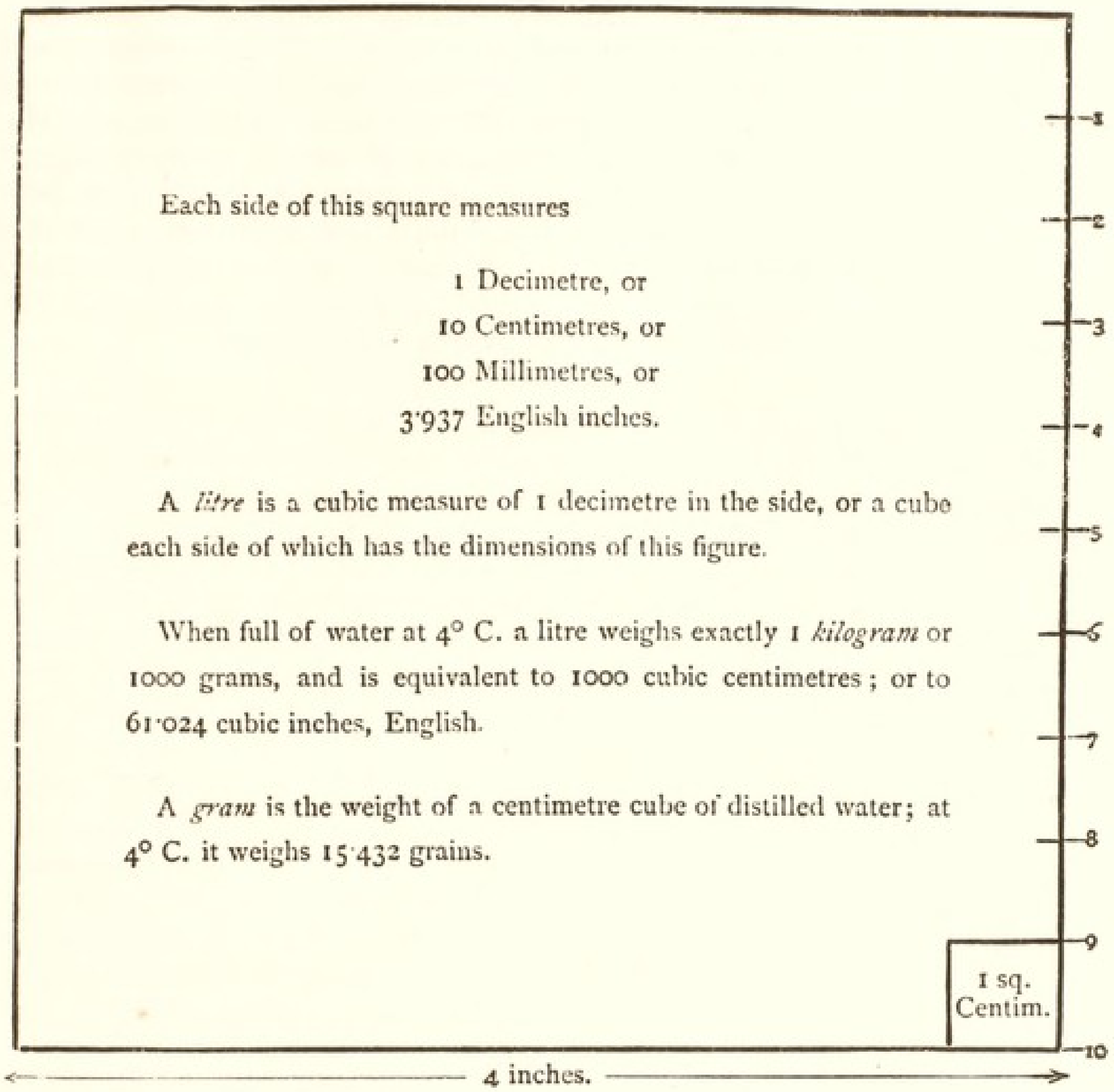
In the above, and all other measures of the metric system, the prefixes "kilo, hecto, and deca" are used to represent 1000, 100, and 10 respectively; and "deci, centi, and milli," to represent a tenth, hundredth, and thousandth. The decimetre is very nearly 4 inches in length, and the millimetre very nearly one twenty-fifth of an inch: remembering this, measures of the one denomination can be roughly translated into those of the other. The exact length of a decimetre is shown in Fig. 1.

The unit of the measure of capacity is the "litre," which is the volume of a cubic decimetre:—

		Cubic Inches.	Pints.	Fluid Ounces.
Kilolitre	= 1000 litres	= 61027	1760·7	35214
Hectolitre	= 100 ,,	= 6102·7	176·07	3521·4
Decalitre	= 10 ,,	= 610·27	17·607	352·14
Litre	=	61·027	1·7607	35·214
Decilitre	= 0·1 litre	= 6·1027	0·17607	3·5214
Centilitre	= 0·01 ,,	= 0·61027	0·017607	0·3521
Millilitre	= 0·001 ,,	= 0·06102	0·00176	0·0352

The decimetre being 10 centimetres in length, it follows that a cubic decimetre must be equal to 1000 cubic centimetres, and that the millilitre has a volume of a cubic centimetre. The name "cubic centimetre," or its abbreviation "c.c.," is almost always used in preference to millilitre; thus, a burette or pipette is said to deliver 50 c.c., while a litre measure is often termed a "1000 c.c." measure.

A cubic inch is equal to 16·38 cubic centimetres.



Each side of this square measures

1 Decimetre, or
10 Centimetres, or
100 Millimetres, or
3·937 English inches.

A *litre* is a cubic measure of 1 decimetre in the side, or a cube each side of which has the dimensions of this figure.

When full of water at 4° C. a litre weighs exactly 1 *kilogram* or 1000 grams, and is equivalent to 1000 cubic centimetres; or to 61·024 cubic inches, English.

A *gram* is the weight of a centimetre cube of distilled water; at 4° C. it weighs 15·432 grains.

FIG. 1.

The unit of the measure of weight is the "gramme," or "gram;" this is the weight of a cubic centimetre of distilled water at its maximum density (4° C. = 39·2° F.):—

					Grains.	Avoirdupois Ounces.
Kilogram	=	1000	grams	=	15432·3	35·2739
Hectogram	=	100	,,	=	1543·23	3·52739
Decagram	=	10	,,	=	154·323	0·35273
Gram	=				15·4323	0·03527
Decigram,	=	0·1	gram	=	1·54323	0·00352
Centigram	=	0·01	,,	=	0·15432	0·00035
Milligram	=	0·001	,,	=	0·01543	0·000035

A kilogram is just over 2 lbs. $3\frac{1}{4}$ oz., and a hectogram is very nearly $3\frac{1}{2}$ oz. An ounce avoirdupois equals 28·35 grams

The relation between the weight and volume of water is a very simple one; the volume being the same number of c.c. as the weight is grams. With other liquids the volume in c.c. × specific gravity = weights in grams.

46. English Weights and Measures.—Familiarity with English weights and measures is assumed, still the following particulars will most likely be of service—one gallon of pure water at a temperature of 62° F. (16·6° C.) weighs 10 pounds or 160 ounces or 70,000 grains; the pint, therefore, weighs 20 ounces. The measure termed a "fluid ounce" is derived from the weight of a pint of water. A fluid ounce is a measure of volume, not of weight, and equals one twentieth part of a pint. The fluid ounce bears the same relation to the avoirdupois ounce, as does the cubic centimetre to the gram. A gallon is equal to 277·274 cubic inches. An ounce avoirdupois weighs 437·5 grains.

CHAPTER II.

DESCRIPTION OF THE PRINCIPAL CHEMICAL ELEMENTS AND THEIR INORGANIC COMPOUNDS.

47. Description of Elements and Compounds.—It is intended in this chapter to give a very brief description of those elements and their inorganic compounds, which are more or less directly connected with the chemistry of wheat, flour, and bread, and to which reference may be made in the latter part of this work. Such descriptions as are here given must not be viewed as being in any way a substitute for a careful study of elementary chemistry. It is thought, however, that to many readers, more particularly those who may not have the time for such a systematic course, an account such as is to follow will be found of service.

48. Hydrogen, H_2.—This element is a gas, and is the lightest substance known; it is consequently selected as the standard by which the density of other gases is measured. One litre of hydrogen at N.T.P. weighs 0·0896 gram. Hydrogen has also the lowest atomic weight of all the elements, and is therefore also selected as the unit of the modern system of atomic or combining weights. Hydrogen is colourless, odourless, tasteless, and non-poisonous. It is not capable of supporting respiration, and therefore animals placed therein quickly die through lack of proper air to breathe. Hydrogen is inflammable, and burns with a pale blue flame; it does not support combustion. Hydrogen is only very slightly soluble in water.

49. Oxygen, O_2.—This element is a colourless, odourless, and non-inflammable gas. Its most remarkable feature is that it supports combustion and also respiration. Bodies which burn in ordinary air do so because that substance is a mixture of oxygen and nitrogen; they burn with much increased brilliancy in oxygen. The respiration or breathing of animals consists of a removal of oxygen from the air, and a return thereto of carbon dioxide gas: the activity of oxygen renders it injurious to breathe in a pure state; in air, the nitrogen acts as a diluting agent, without modifying the essential characteristics of the gas. Oxygen is soluble in water to the extent of three volumes of the gas in one hundred volumes of water at 15° C. This quantity, though small, is of vast importance, as it thus supports the life of fishes, and has also a most important action on fermentation. Although oxygen is such an essential to most forms of life, there are some of the lower microscopic organisms towards which it acts as a most energetic poison. Compounds produced by the union of elements with oxygen are termed "oxides."

50. Ozone, O_3.—This body is a gaseous substance consisting of pure oxygen, but having a density of 24 instead of 16. This is due to there being 3 atoms of the element in the molecule, instead of 2 as in ordinary oxygen. Ozone has a peculiar odour; and is produced during the working of a frictional electric machine, when its smell is recognised. Traces of this gas exist in the air in mountainous districts, and by the sea side. By exposure to a temperature of 237° C. ozone is transformed into ordinary oxygen. Ozone is a powerful oxidising agent, and is inimical to the growth and development of germ life.

51. Water, H_2O.—This most important compound consists of two volumes of hydrogen united to one volume of oxygen, to form two volumes of water-gas or steam. By weight, water contains 16 parts of oxygen to 2 of hydrogen. Water in the pure state is odourless and tasteless; viewed through thick layers it has a blue colour. At temperatures below 0° C. water exists in the solid state; on being heated, ice expands until a temperature of 0° C. is reached. At this point the ice begins to melt; the temperature remains stationary until the whole of the ice is melted, but in order to effect the change from the solid to the liquid condition as much heat is required as would be sufficient to raise 79 times the weight of water from 0° to 1° C. Ice in melting contracts in bulk; 10·9 volumes of ice producing 10 volumes of water. As the ice cold water is further heated, contraction continues until a temperature of 4° C. is reached: at this point water is at its maximum density, and any given weight of it occupies its minimum volume. With further application of heat the water expands, and also rises steadily in temperature. In metal vessels open to the air, water boils at a temperature of 100° C. Continued heating now converts the whole of the water into steam, but does not raise the temperature. The quantity of heat necessary to convert the whole of the water at 100° C. into steam at the same temperature would raise 537·2 times the weight of water from 0° to 1° C. Steam in being further heated expands, and may have its temperature raised indefinitely: steam follows the same law of expansion on increase of temperature as do other gases. Steam, on being cooled, passes through a series of changes which are the exact converse of those just described. At all temperatures water gives off vapour, but with much greater rapidity as the temperature approaches the boiling point. This vapour exerts a definite pressure, the pressure increasing steadily with the temperature; at the boiling point, the pressure exerted by the vapour of water is exactly equal to that of the atmosphere; consequently, if the atmospheric pressure be diminished, the boiling point of water, and also that of all other liquids, is lowered. Advantage is taken of this property in many operations in the arts; thus, in driving off the water from sugar solutions, as in the preparation of malt extract, the boiling is effected in a vacuum, and so the temperature prevented from rising to any great height. On the other hand, by subjecting water to pressure, its boiling point might be raised to any temperature attainable, the only limit being the capacity for resisting the pressure of the material of the vessel. The tubes of steam ovens are constructed on this principle—a certain quantity of water is sealed up in them, which, on being heated, is converted into steam, having a sufficiently high temperature to effect the baking of bread. The boiling point of water also depends on any substances it may have in solution. Salt and other non-volatile bodies raise the temperature of the boiling point, but do not affect that of the steam produced, which immediately falls to 100° C. Admixture of volatile bodies lowers the boiling point; thus, water to which alcohol has been added boils at a temperature below 100° C. until the whole of the alcohol has been expelled.

52. Solvent Power of Water.—Water is, of all bodies, pre-eminently *the* solvent in nature. It dissolves more or less of all gases; thus, as previously stated, oxygen is soluble in it to the extent of about 3 volumes per 100. On the other hand, one volume of water at 0° C. dissolves 1050 volumes of ammonia gas. Many, if not most, liquids mix readily (or are miscible) with water in all proportions; others, as oil, ether, &c., do not so mix, but are nevertheless frequently in part dissolved by the water. Most solid bodies also dissolve in water; water usually dissolves more of these substances when hot than when cold: this, however, does not invariably apply; thus, salt dissolves to as great an extent in cold as in hot water. As a result of this property, water is never found in a state of purity in nature. Even rain is found to have dissolved-out traces of solid matter that were suspended in the air, while river and spring water is always more or less impure from saline and other matter dissolved from the soil and rocky strata from whence it is obtained. In addition to the solid matter there is also invariably more or less gas held in solution in natural waters. A further account of natural waters, having particular reference to their fitness for bread-making, is given in a future chapter. For chemical purposes all such water is purified by distillation, that is, it is converted into steam, and re-condensed; the solid impurities then remain behind. This treatment does not, however, free the water from gases or from volatile impurities. For certain purposes where rigidly pure water is a necessity, special modes of preparation have to be adopted: these will be described in detail hereafter.

53. Chlorine, Cl_2.—This element is, at ordinary temperatures, a gas of a greenish yellow colour, with a most pungent, acrid, and suffocating odour and taste. The presence of comparatively small quantities renders air irrespirable. Chlorine is non-inflammable; but, to a limited extent, supports combustion. Hydrogen burns in it readily, but carbon is incapable of direct combination with chlorine. Chlorine does not exist in the free state in nature; it has so great an attraction for hydrogen that it slowly decomposes water, combining with the hydrogen and liberating oxygen in the free state. Water dissolves 2·368 volumes of chlorine at 15° C.: the solution has a powerful bleaching action on vegetable colours, and also is a most efficient disinfectant. Chlorine forms compounds, termed "Chlorides," with all other elements.

54. Hydrochloric Acid, HCl.—This, the only known compound of hydrogen and chlorine, is a gaseous body. Hydrochloric acid gas is colourless, fumes in coming in contact with moist air, has a most pungent smell, and is neither inflammable nor a supporter of combustion. One volume of hydrogen unites with one volume of chlorine to produce two volumes of hydrochloric acid gas. The gas dissolves readily in water, one volume of which at 15° C. holds in solution 454 volumes of the gas. The concentrated solution fumes on exposure to air, and smells strongly of the gas; it has an extremely sour taste, and turns litmus solution red. The commercial solution has a specific gravity of about 1·16, and contains about 33 per cent. (one third) by weight of hydrochloric acid. Hydrochloric acid attacks many of the metals forming chlorides, with the evolution of hydrogen. Hydrochloric acid and the bases when placed in contact form the salts known as chlorides. Hydrochloric acid and the chlorides may be recognised when in solution by their giving a curdy white precipitate on the addition of dilute nitric acid, and nitrate of silver solution.

55. Chlorides.—Common salt, or sodium chloride, $NaCl$, is the most important of the chlorides. Its principal use is as an antiseptic or preventative of putrefaction; its effect during fermentation of dough will be discussed hereafter. Other chlorides, as calcium chloride, $CaCl_2$, will be referred to as occasion arises.

56. Bleaching Powder, or Chloride of Lime, $CaOCl_2$.—This body is produced by the union of lime (calcium oxide) with chlorine. The addition of almost any acid, even carbon dioxide, is sufficient to effect its decomposition, liberating free chlorine. Chloride of lime is consequently largely used for disinfecting purposes.

57. Carbon, C.—This element is only known in the solid state, being incapable of liquefaction or vaporisation at the highest temperatures at our command (except possibly at the highest temperatures of the electric arc). It exists in nature, uncombined with other elements, in two forms or varieties most strikingly different from each other. One of these constitutes the gem known as the diamond, the other is graphite, or black lead. Both these bodies are almost pure carbon. Carbon also occurs plentifully as a constituent of animal and vegetable substances, as flesh, bones, fat, wood, leaves, seeds, and the almost numberless bodies that may be obtained from them. Limestone, marble, and chalk rocks contain a large percentage of carbon; so also does coal, which is simply fossilised wood. From flesh, bones, wood, and many other substances, carbon may be obtained by heating them to redness in a closed vessel: this form of carbon is termed "charcoal," that from bones being "animal," and that from wood "vegetable charcoal." Carbon prepared in this manner, or charcoal, is a black substance. The operation of thus heating a substance in a closed vessel to a temperature sufficiently high to effect its decomposition into volatile liquid and gaseous products, with usually, as in this case, a non-volatile residue, is termed "destructive distillation." All forms of carbon are inflammable. When burned with an insufficient supply of oxygen, carbon monoxide, CO, is produced; with excess of oxygen, carbon dioxide, or CO_2, is formed. Charcoal possesses a most remarkable property of absorbing and condensing gases within its pores; thus, freshly-burnt wood charcoal is capable of absorbing about ninety times its volume of ammonia gas. Charcoal also absorbs considerable quantities of oxygen; and among other gases, those evolved during the putrefaction of animal and vegetable bodies. The gases resulting from putrefaction are largely composed of carbon and hydrogen, and, when thus brought by their absorption within the charcoal so closely in contact with oxygen, are rapidly burned or oxidised to carbon dioxide, water, and more or less of other inodorous and innocuous substances. Charcoal thus acts as a remedy for bad smells, and acts not by masking them by a more powerful odour, but by absorption of the deleterious vapours, and their conversion in harmless products. In this way charcoal is also capable of removing evil smells from water: for instance, water from a stagnant pond on being shaken up with charcoal loses its disagreeable odour. Not only does charcoal act as an absorbent of gases, but it also removes many colouring matters from solution; thus, a syrup of dark brown sugar on being shaken up with animal charcoal, and then filtered, may be made almost colourless. These properties of charcoal have led to its finding much favour as a filtering medium for the purification of water; for this purpose it is, when fresh, of great efficacy, but after a time loses its activity by becoming saturated with the bodies it is intended to remove. All filters require from time to time to be taken apart, and the filtering medium removed and replaced by some fresh and pure material. Charcoal may be renovated by being heated to redness in a closed vessel. With these precautions, charcoal forms one of the best of filtering agents; but without attention to continuous cleaning, filters, so far from purifying water, become positive sources of the most serious and dangerous impurities. Charcoal is frequently used in the laboratory for decolourising purposes.

58. Carbon Monoxide, CO.—This compound is a colourless, odourless, and exceedingly poisonous gas. It is formed when carbon dioxide gas passes over red-hot charcoal, as it frequently does in a clear coke or charcoal fire. The carbon monoxide thus produced burns with a blue flame on the surface of the fire. Carbon monoxide is also formed together with free hydrogen when steam is passed through a red-hot carbon mass, such as a fire of burning coke. The gas is inflammable, and in burning yields carbon dioxide. Carbon monoxide has no action on lime-water.

59. Carbon Dioxide, CO_2.—This gas plays a most important part in the chemistry of bread-making. It is colourless, has a sweetish taste, and peculiarly brisk and pungent odour. As carbon dioxide is an essential constituent of ærated waters, its taste and smell are familiar, being those perceived on opening and tasting the contents of a bottle of soda-water. Carbon dioxide is neither inflammable, nor under ordinary circumstances a supporter of combustion. The gas is poisonous to breathe, but may be taken into the stomach without injury. Liquids containing carbon dioxide gas in solution are marked by a pleasant brisk flavour. Carbon dioxide has a density of 22, and is 1·527 times as heavy as ordinary air. In the absence of air currents, it consequently has a tendency to remain a considerable time in a layer on the surface of liquids from which it is being evolved, particularly when they are in somewhat confined spaces. Carbon dioxide is soluble in about its own volume of water: as measured by volume the solubility is independent of the pressure to which the gas is subject. Thus, if 100 cubic inches of water be shaken up with carbon dioxide at the ordinary atmospheric pressure of about 15 lbs. to the square inch, the water dissolves at 15° C. its own volume of the gas. If the pressure be increased to 30 lbs. per square inch, the water still dissolves 100 cubic inches of carbon dioxide, but as with double the pressure the density of the gas is doubled, it is evident that the doubled pressure results in effecting the solution of twice the weight of carbon dioxide gas. The weight of carbon dioxide dissolved by water is therefore in direct proportion to the pressure employed. Concentrated solutions of carbon dioxide gas in water are prepared by pumping the gas under pressure (some 10 or 12 atmospheres) into a strong vessel, in which it is agitated with water. The solution thus obtained is permanent under pressure, but on its relaxation the carbon dioxide is again liberated in the gaseous state. Carbon dioxide may be obtained in a variety of ways; the simplest is by the burning of carbon, or organic bodies containing carbon, in air or oxygen—

$$\underset{\text{Carbon.}}{C} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Carbon Dioxide.}}{CO_2}.$$

It is also produced when chalk, limestone, or marble (calcium carbonate) is heated to full redness—

$$\underset{\text{Calcium Carbonate.}}{CaCO_3} = \underset{\text{Calcium Oxide (Lime).}}{CaO} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Likewise, by gently heating sodium bicarbonate or ammonium carbonate—

$$\underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} = \underset{\text{Sodium Carbonate.}}{Na_2CO_3} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

$$\underset{\text{Ammonium Carbonate.}}{(NH_4)_2CO_3} = \underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Another method of obtaining carbon dioxide is by treating any carbonate with an acid: the following equations represent a few of the principal of such reactions—

$$\underset{\text{Calcium Carbonate.}}{CaCO_3} + \underset{\text{Hydrochloric Acid.}}{2HCl} = \underset{\text{Calcium Chloride.}}{CaCl_2} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

$$\underset{\text{Calcium Carbonate.}}{CaCO_3} + \underset{\text{Sulphuric Acid.}}{H_2SO_4} = \underset{\text{Calcium Sulphate.}}{CaSO_4} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

$$\underset{\text{Sodium Carbonate.}}{Na_2CO_3} + \underset{\text{Hydrochloric Acid.}}{2HCl} = \underset{\substack{\text{Sodium Chloride} \\ \text{(Common Salt).}}}{2NaCl} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Carbon dioxide is also evolved during alcoholic fermentation, and the putrefaction and decay of organic bodies. An aqueous solution of carbon dioxide gas changes the colour of litmus solution from full blue to a port wine tint; such a solution has feebly acid properties and forms with bases the salts termed carbonates. The solution in water may be viewed as carbonic acid, H_2CO_3; hence the gas is frequently called carbonic anhydride. Formerly the term acid was applied, by some chemists, indifferently to the anhydrides and their compounds with water; carbon dioxide then received the name of "carbonic acid gas," by which it is still popularly known. Modern definitions of an acid preclude this name being now correctly applied to what are properly termed anhydrides.

60. Carbonates.—With the exception of those of the alkalies, all carbonates are insoluble in water; many are, however, dissolved by water containing carbon dioxide in solution. The most interesting example of this is the solution of considerable quantities of carbonate of lime in natural waters obtained from the chalk and other limestone deposits. Such waters, although perfectly clear, become turbid on being boiled from fifteen to thirty minutes: the boiling drives off the carbon dioxide, and the calcium carbonate is precipitated in the insoluble state. The formation of carbonates is exemplified by the passage of carbon dioxide gas into lime water, *i.e*, a solution of lime in water, CaH_2O_2; the insoluble calcium carbonate, or carbonate of lime, is produced, and turns the clear solution milky. This forms a useful and convenient test for the presence of carbon dioxide in any mixture of gases. Most carbonates are easily decomposed by the addition of an acid, with the formation of the corresponding salt of the acid used. Several instances of this action have been given when describing methods for the production of carbon dioxide. The acid- or bi-carbonates have one half only of the hydrogen replaced by a metal; they may be produced by passing carbon dioxide gas to excess through a solution of the normal carbonates of the alkalies. The bicarbonates are readily decomposed by heat into normal carbonates, free carbon dioxide, and water.

61. Compounds of Carbon with Hydrogen.—These are exceedingly numerous; an account of some of those of most importance will be given when describing the organic bodies more particularly associated with our subject. As a group, they are termed "hydrides of carbon."

62. Nitrogen, N_2.—This gas constitutes about four-fifths, by volume, of the atmosphere; it is also a constituent of nitric acid and its salts, and of many animal and vegetable substances. Nitrogen is colourless, odourless, tasteless, non-inflammable, and a non-supporter of combustion. It does not readily enter into combination with other elements, and in the free state is marked rather by its neutral qualities than by any positive characteristics. In the uncombined state its principal function is that of a diluting agent in the atmosphere. Although not an active element, nitrogen forms an extensive series of compounds.

63. The Atmosphere.—It has already been stated that the atmosphere consists essentially of oxygen and nitrogen; these gases are not united in any way, but simply form a mechanical mixture. In addition to the nitrogen and oxygen, air contains small quantities of carbon dioxide, water vapour, and traces of other substances. Subjoined is a table showing its average composition:—

	Oxygen, O_2, ...	20·61
	Nitrogen, N_2, ...	77·95
	Carbon Dioxide, CO_2, ...	0·04
	Aqueous Vapour, H_2O, ...	1·40
	Nitric Acid, HNO_3, ...	Traces.
	Ammonia, NH_3, ...	
	Hydrides of Carbon, ...	
In towns.	Sulphuretted Hydrogen, SH_2, ...	"
	Sulphur Dioxide, SO_2, ...	

Air, freed from moisture and carbon dioxide, contains the following percentages of nitrogen and oxygen :—

	By Measure.	By Weight.
Nitrogen, ...	79·19	76·99
Oxygen, ...	20·81	23·01
	100·00	100·00

In addition to the bodies already mentioned, air in most localities contains germs of miscroscopic organisms.

64. Ammonia, NH_3.—Traces of this gas, either in the free state or as salts, are found both in air and in water. Its great natural source is the decomposition of animal and vegetable substances which contain nitrogen as a constituent. In this way, ammonia is continually being formed in nature by the decay of refuse nitrogenous matter, such as the urine and excreta of animals, and other bodies. Many nitrogenous vegetable and animal substances also evolve ammonia on being strongly heated : among these is coal, which thus forms the principal source from which ammonia is now derived. Ammonia is a colourless gas, with a most pungent and characteristic odour : in the concentrated state the gas acts as an irritant poison, but when diluted with air possesses a smell rather pleasant than otherwise. Ammonia does not support combustion, and at ordinary temperatures does not burn in air. The gas is very soluble in water ; the solution has the odour of the gas, and constitutes what is commonly known as "liquid ammonia." Ammonia acts as a powerful alkali, neutralising the strongest acids, and restoring the blue colour to reddened litmus.

65. Ammonium Salts.—On the addition of an acid, such as either sulphuric or hydrochloric, to ammonia, the odour disappears, and the acid, as above stated, is found to be completely neutralised. The reaction may be expressed thus :—

$$\underset{\text{Ammonia.}}{NH_3} + \underset{\text{Hydrochloric.}}{HCl} = \underset{\text{Ammonium Chloride.}}{NH_4Cl.}$$

$$\underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Sulphuric Acid.}}{H_2SO_4} = \underset{\text{Ammonium Sulphate.}}{(NH_4)_2SO_4.}$$

On comparing, in each case, the formula of the resulting compound with that of the acid, it will be seen that the group NH_4 replaces the hydrogen of the acid. This compound, NH_4, cannot exist in the free state, but occurs in a number of chemical compounds, and can be transferred from one to another without undergoing decomposition. It is consequently viewed as a compound radical, and has received the name "Ammonium." The solution of ammonia in water may then be represented as ammonium hydrate, NH_4HO; this body, which is alkaline to litmus, is then seen to be analogous to sodium hydrate, $NaHO$, the ammonium occupying a corresponding place to the sodium. This is seen the more clearly when a comparison is instituted between the action of the same acid upon each :—

$$\underset{\text{Ammonium Hydrate.}}{NH_4HO} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Ammonium Chloride.}}{NH_4Cl} + \underset{\text{Water.}}{H_2O.}$$

$$\underset{\text{Sodium Hydrate.}}{NaHO} + \underset{\text{Hydrochloric Acid.}}{HCl} = \underset{\text{Sodium Chloride}}{NaCl} + \underset{\text{Water.}}{H_2O.}$$

Ammonium is often represented by the symbol "Am." instead of NH_4. The stronger bases, as lime, CaO, or soda, $NaHO$, decompose ammonium salts with the liberation of ammonia :—

$$\underset{\text{Ammonium Chloride.}}{NH_4Cl} + \underset{\text{Sodium Hydrate.}}{NaHO} = \underset{\text{Sodium Chloride}}{NaCl} + \underset{\text{Ammonia.}}{NH_3} + \underset{\text{Water.}}{H_2O.}$$

All ammonium salts volatise on being heated, leaving no residue, unless the acid be non-volatile, in which case the acid remains behind.

66. Oxides and Acids of Nitrogen.—No less than five distinct compounds of nitrogen with oxygen are known. These, however, have but little connection with our present subject. Two of these oxides form acids with water—the acids being Nitric Acid, HNO_3, and Nitrous Acid, HNO_2.

67. Nitric Acid, HNO_3.—This is by far the most important oxy-compound of nitrogen. Its usual source in nature is the oxidation of animal matter in the soil. The nitric acid thus produced is found in combination with some base, usually as potassium or calcium nitrate. Pure nitric acid is a colourless fuming liquid; commonly, however, the acid is of a slightly yellow tint, from the presence of some of the lower oxides of nitrogen. The pure acid has a specific gravity of 1·52, and mixes with water in all proportions. Nitric acid is a most powerful oxidising agent, and attacks most animal and vegetable tissues with great vigour. It also freely dissolves most of the metals, forming nitrates. Gold and platinum are not affected by this acid when pure, but are dissolved with the formation of chlorides by a mixture of nitric with hydrochloric acid. Reducing agents convert nitric acid into nitrous acid, or some one or more of the oxides of nitrogen containing less oxygen. Under favourable circumstances, nitric acid may even be reduced to ammonia; that is, the whole of its oxygen may be removed, and its place occupied by hydrogen.

68. Nitrates.—The principal of these is potassium nitrate, KNO_3. Like nitric acid, the nitrates are powerful oxidising agents.

69. Nitrous Acid, HNO_2, and Nitrites.—Nitrous acid is an unstable body; it is at times found in water as an intermediate product in the oxidation to nitrates of nitrogeneous matter that may have been present. Potassium nitrite, KNO_2, is one of its best known salts.

70. Sulphur, S_2.—This element is a brittle yellow solid, which burns in air or oxygen with the formation of sulphur dioxide, SO_2.

The principal interest of sulphur, in connection with our present subject, lies in its compounds. In addition to its occurrence in many inorganic bodies, sulphur is one of the constituents of albumin and other animal and vegetable substances.

71. Sulphuretted Hydrogen, SH_2.—This body is a colourless gas, having a most disgusting odour, resembling that of rotten eggs; the gas is soluble in water, which at 15° C. dissolves 3·23 volumes of sulphuretted hydrogen. During the decomposition of substances, either of animal or vegetable origin, containing sulphur, sulphuretted hydrogen is one of the bodies evolved: it is from the presence of this gas that rotten eggs acquire their characteristic odour. Sulphuretted hydrogen is inflammable, and produces water and sulphur dioxide by its combustion. Moist sulphuretted hydrogen undergoes, in the presence of oxygen, slow oxidation, with the formation of water and deposition of free sulphur:—

$$\underset{\text{Sulphuretted Hydrogen.}}{2HS_2} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad = \quad \underset{\text{Sulphur.}}{S_2} \quad + \quad \underset{\text{Water.}}{2\ H_2O.}$$

72. Sulphur Dioxide, SO_2.—This gas is produced by the combustion of sulphur in either air or oxygen: it is colourless, has a pungent odour, recognised as that of burning sulphur; is neither inflammable nor a supporter of combustion. Sulphur dioxide is soluble in water, which at a temperature of 15° C. dissolves 47 volumes of the gas: the solution thus formed tastes and smells of the gas, it reddens and finally bleaches a solution of litmus. Sulphur dioxide is one of the most powerful antiseptics known.

73. Sulphurous Acid, H_2SO_3, and the Sulphites.—Sulphur dioxide when dissolved in water produces a somewhat unstable acid, H_2SO_3. The sulphites, or salts of this acid, are mostly insoluble in water, the principal exceptions being sodium sulphite, Na_2SO_3, and potassium sulphite. In addition to the normal sulphites, acid or bisulphites occur; these may be produced by passing excess of sulphur dioxide into a solution of the normal salts. The bisulphites readily evolve sulphur dioxide on being heated. Calcium sulphite is insoluble in water, but dissolves in a solution of sulphurous acid, forming calcium bisulphite, or as commonly called "bisulphite of lime." Bisulphite of lime is largely used as an antiseptic. Under the influence of oxidising agents, sulphurous acid and the sulphites are oxidised to sulphuric acid and sulphates.

74. Sulphuric Acid, H_2SO_4, and the Sulphates.—Sulphuric acid is one of the most useful chemical compounds known, forming as it does the starting point in the manufacture of a number of substances of vast importance in the arts. When in the pure state, sulphuric acid is a colourless, odourless liquid of an oily consistency: this latter property has led to its receiving the popular name of "oil of vitriol;" the acid, however, is in no way connected chemically with the class of bodies known as fats or oils. Sulphuric acid is nearly twice as heavy as water, having a specific gravity of 1·842; it boils at a temperature of 338° C. Sulphuric acid has a great attraction for water, with which it probably combines to form definite hydrates; considerable heat is evolved during the act of union. In consequence of this affinity for water, sulphuric acid is largely used as a desiccating or drying agent; on exposure to the air the acid speedily increases in weight by absorption of water vapour, and the air becomes dry; hence, if a vessel of sulphuric acid be placed under a bell jar, it speedily produces a dry atmosphere inside. Less concentrated varieties of the acid form staple articles of commerce. Owing to this attraction for water, sulphuric acid is a most corrosive body; wood, paper, and most vegetable and animal substances are vigorously attacked by it; the acid combines with the hydrogen and oxygen of the substance in the proportions in which they form water, and leaves behind a mass of carbon, together with any excess of either hydrogen or oxygen that may have been present. This, of course, does not in all cases represent the whole of the chemical action that may have occurred. Dilute sulphuric acid contains water in excess, and therefore does not exhibit this dehydrating tendency when placed in contact with other bodies; it is well to remember this, because in a number of reactions, where dilute sulphuric acid is employed, it produces not merely less energetic action, but action absolutely opposite in character to that of the concentrated acid. The dilute acid, if allowed to evaporate in contact with paper, &c., acts in a similar manner to the strong acid, as the water dries off. Sulphuric acid forms a normal and an acid series of salts, of which Na_2SO_4, sodium sulphate, and $NaHSO_4$, acid sodium sulphate, are, respectively, examples. Most of the sulphates are more or less soluble in water; calcium sulphate is only slightly so; barium sulphate is insoluble in water and dilute acids. Sulphuric acid and the sulphates may be detected in solution by the addition of hydrochloric acid and barium chloride, when they produce a white precipitate of $BaSO_4$.

75. Bromine, Br_2; Iodine, I_2; and Fluorine, F_2.—These three elements are very closely allied in properties to chlorine; they have no very intimate connection with the chemistry of wheat and flour. Bromine is a liquid; iodine, at ordinary temperatures, is a solid body. Iodine is slightly soluble in water, readily soluble in alcohol or a solution of potassium iodide, KI. Iodine, or its solution, produces a characteristic blue colour with starch: this reaction is of great delicacy, and is an exceedingly valuable test both for starch and iodine. Fluorine forms an acid with hydrogen, hydrofluoric acid, HF, which is characterised by its power of attacking and dissolving glass, and the silicates generally.

76. Silicon, Si; Silica, SiO_2; and the Silicates.—Silicon is an element somewhat resembling carbon in some of its properties; all that at present need be stated about it is that it forms with oxygen an oxide, SiO_2, analogous in composition to that of carbon, CO_2. This oxide, SiO_2, is termed silica, or at times, silicic anhydride. Flint and quartz are almost chemically pure forms of silica; in this form silica is insoluble in water and all acids, and mixtures of acids, except hydrofluoric acid. On being fused with an alkali, as KHO, or an alkaline carbonate, K_2CO_3, silica produces a glassy substance, entirely soluble in water: this body is potassium silicate, K_4SiO_4, and from it, silicic acid,

H_4SiO_4, may be obtained. Silicic acid is soluble in water, and is tasteless and odourless; on being gently evaporated it first forms a jelly, and then, as the whole of the water is driven off, the silica remains as a white powder, once more insoluble in water and acids. As silica produces a compound with water which, by action on bases, forms salts, silica is rightly viewed as an anhydride. The silicates are the principal constituents of the great rock masses of the earth and of soil. The natural silicates usually contain two or more of the following bases—iron oxides, alumina, lime, magnesia, potash, and soda. With the exception of those of potash and soda, the silicates are mostly insoluble.

77. Phosphorus, P_4; Phosphoric Acid, H_3PO_4; and the Phosphates.—In properties, phosphorus is one of the most striking of the elements; its attraction for oxygen is so great that it has to be kept under water in order to prevent its oxidation. Phosphorus occurs ordinarily as sticks of the colour and consistency of wax; a piece of phosphorus appears luminous in the dark when exposed to air; this is caused by its slow combustion. A slight elevation of temperature, or even friction, suffices to cause phosphorus to burn vigorously; it then produces a vivid light, and forms, by union with oxygen, phosphorus pentoxide, P_2O_5, or, as it is sometimes termed, phosphoric anhydride. Phosphoric anhydride is a white powder, which combines with water with great avidity to form phosphoric acid, H_3PO_4. Phosphoric acid is principally of interest because of its salts, known as phosphates: of these the most important are calcium phosphate, $Ca_3(PO_4)_2$; and potassium phosphate, K_3PO_4. Calcium phosphate is the principal constituent of the mineral matter of bones, and hence in some form or other is an absolutely essential article of food. Phosphates occur in some parts of all plants, and is derived by them from the soil. In wheat, the phosphoric acid is mostly combined with potassium. The alkaline phosphates are soluble in water; the others are insoluble, but may be readily dissolved by the addition of nitric or hydrochloric acid.

78. The Metals and their Compounds.—Within the limits of this work it would be impossible to give even the briefest systematic description of these bodies. An account follows of calcium and potassium, but such other metallic compounds as have any bearing on our subject will be described when reference to them is made.

79. Calcium, Ca, and its Compounds.—Calcium is scarcely known in the free state, as it has such an attraction for oxygen as to almost immediately, on exposure to the air, form calcium oxide. But one oxide of calcium is known that has any practical importance; this body, CaO, is that commonly spoken of as "quicklime." The salts of calcium are also commonly referred to as salts of lime; this is not strictly correct, but in most cases makes no real difference. To this there is one exception. Chloride of calcium, or calcium chloride, is $CaCl_2$; chloride of lime is a very different body, $CaOCl_2$. Calcium oxide is a whitish grey substance, usually obtained by the action of heat on the carbonate; it is infusible at the highest temperatures at our command. Calcium oxide combines readily with water, with the evolution of considerable heat, forming slaked lime, or calcium hydrate, CaH_2O_2. Calcium hydrate occurs as a dry, white powder, which is soluble in water to the extent of one part in 600. This solution is that known as "lime-water," and is employed as a test for carbon dioxide. The solution of lime has a decidedly alkaline reaction, turning reddened litmus blue. Calcium produces an extensive series of salts; of these calcium carbonate has been already referred to when describing carbon dioxide. The next most important salt is calcium sulphate; this body is only slightly soluble, one part being dissolved by about 400 parts of water. The phosphate and chloride have already been referred to; the latter has a great affinity for water, and consequently is often used as a drying agent; it often can be used where sulphuric acid would be unsuitable from its other properties.

80. Potassium, K, and its Compounds.—Potassium is a soft bluish white metal, which has so great an attraction for oxygen that it has to be kept from contact with the air, and even liquids, as water, which contain oxygen as one of their compounds; for this purpose the potassium is generally preserved in mineral naphtha, a compound of carbon and hydrogen The normal oxide of potassium is K_2O; this body has such affinity for water that it practically never occurs in the anhydrous state, but usually as the hydrate, KHO. Potassium hydrate is a white crystalline solid substance; it melts at a red heat, and is supplied commercially either in sticks, or in lumps produced by breaking up fused slabs of the compound. Potassium hydrate is a powerfully caustic body, and rapidly destroys animal tissues. It is one of the most powerful alkalies known, restoring the colour to reddened litmus, and forming salts with acids. Potassium hydrate decomposes ammonium salts with the liberation of ammonia; sodium hydrate and lime behave similarly in this respect. Potassium hydrate is very soluble in water; the solution has a peculiar soapy feel to the fingers. Potassium hydrate has a great attraction for carbon dioxide; its solution absorbs that gas with great rapidity, forming potassium carbonate, K_2CO_3. Potassium carbonate is a white deliquescent body (*i.e*, one that readily becomes moist through the absorption of water). Like other deliquescent bodies, potassium carbonate is very soluble in water; the solution is strongly alkaline to litmus, although the salt is of normal constitution. In fact, the very strong bases produce with certain weak acids normal salts, in which the alkaline compound may be said to predominate. Potassium carbonate was at one time almost exclusively obtained from wood ashes. An acid potassium carbonate, $KHCO_3$, also occurs; this body is neutral to litmus, and is less soluble in water; it is at a temperature of 80° C. decomposed into the normal carbonate and free acid.

81. Sodium Compounds.—Sodium forms a series of compounds which closely resemble those of potassium; of these the most familiar are sodium hydrate, $NaHO$; sodium carbonate, Na_2CO_3; acid sodium carbonate, $NaHCO_3$; and sodium chloride, $NaCl$. Sodium hydrate is a somewhat less powerful base than potassium hydrate.

CHAPTER III.

DESCRIPTION OF ORGANIC COMPOUNDS.

82. "Organic" Chemical Compounds.—Chemical science is commonly divided into two branches, known respectively as "Inorganic" and "Organic" chemistry. Certain substances, whether they occur in nature, or are prepared in the laboratory, are obtained from mineral sources: the bodies described in the preceding chapter are instances of such compounds. There are, on the other hand, bodies which are obtained either from the animal or vegetable kingdom. Animals and vegetables are organised bodies, that is, they have definite organs which adapt them for that series of processes which constitutes what is called "life;" hence chemical compounds having a vegetable or animal origin are termed "organic." Those which are not thus obtained from organic sources are termed "inorganic" compounds: the two names have also been given to the branches of chemistry which treat respectively of these two classes of bodies, and of their properties and reactions. It was formerly supposed that the so-called organic bodies could only be obtained from organic sources; but comparatively recent chemical investigation has demonstrated that many such compounds can be produced by artificial means from the elements of which they are composed, without the intervention of living organisms, and even under such conditions as render the existence of living organisms an impossibility. Alcohol and its derivations are examples. The definition of an organic body as one produced as a result of "life" is evidently no longer tenable, and chemists have endeavoured, with more or less success, to frame new definitions of organic chemistry. As **all organic compounds contain carbon,** it has been proposed to define it as the "chemistry of the carbon compounds;" again, as many organic bodies are well defined compound radicals, the phrase, "chemistry of the compound radicals" has been proposed. These definitions have not been found entirely satisfactory, as they are either too wide or too narrow. For our present purpose, **Organic Chemistry may be viewed, with sufficient accuracy, as that branch of the science which treats of the composition and properties of those compounds whose usual source is either animal or vegetable.**

83. Organised Structures.—Although organic compounds can be prepared by artificial means, it must be clearly understood that **no chemical processes have as yet been found capable of producing an organised structure**; further, all evidence hitherto obtained, so far as it goes, tends to prove the impossibility of such structures being formed other than through living agencies. For instance, starch is found, when viewed under the microscope, to have a structural organisation peculiar to itself. Starch may be dissolved, and after such solution again obtained in the solid state; but the solid thus produced shows no traces of the original structure of the grains of starch; neither is there known any artificial process by which the starch may again be built up into structures of the same kind as those in which it originally occurred. Similarly, it is impossible to artificially produce a blood corpuscle. The same law applies to minute organisms as yeast, *bacteria*, &c.; none of these can be generated otherwise than through the agency of previously existing living beings of the same type. So far as any problem can be proved scientifically, **this fact of the impossibility of spontaneous generation is abundantly demonstrated**; experimental evidence of a most conclusive character has shown as certainly as scientific research can, in any case, possibly show, that living organisms can only be formed by means of similar pre-existing organisms. Man may make a steam engine or a watch, but a yeast cell is beyond his power.

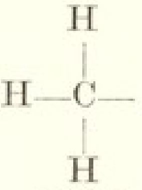
84. Composition of Organic Bodies.—Organic compounds, generally, have a much more complicated chemical composition than have inorganic compounds; they are mostly, however, restricted to comparatively few elements. All organic bodies contain carbon; many are composed of carbon and hydrogen only, a greater number consist of carbon, hydrogen, and oxygen; while others contain the four elements, carbon, hydrogen, oxygen, and nitrogen. The majority of organic compounds belong to one or other of these series. Carbon, more than any other element, is remarkable for the property of, in compounds, combining directly with itself, and so forming most complicated bodies out of comparatively few elements.

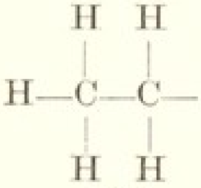
85. Classification of Organic Compounds.—The number of these is so bewildering that, without some classification, it would be impossible to grasp their relationship to each other: recent chemical science has succeeded in very clearly demonstrating the constitution of a vast number of these bodies. There are, in the first place, large numbers of well defined compound radicals, consisting of carbon and hydrogen: it has been found possible to group these into distinct families, the members of each of which may be represented by a common formula.

86. Organic Radicals.—The most important series of these is that known as the "Methyl," or "Ethyl" series; these have the common formula $(C_nH_{2n+1})_2$. This formula signifies that in the first place the molecule consists of two semi-molecules that are similar in composition; secondly, that in each semi-molecule the number of atoms of hydrogen is one more than double the number of atoms of carbon. The following is a list of a few of the radicals of this series:—

Methyl	Me_2	$\left\{\begin{array}{l}CH_3\\CH_3\end{array}\right.$
Ethyl	Et_2	$\left\{\begin{array}{l}C_2H_5\\C_2H_5\end{array}\right.,$ or $\left(\begin{array}{l}CH_3\\C_2H_2\end{array}\right)_2,$ or $\left\{\begin{array}{l}CMeH_2\\CMeH_2\end{array}\right.$
Propyl	Pr_2	$\left\{\begin{array}{l}C_3H_7\\C_3H_7\end{array}\right.,$ or $\left\{\begin{array}{l}CEtH_2\\CEtH_2\end{array}\right.$
Butyl	Bu_2	$\left\{\begin{array}{l}C_4H_9\\C_4H_9\end{array}\right.$
Amyl	Ay_2	$\left\{\begin{array}{l}C_5H_{11}\\C_5H_{11}\end{array}\right.$
Caproyl	Cp_2	$\left\{\begin{array}{l}C_6H_{13}\\C_6H_{13}\end{array}\right.$

Each semi-molecule of these radicals behaves in compounds as though it were an atom of a monad element; the atomicity is shown by the following graphic formulæ—


Methyl.


Ethyl.

From these formulæ it is seen that in each case there is one of the carbon bonds free; in the free state two semi-molecules unite by these bonds to form the molecule. The graphic formulæ also show how each of the higher radicals of the series may be viewed as compounds of the next lower radical with an additional CH_2. The temperature of the boiling points of these bodies increases as the series is ascended.

87. Hydrides of Organic Radicals (Paraffin Group).—These bodies are compounds of the radicals with hydrogen; those of the series already referred to have the general formula, C_nH_{2n+2}. Among them there is, as the lowest, methyl hydride (marsh gas), CH_3H or CH_4; from this the series ascends regularly to $C_{16}H_{34}$. These compounds are distinguished by their not being readily attacked by the most powerful oxidising agents, they consequently have received the name of "paraffins" (from the Latin, *parum affinis*, having little affinity). The lower members of the series are gases, the middle are liquids, and the higher members are solid at ordinary temperatures. The paraffins are produced by the destructive distillation of wood, coal, and many other organic substances, and also occur in rock-oils. Some varieties of American petroleum consist almost entirely of paraffins. In distilling the crude petroleum, it is found that the temperature of the vapour produced rises as the operation progresses. The more volatile portions distil off first; the distillate may be collected in separate portions or fractions; the operation is then termed "fractional distillation." The lighter or more volatile paraffins constitute what is known as light petroleum spirit; this substance, when carefully freed from solid impurities, is of great use as a solvent for fatty substances, both in the arts and chemical analysis. Good light petroleum spirit should distil entirely at a temperature of 70° C. Such spirit is a mixture of several of the lower paraffins. The petroleum of commerce consists of a somewhat higher fraction, and mineral lubricating greases and "vaseline" of a yet less volatile portion. The least volatile portion of all constitutes, when pure, the hard white solid substance known as "solid paraffin," or paraffin "wax."

88. The Alcohols.—These bodies are hydrates of the organic radicals; they possess basic properties, and enter into combination with acids to form organic salts. Thus ethyl alcohol, being C_2H_5HO, is converted by the action of hydrochloric acid into C_2H_5Cl, ethyl chloride. This reaction is analagous to that by which sodium hydrate is converted into sodium chloride. Of the various alcohols, those of the methyl series are the most important, and are represented by the formula, $C_nH_{2n+1}HO$. Subjoined are a few examples of these compounds:—

Methyl Alcohol,		CH_3HO, or	$\left\{\begin{matrix} H \\ CH_2HO. \end{matrix}\right.$	Butyl Alcohol,		C_4H_9HO.
Ethyl	,,	C_2H_5HO, or	$\left\{\begin{matrix} CH_3 \\ CH_2HO. \end{matrix}\right.$	Amyl	,,	$C_5H_{11}HO$.
Propyl	,,	C_3H_7HO.		Melissic	,,	$C_{30}H_{61}HO$.

The lower members of the series are liquid, and the higher solid.

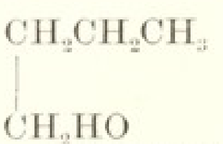
89. Methyl Alcohol, CH_3HO.—This body, in an impure form, is yielded on the destructive distillation of wood, and hence is commonly known as "wood spirit," or "wood naphtha." This crude preparation has a nauseous flavour, which renders it unfit for drinking: the pure methyl alcohol has, on the contrary, a purely spirituous taste and odour. Methyl alcohol mixes in all proportions with water, ethyl alcohol, and ether; it has at 15° C. a specific gravity of 0·8021.

90. Ethyl Alcohol, $\left\{\begin{matrix} C_2H_3 \\ CH_2HO, \end{matrix}\right.$ or C_2H_5HO.—This body constitutes the active ingredient of beer, wine, and of all spirituous liquors, as brandy, whisky, &c. The term "alcohol," when used without any prefix, is always understood to refer to this compound, which is known popularly as "spirits of wine." Alcohol may be produced artificially from its elements by purely chemical means, but is always manufactured by the process of fermentation, of which a detailed account is hereafter given. Pure ethyl alcohol is a colourless, mobile liquid, having an agreeable spirituous odour, and a burning taste. Alcohol is inflammable, and burns with a scarcely luminous smokeless flame, evolving considerable heat; it is on this account largely used in "spirit" lamps as a fuel. Alcohol rapidly evaporates at ordinary temperatures, and when pure, boils at 78·4° C. (=173·1° F.) At a temperature of 15·5° C., alcohol has a specific gravity of 0·79350; that of water, at the same temperature, being taken as unity. Alcohol mixes with water, and also ether, in all proportions: for the former compound it has a great affinity, and evolves considerable heat on the two being mixed; the volume of the mixture is less than that of the two liquids taken separately. As previously mentioned, alcohol is manufactured by fermentation; this process is only capable of producing a comparatively dilute solution of alcohol in water. In order to obtain a stronger spirit, the fermented liquid is distilled; as alcohol boils at a lower temperature than water, the earlier portions of the distillate are the stronger in spirit, until finally no alcohol remains in the liquid being distilled. It is not possible to obtain in this manner alcohol free from water, as even the very first portions of spirit which distil over carry water with them. By several times distilling the spirit it is possible to obtain a mixture containing about 90 per cent. of the pure spirit: special distilling arrangements have resulted in the production of a distillate containing as much as 95 per cent. of alcohol. In order to remove this small quantity of water, the spirit is treated with quicklime or potassium carbonate, and then allowed to stand, and after a time distilled: in this manner alcohol can be obtained in which there is only the most minute trace of water. This desiccated alcohol is termed "alsolute" alcohol. Alcohol is of very great use as a solvent, particularly for many organic bodies; it also acts as an antiseptic, and hence is employed for the preservation of biological and other specimens. The solvent power of alcohol is modified considerably by its admixture with more or less water: for many purposes alcohol of a certain definite strength is necessary. As water and alcohol have different densities, and as density is easily measured, it is a usual method of testing the strength of alcohol to take its specific gravity. Tables have been prepared giving the strength in percentages of alcohol present for different densities. Three distinct standards of strength of alcoholic spirit are commercially recognised. The "Rectified Spirit of Wine" of the British Pharmacopœia is the strongest spirit that can be produced by the ordinary methods of distillation: such spirit should contain 84 per cent. by weight of absolute alcohol, and should have a density of 0·838. "Proof Spirit" is a term that has survived its original application: it is now legally defined as spirit of such a strength, that 13 volumes of it shall weigh at 51° F. the same as 12 volumes of water at the same temperature. Proof spirit has at 15·5° C. a density of 0·91984, and contains 49·24 per cent. by weight of alcohol and 50·76 of water. Weaker spirits are defined as being so many degrees "under proof" (U.P.), while stronger spirits are referred to as being so many degrees "over proof" (O.P.). A spirit of 10 degress U.P. is such that it contains 90 per cent. of proof spirit and 10 per cent. of water; spirit of 10 degrees O.P. is of such a strength that it may be made up to 110 volumes by the addition of water, and would then have the same percentage of alcohol as proof spirit. Absolute alcohol is that, as before stated, which contains no water. For chemical purposes it is usual to specify the strength of alcohol, either as so much per cent. spirit, or by its density. When for any purpose it is directed that alcohol of a certain strength must be employed, particulars will be given as to its density; for complete tables of densities and corresponding strengths, the larger treatises on chemistry must be consulted.

91. Detection of Alcohol.—Alcohol when present in any quantity is easily recognised by its smell; in liquids which contain traces only, it is best to distil and then examine the first portions of the distillate. When using a Liebig's condenser, it will be seen, at the point where the vapour begins to condense, that when alcohol is present, the distillate trickles down the sides of the tube in peculiar oily looking drops or "tears." This appearance ceases as soon as the whole of the alcohol has distilled off. Very minute quantities of alcohol suffice to produce this effect. Another and more delicate method for its detection depends on the production of iodoform. This body has the symbol CHI_3, and is similar in constitution to chloroform, $CHCl_3$. The liquid under examination should first be distilled, and the tests applied to the first portion of the distillate. Ten c.c. are to be taken and rendered alkaline by the addition of about a quarter of a c.c. (five or six drops) of a 10 per cent. solution of sodium hydrate; the liquid must next be warmed to about 50° C., and then a solution of potassium iodide, saturated with iodine, added drop by drop until a slight excess of free iodine is present; this is indicated by the liquid acquiring a permanent sherry yellow tint. The liquid must next be just decolourised by the addition of a minute quantity of the sodium hydrate solution. If there be any alcohol present, a yellow crystalline precipitate of iodoform gradually forms. Certain other organic compounds, however, are capable of producing the same reaction.

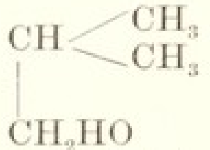
92. Methylated Spirits of Wine.—Alcoholic liquors are subject to a high duty; consequently, for purposes other than the production of drinkable spirits, the Excise authorities permit the sale, duty free, of a mixture of nine volumes of rectified spirit with one volume of commercial wood spirit. This mixture is known as "methylated spirits of wine;" the impurities of the wood spirit impart a flavour which renders the whole absolutely undrinkable, except to the palates of the most debased dipsomaniacs. For most laboratory operations, methylated spirits can be used as a substitute for rectified spirits of wine: for delicate purposes it is well to re-distil the spirits prior to use. Methylated spirits may be rendered almost absolute by adding about one-third of its weight of recently burned quicklime, and thoroughly shaking: the mixture must be allowed to stand some three or four days, and the shaking repeated two or three times daily. The spirit must then be distilled, precautions being taken to prevent the temperature unduly rising. The still should be fixed in a water bath, consisting of an iron saucepan containing brine. The clear portions of the spirits should first be poured into the still, without disturbing the sediment, and distilled to dryness by application of heat to the water bath. Care must be taken that the bath does not boil dry. The pasty mass of lime may next be placed in the still, preferably in small quantities at a time, and heated by the bath so long as any alcohol distils over. An efficient condensing worm must be used, and the tube connecting it with the still ought to be a long one. At the close of the operation the lime may be removed from the vessel used as a still by soaking with water.

93. Propyl, Butyl, and Amyl Alcohols.—These bodies are produced in small quantities during fermentation. They all boil at a higher temperature than ethyl alcohol, and are found in the residual liquor after most of the spirit has been distilled over. Propyl alcohol occurs in the residues of the distillation of the fermented liquor of the marc of grapes in the production of low-class brandy. Normal butyl alcohol occurs in genuine cognac, from which it may be obtained by fractional distillation: it has a boiling point of 116·8° C., and possesses an agreeable odour. But spirits from potatoes, beet-root, maize, and certain other substances contain isobutyl alcohol, an isomeride of the normal alcohol. Isobutyl alcohol has a disagreeable fusel-oil like odour. The following formulæ indicate their difference in constitution:—



$$\begin{array}{l}CH_2CH_2CH_3\\ |\\ CH_2HO\end{array}$$

Normal Butyl Alcohol.



Isobutyl Alcohol.

In addition to isobutyl alcohol, amyl alcohol is also produced as a bye-product during the manufacture of alcohol from potatoes or grain. Amyl alcohol is an oily looking liquid, which does not mix with water, but with alcohol and ether in all proportions; it boils at 137° C. Amyl alcohol has a strong, disagreeable smell, and burning taste. Its intoxicating effects are similar to those of ethyl alcohol, but a few drops of amyl alcohol suffice to produce all symptoms of intoxication; it has been estimated that amyl alcohol is fifteen times as intoxicating as is ethyl alcohol. More or less of this alcohol is found in newly made spirits, hence new whiskies, especially such as have been manufactured in "small" stills, are exceedingly deleterious; by keeping, the amyl alcohol is oxidised into harmless compounds.

94. Fusel or Fousel Oil.—This name is applied to the oily mixture of spirits above referred to as being formed during fermentation. The fusel oil of potato and grain spirits principally consists of amyl alcohol.

95. Glycerin, $C_3H_5(HO)_3$.—In constitution this body is an alcohol. When pure, glycerin is a colourless, odourless, and thick sirupy liquid, having a sweet taste, and boiling at a temperature of 290° C. Glycerin is one of the substances produced during the normal fermentation of sugar, and also is the basic constituent of fats and oils.

96. Mannite, $C_6H_8(HO)_6$.—This is a substance possessing a sweet taste and found in the sap of certain plants, which sap when dried constitutes what is known as *manna*. In constitution mannite is a hexatomic alcohol, and is of interest as being the compound of which the carbohydrates are viewed as chemical derivatives.

97. The Ethers.—These bodies are the oxides of the organic radicals; the most important is ethylic ether, or ethyl oxide, $\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right.O$. When the term "ether" is employed without any qualification, it is this body to which reference is made. From its mode of preparation, ether is often termed "sulphuric ether;" sulphuric acid, of course, does not enter into its composition. Ether is a colourless, very mobile liquid, having a peculiar, penetrating, and characteristic smell. This smell has given rise to the term "ethereal odour." Ether has a specific gravity of 0·736, it does not mix with water; but, on being added, forms a layer on the surface. The ether dissolves a certain quantity of water, while the water, on the other hand, holds a portion of the ether in solution. Ether boils at 34·5° C., and is very volatile at ordinary temperature. The vapour is inflammable; and, as may be gathered from the formula, is very heavy. Great care must be taken when working with ether to keep all lights at a safe distance. The high density of the vapour causes it to flow as a dense layer along a level surface for a considerable distance; in this way there is danger of the vapour communicating with a light that may be placed even at the further end of a long table. The rule should invariably be adopted of having no more of the liquid in the immediate neighbourhood, where experiments are being made, than is necessary for the purpose in hand; the store bottle should not be kept in the laboratory. Ether is of great use as a solvent for fats, resins, and other organic bodies.

98. Ethereal Salts.—These bodies are produced by the displacement of the hydrogen of acids by organic radicals; the acid may be organic or inorganic. The compounds of such radicals, with chlorine, bromine, and iodine, are at times viewed as a sub-class of these bodies, and are termed "haloid" ethers.

99. Chloroform, $CHCl_3$.—In a number of organic compounds it is possible to replace the atoms of certain elements present by those of others; in this way what are called "substitution products" are formed. Starting with methyl hydride, CH_4, the hydrogen of this body may be replaced atom by atom by chlorine until CCl_4 is formed. The replacement of three atoms of hydrogen by chlorine results in the production of chloroform, $CHCl_3$. This compound is at ordinary temperatures a heavy volatile liquid, having a specific gravity of 1·48. The vapour of chloroform has a peculiar but pleasant smell, and when inhaled produces insensibility to pain, while in less quantities it causes stupefaction. No danger need, however, be apprehended during any ordinary working with this substance. Chloroform boils at a temperature of 60·8° C. Chloroform, like ether, acts as a solvent of many organic bodies; it is not soluble in water, and after being shaken up with that liquid more or less quickly subsides and forms a layer at the bottom.

100. Iodoform, CHI_3.—This is a yellow solid body, analogous in constitution to chloroform.

101. Organic Acids.—These bodies constitute a numerous class of organic compounds; like the radicals, they are capable of subdivision into distinct families, the members of which exhibit considerable resemblance to each other. Several of these groups of acids are derivatives from corresponding series of alcohols.

102. Fatty Acids, or Acids of Acetic Series.—These acids may be represented by the general formula, $\left\{\begin{matrix} C_nH_{2n+1} \\ COHO \end{matrix}\right.$. The lowest member of the series is formic acid, $\left\{\begin{matrix} H \\ COHO, \end{matrix}\right.$ or $HCHO_2$. The next and best known is acetic acid $\left\{\begin{matrix}CH_3\\COHO,\end{matrix}\right.$ or $HC_2H_3O_2$. Acetic acid is the derivative from ethyl alcohol. It will be of service to place side by side for comparison the formulæ of ethyl and some of its principal derivatives:—

$$\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right.$$

Ethyl.

$$\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right. O$$

Ethyl Oxide or Ether.

$$C_2H_5HO, \text{ or } \left\{\begin{matrix}CH_3\\CH_2HO\end{matrix}\right.$$

Ethyl Hydrate or Alcohol.

$$\left\{\begin{matrix}CH_3\\COH\end{matrix}\right.$$

Acetic Aldehyde.

$$\begin{matrix}CH_3\\COHO\end{matrix}$$

Acetic Acid.

By oxidising agents, two atoms of hydrogen may be removed from alcohol with the formation of acetic aldehyde. This body is formed as an intermediate step between alcohol and acetic acid. Aldehyde readily combines with another atom of oxygen to form acetic acid. Aldehyde is one of the products of oxidation of casein, fibrin, and albumin.

103. Acetic Acid.—This body is a liquid which boils at a temperature of 117° and freezes at 17° C.; it has a sharp but pleasant smell, and is well known in a dilute form as vinegar. Vinegar is manufactured by a species of fermentation from alcohol: its interest in connection with our present subject lies in the fact, that during many fermenting processes acetic acid is accidentally produced.

104. Butyric Acid, $\left\{\begin{matrix}C_3H_7\\COHO,\end{matrix}\right.$ or $HC_4H_7O_2$. This body bears the same relation to butyl alcohol that acetic acid does to that of ethyl. Butyric acid occurs in rancid butter, sweat, and many animal secretions. It is also one of the products of putrefaction, or putrid fermentation, of many organic substances; for instance, it may be formed in considerable quantity by the action of putrid cheese on sugar. Butyric acid is a liquid having a sharp odour resembling that of rancid butter.

105. The Higher Fatty Acids.—These have received their special name because of their occurrence as constituents of many natural fats; among those thus found are butyric acid (above described); palmitic acid $\left\{\begin{matrix}C_{15}H_{31}\\COHO,\end{matrix}\right.$ or $HC_{16}H_{31}O_2$; margaric acid, $\left\{\begin{matrix}C_{16}H_{33}\\COHO,\end{matrix}\right.$ or $HC_{17}H_{33}O_2$; and stearic acid, $\left\{\begin{matrix}C_{17}H_{35}\\COHO,\end{matrix}\right.$ or $HC_{18}H_{35}O_2$. These latter bodies are at ordinary temperatures fatty solids, melting into oils with an increase of temperature. Physically, they bear little resemblance to acetic acid; but the formulæ at once show their similarity in constitution.

106. Fats and Soaps, or Salts of Higher Fatty Acids.—Most natural fats are salts of the higher fatty acids, with glycerin as the base; for example, mutton fat is essentially composed of the stearate of glycerin. This body may be artificially produced by heating together stearic acid and glycerin, according to the following equation—

$$\underset{\text{Stearic Acid.}}{3HC_{18}H_{35}O_2} + \underset{\text{Glycerin.}}{C_3H_5(HO)_3} = \underset{\text{Glycerin Stearate.}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{Water.}}{3H_2O.}$$

Some natural fats contain an excess of the fatty acid over and above that sufficient to combine with the whole of the glycerin present.

In addition to the "fatty" acids, acids of another group, known as the oleic series, are found as constituents of natural oils and fats. Oleic acid, $HC_{18}H_{33}O_2$, is the product of oxidation of an alcohol of the family $C_nH_{2n-1}HO$ series: it will be noticed that the formula of the acid differs from that of stearic acid by containing two atoms less of hydrogen: this difference follows from the difference in the typical formulæ of the two series of alcohols. The oleates of glycerin constitute the oils or liquid portions of fats.

By the action of alkalies, as soda or potash, the fats are decomposed, with the formation of sodium or potassium salts of the fatty acids, and the liberation of glycerin in the free state. These salts constitute the bodies known technically as "soaps," those of sodium are the "hard," and those of potassium "soft" soaps. The separation of fats into glycerin and the fatty acids may also be effected by forcing a current of steam through the melted fat. The glycerin distils over with the steam. This operation of decomposing fat by the aid of alkalies is termed "saponification," and, in addition to its great use in the commercial manufacture of soap, constitutes a valuable method of investigating the composition and properties of natural fats and oils.

Some few other organic acids of interest yet remain to be described: among these there is:—

107. Lactic Acid, $HC_3H_5O_3$.—This body occurs in sour milk, and is also produced in greater or less quantities during fermentation with ordinary commercial yeast. Lactic acid is a sirupy liquid of specific gravity 1·215, colourless and odourless, and having a very sharp sour taste. It forms a well-defined series of salts.

108. Succinic Acid, $H_2C_4H_4O_4$.—Succinic acid is a white solid body, soluble in water. It is one of the bodies produced during the normal alcoholic fermentation of sugar. On being heated, succinic acid evolves dense suffocating fumes.

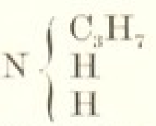
109. Tartaric Acid, $H_2C_4H_4O_6$.—This body occurs naturally as a constituent of the juice of the grape, and in various other plants. It is when pure a white solid crystalline body, soluble in water, and possessing a pleasant sour taste. On being heated, tartaric acid evolves an odour of burnt sugar. Tartaric acid is dibasic, and forms both an acid and a normal series of salts, termed "tartrates." The well-known substance "cream of tartar" is acid potassium tartrate, $KHC_4H_4O_6$; this body has an acid reaction, and, like tartaric acid, decomposes sodium carbonate with the evolution of carbon dioxide gas. As, however, one-half the hydrogen has been already replaced in cream of tartar by potassium, that salt has only half the power of decomposing sodium carbonate that is possessed by free tartaric acid. When acid potassium tartrate is neutralised by the addition of sodium carbonate, so long as effervescence occurs, there is produced a double tartrate of potassium and sodium, $KNaC_4H_4O_6$. This body is soluble in water, and is known as "Rochelle Salt."

110. Definition of Homologues, &c.—At this stage of the subject it will be convenient to explain the meaning which is attached to "homologue" and other similar terms used in describing organic bodies. **Series of bodies are termed homologous, in which their general constitution may be represented by a typical formula**; thus, the organic radicals of the methyl series are homologous, so too are the corresponding alcohols, and also the fatty acids. The melting and boiling points of the members of a homologous series usually rise as the series is ascended. When capable of being vaporised, their density in the gaseous condition increases with the ascent of the series. Usually, the lower members of a series of homologues are more chemically active than are those of a more complicated constitution.

Many organic bodies are known which not only contain the same elements, but also contain them in the same proportion, while their physical and chemical character show them, nevertheless, to be distinct compounds. **Distinct compounds, having the same percentage composition, are said to be "isomers," or "isomeric with each other.** Isomerism may be of different kinds. Thus, bodies may have the same percentage composition, and yet have different molecular weights: in these cases the molecular weights are multiples of the simplest possible molecular weight that can be deduced from the percentage composition. **Bodies having the same percentage composition, but different molecular weights, are said to be "polymers," or "polymeric" with each other.** The following are instances of polymeric bodies:—

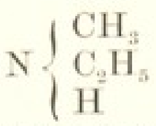
Ethylene —C_2H_4.
Propylene—C_3H_6.
Butylene —C_4H_8.

In addition to isomerism of the above type there is yet another more striking variety. **When distinct chemical compounds have not only the same percentage composition, but also the same molecular weight, they are said to be "metamers," or "metameric" with each other.** As examples of metameric compounds the following three bodies may be cited—propylamine, methylethylamine, and trimethylamine. These three bodies all have the formula, NC_3H_9. That they are distinct compounds containing the same proportions of carbon and hydrogen, but united together to form different organic radicals, is seen when the formulæ are written as below:—



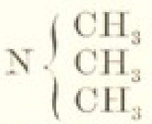
$$N\left\{\begin{matrix}C_3H_7\\H\\H\end{matrix}\right.$$

Propylamine.



$$N\left\{\begin{matrix}CH_3\\C_2H_5\\H\end{matrix}\right.$$

Methylethylamine.



$$N\left\{\begin{matrix}CH_3\\CH_3\\CH_3\end{matrix}\right.$$

Trimethylamine.

The nature and constitution of these bodies are described in paragraph 112.

111. Nitrogenous Organic Bodies.—Many organic compounds, both from animal and vegetable sources, contain nitrogen as one of their constituents. Of the great majority of these bodies nothing very definite is known as to their constitution; a large number of them are basic in their character, and hence are known as nitrogenous organic bases, or "alkaloids."

112. Substitution, or Compound, Ammonias.—Many of the nitrogenous organic bodies are built upon the same type as ammonia, and may be viewed as ammonia in which one or more of the atoms of hydrogen are replaced by compound radicals. These compounds are termed "amines," or "substitution ammonias." The three bodies, propylamine, methylethylamine, and trimethylamine, whose formulæ are given in a preceding paragraph, are examples of amines. The methylamines are gases at ordinary temperatures, having a strong ammonical and fish-like smell. Trimethylamine is produced by decomposing proteids, and is the source of the characteristic smell of fish.

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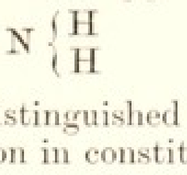
114. Amides and Amido-Acids.—Amides may be viewed as derivatives of acids in which amidogen, NH_2, replaces hydroxyl, HO; or they may be looked on as ammonia in which one or more of the hydrogen atoms are replaced by organic radicals. Urea, CON_2H_4, is a typical amide. It may be viewed as a derivative of carbonic acid $CO(HO)_2$, in which case the two groups of HO are replaced by two groups of NH_2; or on the other hypothesis may be regarded as two molecules of ammonia, NH_3, with a pair of hydrogen atoms replaced by CO, thus:—



$$\begin{matrix} N\left\{\begin{matrix}H\\H\end{matrix}\right. \\ N\left\{\begin{matrix}H\\H\end{matrix}\right. \end{matrix} CO \quad = \quad CON_2H_4.$$

Urea, Carbamide.

The amides are distinguished from the amines by the latter being incapable of derivation in constitution from an acid.

Among amides found in plants are asparagine, $C_4H_8N_2O_3$, and glutamine, $C_5H_{10}N_2O_3$. The amides are crystalline, diffusible bodies. Asparagine is soluble in hot water, but not in alcohol or ether.

The amido-acids are bodies intermediate in character between an acid and a weak base, fulfilling under different circumstances the functions of either. They may be viewed as derivatives from organic acids in which hydrogen of the acid radical is replaced by amidogen.

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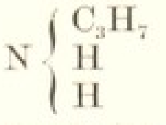

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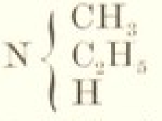
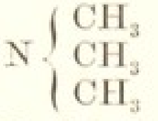


$$N\left\{\begin{array}{l}CH_3\\C_2H_5\\H\end{array}\right.$$

Methylethylamine.



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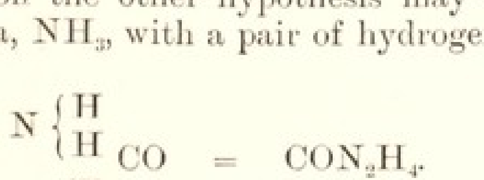

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Aspartic acid, amido-succinic acid, $C_4H_7NO_4$, and glutamic acid, amido-glutaric acid, $C_5H_9NO_4$, are members of this group. So also are leucine, amido-caproic acid, $C_6H_{13}NO_2$, and tyrosine, amido-oxy-phenyl-propionic acid, $C_9H_{11}NO_3$; all these bodies being important decomposition products of the proteids. Leucine is soluble at 12° C. in 48 parts of water and 800 of alcohol; and insoluble in ether. Tyrosine dissolves in 150 parts of boiling water, and is insoluble in alcohol and ether.

CHAPTER IV.

THE MICROSCOPE, AND POLARISATION OF LIGHT.

115. Object of Microscope.—A description of the microscope, and method of using it, is given at this early stage, because the student will continually find it requisite to have recourse to this instrument from time to time, while going on with his study of the chemical properties of the various grain constituents. In order to thoroughly understand the physical construction of bodies it is necessary to *see* them. The microscope is an instrument to enable us to see points of physical construction which are so minute as to escape the unaided vision.

116. Description of Microscope.—The demand for good microscopes has led to the supply by a number of makers, both English and Continental, of really excellent instruments at low cost. In consequence, the microscope is not now, even to the general public, an unfamiliar piece of apparatus. These pages are not the place where an exhaustive description of microscopes could with fitness be given, but as the instrument should be in the hands of every miller and baker, a few hints as to how to use it for such purposes as those occurring during milling and bread-making will naturally find a place in this work. As an instrument suitable for the work of miller and baker, the writer has figured one supplied by Charles Baker, of 244, High Holborn, London. These microscopes are cheap (in the best sense of the term), of excellent make, and always trustworthy.

Every reader will probably be familiar with the general appearance of the instrument as shown in the illustration. The microscope proper consists of the stand, to which is attached the main tube of the instrument, by means of a sliding "dove-tail" arrangement, that can be raised or lowered by a rack and pinion: the pair of milled heads, D, actuate this pinion. The stage is that part of the instrument arranged for the reception of the object being examined. It consists of a flat surface at right angles to the axis through the tube of the microscope, and carries on it a sliding piece, E, which can easily be moved upward or downward on the stage. By means of spring clips, the glass on which the object is mounted is held on this sliding piece, and thus may be shifted in the one direction; it is easily moved from right to left by adjustment of the object itself with the fingers. Underneath the stage is a contrivance known technically as the sub-stage: this is also fitted with a rack and pinion, and may be raised or lowered by the milled head, G. The central aperture of the sub-stage, J, is arranged to take either a sub-stage illuminator (Abbé condenser), a series of diaphragms, the polariser degree; on the other hand, it should be sufficient for the object to be seen comfortably. The 3-inch objective will show the grain of wheat occupying almost the whole of the field of vision. Any object when seen through the microscope is inverted; that is, the top is seen at the bottom, and the left side at the right. By pulling out the draw tube the object is still further magnified.

In the next place, unscrew the 3-inch and substitute for it the 1-inch objective. The microscope tube will now have to be lowered considerably until the object is again in focus. A portion only of the wheat-grain is seen in the field, but that portion is magnified to a much greater degree.

The illumination is much less than with the 3-inch object glass. Notice that more of the details of the object can be distinguished.

The $\frac{1}{8}$-inch objective may now be tried. Unless the section is a very thin one, it will not, however, show up well. Having exchanged the inch for this power, lower the microscope tube until the end of the object glass is within an eighth of an inch from the slide; then move the milled head, D, very slowly and carefully, watching all the time until the object is again in focus: for this purpose it is well to move the slide until a portion of the skin of the grain is in view. The milled head, E, at the back of the instrument, may now be used for making the final adjustment of the focus. This latter milled head is termed the "fine adjustment," while that by means of the rack and pinion is spoken of as the "coarse adjustment." For the lower powers the coarse adjustment is sufficient.

This exercise with the three powers will have shown the student the mode of using his microscope. He must accustom himself to moving the object about on the stage, so as to get any portion he wishes in view; this presents some little difficulty at first, because the movement must be made in the opposite direction to that in which it is desired that the magnified image shall travel.

118. Measurement of Microscopic Objects.—The microscope is not merely used for the purpose of seeing small objects, but, with the addition of certain accessories, is also employed for measuring their size. The first object requisite for this purpose is a "stage micrometer;" an eye-piece micrometer should also be procured. The stage micrometer may consist of a fraction of an inch further divided up into tenths and hundredths, or preferably of a millimetre similarly graduated. The scale for this purpose is accurately photographed on a glass slip, the same as an ordinary slide. It will be remembered that the millimetre is very nearly the twenty-fifth part of an inch, consequently the tenth or hundredth of a millimetre may be taken as equal to the two hundred and fiftieth, or two thousand five hundredth part of an inch. Working with low powers, it is sufficient for rough purposes to place the stage micrometer face downwards on the object to be measured, and then to read the number of divisions of the micrometer over which the object to be measured extends. This can only be done with powers sufficiently low to permit the lines on the micrometer, and the object under examination, to be in focus, or nearly so, at the same time. The eye-piece micrometer is, for all purposes, far preferable.

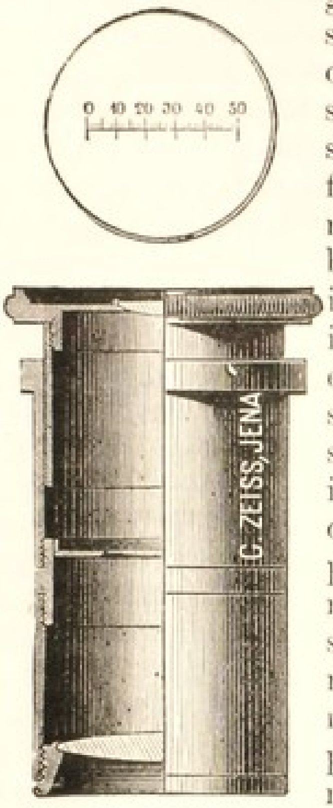


FIG. 3.—EYE-PIECE MICROMETER.

This instrument consists of a scale engraved on a circular piece of glass, as shown in Figure 3, which is fixed in a specially adapted eye-piece, also figured. The top of the eye-piece draws out, and the micrometer scale dropped in, so as to rest on the diaphragm shown in section midway of the eye-piece. The figures, of course, must be uppermost, so as to read rightly on looking down the microscope. The scale being in position, the sliding tube of the eye-piece itself is drawn up or down until, on looking through it, the graduations are sharply focussed. With the eye-piece in position, on looking down the microscope, both the eye-piece scale and the object are seen in focus together. The scale looks as though it were simply superposed on the object The value of this scale varies with each different power employed, but may be determined in the following manner—screw the lowest power into the microscope; put the stage micrometer on the stage, and read off carefully in tenths and hundredths of a millimetre the value of one division of the eye-piece micrometer. Next repeat the same measurement in exactly the same way with each of the other objectives. In these determinations the draw tube must invariably be in the same position; it is best to have it always closed when the microscope is being used for measuring purposes. Thus, for example, with one of the microscopes in the possession of the writer, one division of the eye-piece has the following values with different objectives:—

Objective.	M.M.	M.K.M.	Inch.
aa, Zeiss,	0.286	28·6	0·00112
A, ,,	0·172	17·2	0·00067
DD, ,,	0·0041	4·1	0·00016
One-twentieth inch, Oil immersion,	0·00104	1·04	0·00004

Supposing that an object, under examination with the highest power, on being measured is 3·2 eye-piece divisions in length, then its real length is

$$0{\cdot}00104 \times 2{\cdot}2 = 0{\cdot}00333 \text{ m.m., or } 0{\cdot}00013 \text{ inch.}$$

119. The Micromillimetre.—When the dimensions of minute objects are expressed, either in inches or in millimetres, they require such a number of figures that it is difficult to at first realise the value of the dimension. It has therefore been proposed to employ the one-thousandth part of a millimetre as a unit of length for microscopic measurements. This unit is called a micromillimetre, for which the following abbreviation, "mkm.," may be used. The mkm. is also sometimes called a "μ" (pronounced *mu*); its value in inches is very nearly $\frac{1}{25400}$ inch. The eye-piece measurements given in the preceding paragraph have also their values expressed in micromillimetres.

120. Magnification in Diameters.—There remains to be explained a convenient method of measuring the magnifying power of objectives and eye-pieces. A common method of expressing the value of particular combinations of these two is to say that they magnify so many diameters. A moment's reflection will show that the image seen with a microscope will vary in actual dimensions, according to whether it be supposed to be near to or far from the eye. The only real measurement, in fact, is the visual angle it subtends. This being the case, the measurement in diameters is always expressed with the understanding that the object is supposed to be 10 inches from the eye.

Here for a moment a slight digression must be made. Most beginners when looking through a microscope close the eye not in use. This is a bad plan, as the eyes are thereby much more fatigued. Both eyes should be kept open. At first the surrounding objects are continually being seen with the unoccupied eye, and it is apparently a hopeless case to see the object under the microscope at all. Practice overcomes this, but the writer has found the best plan is to fix to the microscope tube a piece of dead black cardboard, so that the unoccupied eye sees only a black surface. The object will now be observed with the greatest readiness, and probably not one quarter the fatigue. In a very short time the cardboard shield may be dispensed with, and the trained eyes so behave that the one is transmitting the view of the microscopic object to the brain, while the other is remaining idle and resting. The student should accustom himself to use either eye indifferently; he will soon find that he will no more think of closing one eye when looking through his microscope than he would of tying his left hand behind his back before he shakes hands with his right.

Now, the object of our momentary departure will be evident; the idle eye can, at will, be used for looking at something else, so that the one eye is looking at the microscopic object, the other, if wished, at say a piece of paper. Place the stage micrometer in focus, and fix a piece of stiff paper or cardboard as near as possible to the microscope, at right angles to its axis, and ten inches from the eye-piece. Look down the tube with the one eye, and with the other at the piece of paper. The magnified micrometer scale appears as though drawn on the paper. Still using both eyes, trace with a pencil on the paper the exact position of each line representing the tenths or hundredths of the millimetre. Next measure on the paper the distance between the two marks traced from, say, the tenths of a millimetre; suppose that this distance is five millimetres, then that particular combination of eye-piece and objective has a magnifying power of fifty diameters. Measure each other combination possible with the various eye-pieces and objectives in your possession in the same way.

121. Microscopic Sketching and Tracing.—The above method of measuring is very useful, because with small objects occupying a portion only of the field, it is possible to trace them on the paper in the manner described, and such tracings are then known to be magnified to the extent ascertained by previous measurement as directed. Such sketching by actual tracing is very desirable in microscopic work, as otherwise the student is extremely likely to draw an object either too large or too small; this is to be avoided, as one object of microscopic examination is to definitely ascertain the size of objects. It is the writer's practice when working without sketching to note the measurements with the eye-piece micrometer. When sketching he makes tracings of sufficient at least of the object to give its actual dimensions by a process similar in principle to that already described.

122. Camera Lucida.—For tracing with the microscope an appliance has been invented, which is known as a "camera lucida;" there is also a modification termed a neutral tint camera. An ingenious combination of eye-piece and camera lucida in one piece of apparatus is shown in section in figure 4. The principal portion of the figure consists of the ordinary eye piece, *a*, *b*, with its upper and lower lenses, *c*, *d*: the central dotted line, *e*, *f*, is the direct axis of vision through the microscope. At the top right hand of the figure is a glass prism, *g*, of peculiar shape. The angles of this are so arranged that a ray of light, passing in the direction *h*, *i*, is totally reflected at *i*, in the direction *i*, *k*, and again at *k*, is totally reflected in the line *k*, *l*. The result is that the eye placed over the aperture of the eye-piece, at *m*, receives both rays of light, *f*, *e*, and *h*, *i*, *k*, *l*, which enter the eye parallel to each other. The result of this is that the eye sees simultaneously with the object under the microscope any other object placed in the direction of the line *i*, *h*; both are combined and appear to be in the direct line of vision through the instrument. Consequently if a sheet of paper be placed under *i*, *h*, it and the microscope image appear to the eye to coincide.

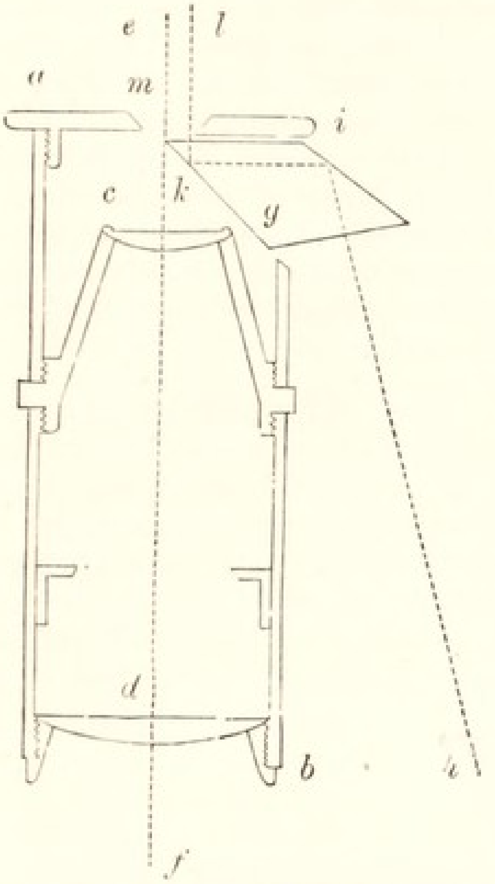


FIG. 4.—COMBINATION OF EYE-PIECE AND CAMERA LUCIDA.

When wishing to use the camera, place the microscope in a vertical position, directly facing the source of light, and turn the camera so that the prism, *g*, is at the right hand side (as figured). Procure a box or other convenient stand of such a height that its upper surface, when placed beside the microscope, is of the same height as the microscope stage. Place this box on the right hand side of the instrument, under the prism, *g*, so that the line, *i*, *h*, points to it. For drawing purposes the most convenient arrangement is a small drawing "block" of hot pressed paper, sheet after sheet of which can be removed as finished. Place this on the stand, under *i*, *h*, and look through the instrument; both object and paper should be seen in combination; that is, the image should appear to be superposed on the paper. To properly get this effect the paper and image should, as nearly as possible, be equally illuminated. As the paper is usually brighter than the image, provision is made for cutting off some of the light from it by introducing plates of neutral tinted glass in the path of *i*, *h*, just below the prism, *g*. On the other hand the illumination of the object may be adjusted by means of the reflecting mirror of the microscope.

As a preliminary to tracing with the camera, place the stage micrometer in focus, and the microscope and paper in their respective positions. Then, by means of a pencil, mark on the paper the length of the millimetre or fraction of the millimetre, and calculate out once for all the magnification in exact number of diameters. This is very easily done, as the lines of the object appear to be drawn on the paper; the pencil point being also seen, the operation of tracing simply consists of going over lines apparently already on the paper. With the same powers and eye-pieces, and microscope and paper in the same relative positions, the magnification is always the same. In actual sketching it is usually sufficient to trace in the principal outlines; the details may then be added with sufficient accuracy by the ordinary method of judging dimensions by the eye, as in freehand drawing.

123. Microscopic Counting: the Hæmatimeter.—For certain purposes it is highly important to be able to count the number of small solid particles suspended in a fluid. Among them is the counting of blood corpuscles, and of yeast cells suspended in water or fermenting liquid. An instrument was first devised for this purpose, in order to count blood corpuscles, and hence is called a hæmatimeter: the same appliance is adapted to the counting of yeast cells, and is illustrated in Figure 5. The instrument consists of a stout glass slide, *a*, on which is cemented a cover-glass, *b*, with a circular opening, thus constituting a cell. On the glass slide, and in the centre of this cell, is arranged a raised circle of glass, *c*, on which is engraved a series of lines at right angles to each other, thus marking its surface off into a number of squares. Each of these squares has an area of $\frac{1}{400}$ (0·0025) square millimetre. The inner circle of glass, *c*, and the cover-glass, *b*, are so arranged that the former is exactly $\frac{1}{10}$ mm. the thinner; so that when the cover-glass, *d*, is brought down into absolute contact with *b*, the space between the lower surface of *d* and the upper of *c* is exactly 0·1 mm. in thickness. Therefore the cubic contents of the space above each square on *c* is

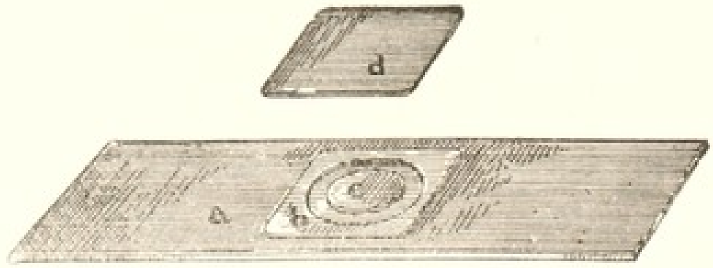


FIG. 5—THE HÆMATIMETER.

$$0·0025 \times 0·1 = 0·00025 = \frac{1}{4000} \text{ cubic mm.}$$

To perform a counting operation on yeast, for example, an average sample must be taken, diluted, and shaken up until the cells are uniformly distributed through the liquid. Hansen considers that the liquid most suitable for this purpose is dilute sulphuric acid, 1 part to 10 of water: for yeast the author prefers to employ 1 part sulphuric acid, 1 part glycerin, and 8 of water. The viscid nature of the glycerin enables the liquid to keep the cells uniformly suspended through it for a longer time. The method of employing the hæmatimeter is best explained by giving an actual example. From a sample of compressed yeast, 0·25 grams were weighed off and made up to 50 c.c. with dilute glycerin and sulphuric acid. The yeast was broken down and thoroughly mixed with the liquid by violent shaking for some time in a flask. A droplet was then removed by means of a pointed glass rod, and placed on the centre of the glass, *c*, of the hæmatimeter, and immediately covered with the cover, *d*: this is held in close contact either by a pair of small spring clips or by a weight put on *d*. (The minute drop for this purpose must not be more than sufficient to nearly fill the space between the two glass surfaces: it must not be enough to run over into the annular space between *b* and *c*.) The apparatus is placed aside in a horizontal position to rest sufficiently long for the suspended cells to fall to the bottom of the layer of liquid between *c* and *d*. The yeast cells having settled down, say in ten minutes, place the hæmatimeter on the horizontal stage of the microscope, and prepare to commence counting, using about $\frac{1}{6}$-inch objective (Zeiss D). The yeast cells will be seen lying on the engraved squares, some within the squares, and others directly on the dividing lines. Commence counting the cells within the top left-hand square, and make a note of the number, then go on along the line, come back and count those on the squares of the next line, and so on. The cells lying on the lines must also, of course, be counted, but only once: that is, all lying on the horizontal lines must be counted in the squares above them, and all on vertical lines in the squares to the right of them. The counting must be continued until a sufficient number of squares have been taken to give a true average. By experiment it should be ascertained how many squares must be counted in order that an additional number has no influence on the average obtained. It is usually sufficient to count some 50 or 60 of the small squares. It is convenient to have the liquid of such a degree of dilution that about 8—10 cells occur in each square. Approximately the accidental errors amount,

by counting 200 cells, to 5 per cent. of the total result.
,, 1250 ,, 2 ,, ,,
,, 5000 ,, 1 ,, ,,

In the experiment being described, 100 squares were counted, and contained 738 yeast cells.

Now the space above each square = 0·00025 cbc. m.m.

Therefore 100 spaces = 0·025 cbc. m.m., and contain 738 cells.

Therefore 4000 spaces = 1·000 cbc. m.m., and contain 7·38 × 4000 = 29,520 cells.

Therefore 1 c.c. = 1000 cbc. m.m., and contains 29,520 × 1000 = 29,520,000 cells.

But 1 c.c. contained 0·005 gram of yeast, and therefore 1 gram contains 29,520,000 × 200 = 5,904,000,000 cells.

But 1 lb. avoirdupois = 453·59 grams, and therefore 1 lb. of the yeast contained—

5,904,000,000 × 453·59 = 2,677,995,360,000 cells.

The smaller grained starches may also be counted in the same manner.

124. The methods of using the microscope having been briefly described, directions for its use for special purposes will be given as occasion arises. For fuller descriptions of the instrument itself, its accessories and the method of using them, the student is referred to one of the many excellent works already published on the subject.

125. Polarisation of Light.—There are many substances which exert a special action on "polarised light," among these are a variety of crystalline compounds, and certain organised bodies. It will be necessary at this stage to give a short description of the nature of a ray of light, and the way in which its character may be altered by the action of these substances just mentioned. As is well known, light travels in straight lines called rays. The actual motion of such a ray of light is somewhat like to that of a sea-wave, or the ripples produced on the smooth surface of a pond by throwing a stone therein. In waves, the water itself does not move forward, but only the undulating motion of the surface; this is readily seen by floating a cork on the water; each little wave in its passage onward simply raises and depresses the cork, but leaves it in the same position as it found it. Light, then, also travels in waves, these waves being undulations in a substance filling all space, and known by the name of "ether." The waves of light differ remarkably in one particular from those on the surface of water; the undulatory motion in the latter is simply up and down, or, to use the scientific term, in a vertical plane. If the actual movements of the ether in a ray of light could only be rendered visible, a much more complicated motion would be perceived. Just as in the case of the water wave, the particles would move across, or transversely to, the direction of the path of the ray. Some of the particles would rise and fall like those in the water wave, but others would swing from side to side, or horizontically instead of vertically; further than this, others again would vibrate at every intermediate angle. This condition of things is expressed in the statement that the undulations of a wave of light are in a plane transverse to the path of the ray, and that the ether particles vibrate in every direction in that plane.

For our present purpose it will be sufficient to regard the wave of light as composed of two sets of vibrations, the one vertical and the other horizontal, and therefore at right angles to each other; the intermediate vibrations may be ignored. The character of the undulations of a wave of light is not greatly altered by passing through glass, water, and many other bodies; the same does not, however, hold good with all transparent substances—of these one of the most striking is a mineral named tourmaline. Let two thin plates be cut from a crystal of this substance in a certain direction; on examination each is seen to be fairly transparent. Let one be placed over the other, and then slowly twisted round. In one particular position light passes through them both as readily as through either taken singly; but as one of the pair is turned round, less and less light is transmitted; until, when it has been rotated through an angle of 90 degrees, no light whatever passes. As the revolution is continued, the plates allow more and more light to pass; until, when an angle of 180 degrees has been reached, the combination of two plates is again transparent. A further revolution of 90 degrees once more causes opacity. This peculiar effect is due to the fact that tourmaline plates, such as described, permit the passage through them of only the vibrations of light in one plane, so that the ray of light, after passing through the tourmaline, instead of having its vibrations in all directions of the plane, has them occurring in one direction only; the ray may then be compared to a water wave. Such a ray of light is said to be "polarised," and the change effected is termed the "polarisation of light."

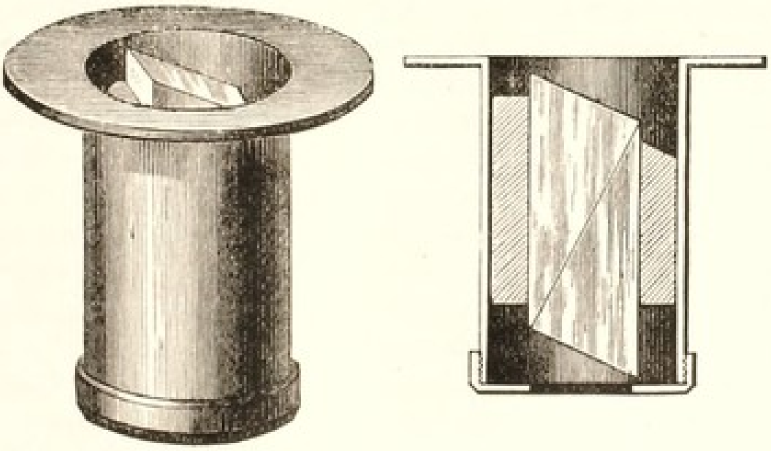


FIGURE 6.—POLARISER OF MICROSCOPE CONTAINING NICOL'S PRISM.

The tourmaline plate may be compared to a sieve composed of a set of wires in but one direction. Using this similitude, only those vibrations which are in the same direction as the wires of the sieve succeed in effecting a passage. The second tourmaline plate being set so that its wires are parallel to those of the first, the light which passed through the one succeeds also in passing through the other. But when the second tourmaline is turned at right angles to the first, then the light which passed through the one is cut off by the other, and so the two together refuse to transmit any light whatever.

Persons who are acquainted with the beautiful mineral known as Iceland spar, know that when a single dot is looked at through a piece of the spar, it is seen double; this is due to the fact that the spar splits the ray of light into two distinct rays; further, the light of each of these sub-rays is polarised in such a manner that the plane of polarisation (that is, the directions in which the vibrations occur) of the one ray is at right angles to that of the other. When pieces of Iceland spar are cut and re-joined in a particular manner, they transmit the one only of these two rays, the other being lost by internal reflection within the crystal. Such pieces of spar are termed "Nicol's prisms," and may be used for the same purpose as the tourmaline plates; they have the great advantage of being composed of material as transparent as glass, while the tourmaline is usually only semi-transparent, apart from its polarising properties. The first Nicol's prism placed in the path of a ray of light is termed the polariser, because it effects the polarisation; the second is known as the analyser, because it enables us to determine direction of the plane of the polarised ray. The construction of the Nicol's prism is shown in Figure 6, which is an illustration of the polariser of a microscope. The left hand figure is an external view of the polariser, which in use is fitted to the sub-stage. A section is given on the right in which the Nicol's prism appears very clearly. The line joining the obtuse angles of the prism is that where the crystal has been cut and re-cemented together.

Returning again to the similitude of the sieves, suppose that, with the two at right angles to each other, it were possible to take the light after it had passed through the one, and was thus polarised, and twist or rotate its plane of polarisation through an angle of 90° before it came to the second, it would evidently then be able to pass through that also. Certain substances possess this remarkable property: among those of immediate interest in connection with the present subject are starch, sugar, and other of the carbohydrates. It is further found that while some compounds twist the polarised ray to the right, or in the direction of the hands of a watch, others rotate polarised light to the left. If two Nicol's prisms were so arranged as to give absolute darkness, and then a plate of sugar were placed between them, light would be transmitted. If the analyser were next turned around in a right-handed direction, the point of absolute darkness would again be reached, and then by measuring the angle of rotation, the number of degrees through which the plane of polarisation of light had been rotated by the sugar could be ascertained. Instruments are constructed for the purpose of making this measurement with great delicacy, and are termed "polarimeters." The exact point at which maximum light and darkness is reached during the rotation of the analyser cannot be observed with great accuracy; recourse is therefore had to observing some of the other characteristics of polarised light more easily detected by the eye. In the analytic section of this work, an explanation is given of the principles which guide chemists in the application of the rotation of the plane of the polarisation of light by sugar and other bodies to their estimation; a practical description then follows of one of the best forms of polarimeter and the method of using it. For microscopic purposes a polariser is fitted underneath the stage, and an analyser either within the body of the tube or over the eye-piece. The object under examination is thus illuminated by polarised light. For further information on the polarisation of light, the student is referred to Ganot's, or some other standard work on physics.

CHAPTER V.

CONSTITUENTS OF WHEAT AND FLOUR.

MINERAL AND FATTY MATTERS.

126. Construction of Wheat Grain.—Having giving a brief outline of the principles and theory of Chemistry, in so far as they are more or less connected with the present subject, our next object must be to describe the chemical properties of the different compounds found in the grain, and to trace them out in the history of the flour and offal. The "Cereals," to which wheat belongs, is the name given to the grasses which have been cultivated for use as food. The grain, as is of course well known, is the seed of the plant; although not strictly chemical, it will be well to give here a short description of its various parts. The most important portion of the seed is the embryo or germ; this, which is a body rich in fatty matters, is that part of the seed which grows into the future plant. The interior of the seed contains a quantity of starch and other compounds, designed for the nutrition of the young plant when growing. The whole is enclosed in an envelope, made up principally of woody fibre, and arranged in a series of coats, one outside the other, somewhat like those of an onion, only on a much finer scale. During the process of milling, the grain is divided into flour and what is technically known as offal. This latter substance, or group of substances, includes the germ, bran, pollard, &c. The bran and pollard are the different skins of the grain broken up into fragments of various sizes. This department of the subject will be dealt with fully in a subsequent part of the work.

127. Constituents of Wheat.—A large number of chemical compounds may be obtained from grain: these naturally divide themselves into Mineral or Inorganic Constituents, and Organic Constituents. The inorganic portions of wheat consist of water and the mineral bodies found in the ash. The organic compounds may be conveniently grouped into—fatty matters, starch, and allied bodies having a similar chemical composition, and nitrogenous bodies or proteids. Of these substances the fats have the simplest composition, next come the starchy bodies, and lastly, the proteids, whose constitution is extremely complex.

128. Mineral Constituents.—The properties of water are already sufficiently described; the actual amount present in grain varies from about 10 to 15 per cent. In sound wheats and flours there is no perceptible dampness, the water being chemically combined with the starch, which body probably exists in grain as a hydrate. The other mineral constituents are usually obtained by heating the powdered grain to faint redness in a current of air; the organic bodies burn away and leave an ash consisting of the inorganic substances present. The ash of wheat has been made the subject of prolonged investigations and research, conducted principally, however, from an agricultural point of view. Land being impoverished by the growth of crops, the constitution of the ash of wheaten grain and straw is an indication of what mineral matters are removed from the soil by wheat crops, and therefore also affords information as to what additions have to be made to an exhausted soil in order to replenish its necessary mineral components. Lawes and Gilbert have from time to time published elaborate tables of results obtained on their experimental farm at Rothampsted; the following table is abstracted from a recent communication of theirs to the Chemical Society (Chem. Soc. Jour. Vol. XLV., page 305 *et seq.*). It gives the composition of the grain-ash of wheat, grown on the same land, in four characteristic seasons—1852, 1856, 1858, and 1863; the land being treated with farmyard manure:—

HARVESTS:—	1852.	1856.	1858.	1863.
Weight per bushel of grain, lbs. ...	58·2	58·6	62·6	63·1
PERCENTAGE COMPOSITION OF ASH.				
Iron Oxide, Fe_2O_3, ...	0·95	0·86	0·90	0·43
Lime, CaO, ...	2·79	2·53	2·61	2·34
Magnesia, MgO, ...	12·77	11·71	11·17	11·41
Potash, K_2O, ...	27·22	29·27	31·87	31·54
Soda, Na_2O, ...	0·45	0·42	0·28	0·66
Phosphoric Anhydride, P_2O_5, ...	54·69	54·18	51·88	52·04
Sulphuric Anhydride, SO_3, ...	0·14	0·23	0·75	0·93
Chlorine, Cl_2, ...	trace	0·07	0·06	trace
Silica, SiO_2, ...	0·99	0·75	0·49	0·65
Total, ...	100·00	100·02	100·01	100·00

The ash constitutes about 1·5 per cent. of wheat, and about 0·4 per cent. of the finished flour, while bran yields from 6 to 7 per cent. of ash. It will be noticed that more than half the wheat ash consists of anhydrous phosphoric acid; this is principally in combination with potash, forming potassium phosphate. The magnesia is also present as a salt of phosphoric acid. The greater part of wheat ash, therefore, consists of potassium phosphate, and is soluble in water. The phosphates are of importance from their value as articles of food: where wheaten flour or bread is almost the sole article of diet, the removal of the phosphates during the purification of the flour diminishes its nutritive value. In an ordinary mixed diet, where bread is simply one of several articles consumed, this does not apply, as sufficient phosphates are always present in other articles of food.

129. Organic Constituents: Fatty Matters.—Of the numerous organic bodies found in wheat, fat has not been chosen as the first to be described because of its importance as a grain constituent, but because it has the simplest composition of the organic bodies present, and therefore may fitly serve as an introduction to the chemistry of the more complicated compounds to follow. All grains contain more or less fat; rice has the least quantity, viz. 0·1 per cent.; maize and oats have respectively 4·7 and 4·6 per cent.; wheat occupies a medium position with a percentage of 1·2 to 1·5. The fat of wheat is not equally disseminated through the grain, but is almost entirely contained in the germ and husk or bran. An analysis by Church gives the quantity of fat in "fine wheat flour" as 0·8; it is, however, doubtful if this analysis were made since the time when the problem of degerming flour has received so much attention from the miller.

It has been already explained that the fats are salts of certain acids, with glycerin as a base. They are characterised by their unctuous nature and by leaving a greasy stain on paper or linen. Fats are insoluble in water, and from their low specific gravity float on the surface of that liquid. On the other hand, all fatty bodies dissolve readily in either ether or light petroleum spirit. As food stuffs, the fats occupy a high position; in tables giving the relative nutritive value of different articles of food, fat heads the list. If this were the only point to be considered, the presence of fats in wheat and flour would be highly advantageous. They have, unfortunately, one great drawback, and that is that they become rancid on standing. This effect is particularly noticeable in flour imperfectly freed from germ. The rancidity is due to slow oxidation of certain constituents of the fat; this change may proceed sufficiently far to seriously affect the flavour of the flour, without the fat as a whole being very greatly changed. The fat of wheat is of a light yellow colour, melts at a low temperature, and gradually darkens in colour on being kept. This change proceeds rapidly in the fat when maintained at a temperature of 70 or 80° C.

König states that the fat of rye, a grain very similar to wheat, has the following composition:—

Glycerin, ...	1·30 per cent.
Oleic acid, ...	90·60 ,,
Palmitic and stearic acids, ...	8·10 ,,

According to König, therefore, the fat of rye consists largely of free fatty acids, the glycerin present being insufficient to neutralise but a small proportion of the acids present.

Recently, Stellwaag made an analysis of the fat of barley as extracted by ether with the following results:—

Free fatty acids, ...	13·62 per cent.
Neutral fats, ...	77·78 ,,
Lecithin, ...	4·24 ,,
Cholesterin, ...	6·08 ,,

An examination of wheat fat has recently been made in the author's laboratory, the results of which are as follows:—A sample of perfectly fresh wheat germs was obtained from the miller and extracted repeatedly with light petroleum spirit in the cold. The extract was filtered, the spirit distilled off, and the residue heated very gently until completely free from the odour of petroleum. A light yellow oil, which in twenty-four hours deposited a trace of crystalline fat, was the result. The following analytic data were obtained on the thoroughly mixed oil and fat:—

Free fatty acids, ...	5·92	per cent.
Neutral fats, ...	94·08	,,
	100·00	

More detailed analysis gave the following results:—

Lower fatty acids (reckoned as butyric),	0·11	per cent.
Higher fatty acids (palmitic, stearic, &c.),	20·72	,,
Oleic acid, ...	52·24	,,
Glycerin, ...	26·93	,,
	100·00	

The fat completely saponified very readily, and yielded nothing to extraction with ether, showing the absence of lecithin and cholesterin.

EXPERIMENTAL WORK.

130. The student who proposes to master for himself the contents of this work, should endeavour to verify as many as possible of the various statements and descriptions by direct experiment. The following outline of experimental work is intended as a laboratory course of study on the subject.

131. Mineral Constituents.—Take a small quantity of whole wheaten meal, heat it to redness over a bunsen in a shallow platinum capsule or basin. At first the volatile constituents of the grain burn with flame, leaving a black mass of carbon and ash. Continue the aplication of heat until the carbon entirely burns away, leaving behind a greyish white ash. To this, when cool, add water; notice that most of it dissolves; add a few drops of hydrochloric acid, filter the solution, and make a qualitative analysis of it; test specially for calcium, magnesium, potassium, and phosphoric acid. It is well to test direct for these two latter constituents in separate small portions of ash. To test for potassium, dissolve up a portion in hydrochloric acid, filter and add a few drops of platinum chloride to some of the solution in a watch-glass, the presence of potassium is demonstrated by the formation of the yellow precipitate of the double chloride of platinum and potassium. Dissolve another portion of the ash in nitric acid, filter and add nitric acid and ammonium molybdate solution; after standing for some time in a warm place, phosphoric acid throws down a canary-yellow precipitate.

132. Fat.—In a tightly corked or stoppered bottle, shake up together some wheat meal and ether (or light petroleum spirit), allow the mixture to stand for an hour, giving it an occasional shake meanwhile. At the end of that time filter the solution through a paper into a clean evaporating basin and allow it to spontaneously evaporate. Notice that it leaves a small quantity of fat in the basin. Remember that the greatest care must be taken in all experiments with ether to avoid its taking fire. It is best to make this experiment in a room where there are no lights.

CHAPTER VI.

THE CARBOHYDRATES.

133. Definition of "Carbohydrates."—This name has been applied to a class of bodies composed of carbon, hydrogen, and oxygen, in which the latter two elements are present in the same proportion as in water, namely, two atoms of hydrogen for every one of oxygen. Thus, for example, starch contains to the six atoms of carbon, ten atoms of hydrogen to five atoms of oxygen. The carbohydrates comprise, among their number, bodies differing considerably in physical appearance and character, but yet exhibiting signs of close chemical relationship. Subjoined is a table of the more important carbohydrates, arranged into three groups, according to their empirical or simplest possible formulæ :—

CLASSIFICATION OF CARBOHYDRATES.

1. Amyloses, $n(C_6H_{10}O_5)$.	2. Sucroses or Saccharoses, $(C_{12}H_{22}O_{11})$.	3. Glucoses, $(C_6H_{12}O_6)$.
+ Starch + Dextrin Cellulose Gums	+ Cane Sugar + Lactose + Maltose	+ Dextrose − Lævulose + Galactose

134. Constitution of Carbohydrates.—In constitution these bodies must be viewed as derivatives of the hexatomic alcohol, mannite. The glucoses are the aldehydes of mannite, containing the aldehyde group, COH, as part of their rational formula, and may be formed by processes of moderate oxidation from that alcohol :—

$$\left\{\begin{array}{l} CH_2HO\\ CHHO\\ CHHO\\ CHHO\\ CHHO\\ CH_2HO \end{array}\right. \text{or } C_6H_8(HO)_6 + O = \left\{\begin{array}{l} CH_2HO\\ CHHO\\ CHHO\\ CHHO\\ CHHO\\ COH \end{array}\right. \text{or } C_6H_{12}O_6 + H_2O.$$

Mannite. Oxygen. Glucose. Water.

In their capacity for further oxidation, and other chemical properties, the glucoses evince the general characteristics of aldehydes

The sucroses may be viewed, as formed by the union of two molecules of glucose, with the elimination of a molecule of water; while the amyloses correspond with the anhydrides of glucose :—

$$\underset{\text{Glucose.}}{2C_6H_{12}O_6} \quad - \quad \underset{\text{Water.}}{H_2O} \quad = \quad \underset{\text{Sucrose.}}{C_{12}H_{22}O_{11}}.$$

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} \quad - \quad \underset{\text{Water.}}{H_2O} \quad = \quad \underset{\text{Amylose.}}{C_6H_{10}O_5}.$$

Looking on sucrose and amylose as resulting from dehydration of the glucose molecule, it should be noticed that sucrose occupies the intermediate position between glucose and amylose.

Brown and Morris in 1888 and 1889 contributed to the Chemical Society's Journal important papers on the Molecular Weights of the Carbohydrates. Their researches were based on Raoult's investigations on the lowering of the freezing point of a solvent by the solution in it of any substance. (Thus, salt water freezes at a lower temperature than pure water.) Raoult found that equivalent molecular proportions of different compounds cause under the same conditions a similar depression of the freezing point of the solvent. This offers a valuable means of determining molecular weight, as, knowing that of one body dissolved, that of others may be determined. Brown and Morris applied this method to the investigation of the carbohydrates.

MOLECULAR CONSTITUTION OF CARBOHYDRATES.

SUBSTANCE.	Formula of Molecule.	Molecular Weight.
Dextrose, ...	$C_6H_{12}O_6$	180
Cane Sugar, ...	$C_{12}H_{22}O_{11}$	342
Cane Sugar, *same solution after inversion*,[1]	$C_6H_{12}O_6$	180
Maltose, ...	$C_{12}H_{22}O_{11}$	342
Lactose, Milk Sugar, ...	$C_{12}H_{22}O_{11}$	342
Arabinose, ...	$C_5H_{10}O_5$	150
Raffinose, ...	$C_{18}H_{32}O_{16}, 5H_2O$	594
Mannite or Mannitol, ...	$C_6H_8(HO)_6$	182
Galactose,[2]	$C_6H_{12}O_6$	180
Maltodextrin, ...	$\left\{\begin{array}{l}C_{12}H_{22}O_{11}\\(C_{12}H_{20}O_{10})_2\end{array}\right.$	990
Amylodextrin, ...	$\left\{\begin{array}{l}C_{12}H_{22}O_{11}\\(C_{12}H_{20}O_{10})_6\end{array}\right.$	2286
Lowest or Stable Dextrin,[3] ...	$20C_{12}H_{20}O_{10}$	6480
Soluble Starch,...	$5(C_{12}H_{20}O_{10})_{20}$	32,400

[1] Cane Sugar after inversion is split up into dextrose and lævulose, and dextrose having a molecular weight of 180, so must lævulose, and be represented by the formula, $C_6H_{12}O_6$.

[2] Galactose is the "dextrose" of Lactose.

[3] The molecular weight, not only of the lowest or stable dextrin, is represented by the formula $(C_{12}H_{20}O_{10})_{20}$, but so also are those of the so-called higher dextrins, of which Brown and Morris examined a series. They find that "the numbers obtained with dextrins occupying very different positions in the series are strikingly identical."

The above table contains the results of their determinations, which molecular weights, with the exception of that of starch, were obtained by direct estimations. In this latter case the direct method was inapplicable, and, accordingly, recourse was had to an indirect method, based on the generally accepted hypothesis that the starch molecule must be at least five times the size of the dextrin molecule produced under certain conditions. Mannite or mannitol, having such an intimate relationship in constitution to the carbohydrates, is also included in the table.

CELLULOSE, $nC_6H_{10}O_5$.

135. Occurrence and Physical Properties.—This body, of which there are numerous physical modifications, constitutes the framework or skeleton of vegetable organisms, in which it acts as a sort of connective tissue, binding and holding together the various parts and organs of plants. Woody fibre consists largely of cellulose and one or two closely allied substances.

The pith of certain plants and also the horny part of certain seeds, as "vegetable ivory," are nearly pure cellulose. Manufactured vegetable fabrics, as cotton and linen goods, and likewise unsized paper, are also cellulose in an almost pure form. Chemically pure Swedish filters consist of cellulose with only the most minute traces of other bodies.

Pure cellulose is white, translucent, of specific gravity of about 1·5, and is insoluble in water, alcohol, ether, and both fixed and volatile oils. An ammoniacal solution of copper hydrate dissolves cellulose completely; this reagent may be prepared by precipitating copper hydrate from the sulphate, by sodium hydrate, and then dissolving the thoroughly washed precipitate in strong ammonia. This solution dissolves cotton wool, or thin filtering paper, forming a sirupy solution; on the addition of slight excess of hydrochloric acid, the cellulose is precipitated in flaky masses; these, on being washed and dried, produce a brittle horny mass. This re-precipitated cellulose is not coloured blue by iodine, and still presents the same chemical properties as ordinary cellulose.

136. Behaviour with Chemical Reagents.—Cellulose, on being boiled with water under pressure, is converted into a body bearing some resemblance to dissolved starch, inasmuch as it is coloured blue by iodine. The same effect is produced more rapidly by treatment with acids. Boiling with dilute sulphuric or nitric acid, or strong hydrochloric acid, breaks up cellulose into a flocculent mass, but without any change in composition. Treatment with stronger nitric acid changes cellulose into nitro-substitution products called gun cottons or pyroxylin; while that acid, in a yet more concentrated form, oxidises cellulose to oxalic acid. By the action of strong sulphuric acid, cellulose is converted into dextrin. Concentrated solutions of potash or soda also dissolve cellulose, with the formation apparently of the same compound. Sulphuric acid, diluted with about half or quarter its bulk of water, has a most remarkable action on unsized paper. The paper on being dipped in the acid for a few seconds, and then washed with weak ammonia, is found to be changed into a tough parchment-like material, which may be used for many of the purposes to which animal parchment is applied. This body is familiar to confectioners, as being sold under the name of parchment paper for tying down pots containing jam and other substances. Filter papers, on being momentarily immersed in nitric acid of density 1·42, are remarkably toughened, the product being still pervious to liquids and therefore suitable for filtering purposes. Such papers are recommended for filtering bodies that have to be removed from the paper while wet, and are now sold commercially for that purpose.

137. Existence in Wheat.—There are three forms of cellulose present in wheat, of which the following is a brief description :—

1. The lignified or woody cellulose of the bran, which is entirely removed in the process of making white flour. In whole-meal, which contains the bran, the lignified cellulose undergoes no change in the operations of bread-making, nor afterwards during the processes of human digestion.

2. The parenchymatous cellulose, which forms the cell-walls of the endosperm. This disappears during germination of the grain, and is far more easily dissolved by all reagents than is lignose or woody cellulose.

3. So-called starch cellulose constitutes the envelopes or cellulose-skeleton of the starch cells. It is this form which is most readily converted into the starch-like body, giving a blue colouration with iodine.

138. Composition.—The formula, $C_6H_{10}O_5$, is the simplest that can be derived from the percentage composition of cellulose, but there is little doubt that the molecule really consists of a number of groups of $C_6H_{10}O_5$ united together, and is at least as complex as that of starch.

$$\text{STARCH,}\ \left\{\begin{array}{l}(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\end{array}\right.$$

139. Occurrence.—The starchy matters of wheat are of vast importance as constituting the greatest portion of the whole seed. Starch is not only found in wheat, but also in other seeds ; and in fact in most if not all vegetable substances used as food. From whatever source obtained, starch has the same chemical composition, but varies somewhat in physical character.

140. Physical Character.—Starch, when pure, is a glistening, white, inodorous granular powder. If a pinch be taken and squeezed between the thumb and finger, a peculiar "crunching" (crepitating) sound is heard. Starch has a specific gravity of from 1·55 to 1·60. Starch is extremely hygroscopic, absorbing moisture with avidity ; in the form in which it is usually sold it contains about 18 per cent. of water. Wheat starch after drying in a vacuum still retains about 11 per cent. of water. Heating in a current of dry air to a temperature of 110° C. renders it practically anhydrous.

141. Microscopic Appearance.—The microscope shows starch to be composed of minute grains, each having a well defined structure. These grains are respectively termed starch cells, granules, or corpuscles. Careful examination reveals that each cell consists of an outer coating or pellicle formed of a very delicate type of cellulose, to which the name "starch cellulose" is applied. This envelope is built up of several layers, arranged concentrically one over the other, and contains within its interior a substance which may be called starch proper, in distinction from the enclosing matter. This starch proper is also termed "starch granulose" or "amylose." On careful examination these separate coats appear as a series of more or less concentric rings, having for a nucleus a dark spot or cross, termed the "hilum." The actual size and shape of starch cells varies with the source from which the starch is derived; thus the grains of starch from potatoes are comparatively large, while those of rice are extremely minute. When examined by polarised light certain starches exhibit characteristic appearances—these are referred to in detail in the table following. A description of the phenomena of polarisation is given in chapter IV. It is possible in many instances to determine the origin of a sample of starch by its microscopic characteristics; it follows that impurities may similarly be detected; also, as all vegetable adulterants of flour contain starch, admixture of other grains, as maize, rice, &c., is in this manner revealed.

In Plate I. is given the appearance of the more important starches as seen under the microscope.

MICROSCOPIC CHARACTERS OF VARIOUS STARCHES.

142. Wheat.—Wheat starch is extremely variable in size, the diameter of the corpuscles being from 0·0022 to 0·052 m.m. (0.00009 to 0·0019 inch). Many observers point out that medium sized granules are comparatively absent. The grains are circular or nearly so, being at times somewhat flattened. The concentric rings are only seen with difficulty; the hilum is not so visible as in certain other starches. Polarised light shows a faint cross. In old samples of wheat or flour the granules show cracks and fissures: this applies more or less to all starches.

143. Barley.—Granules more uniform in size than those of wheat, also somewhat smaller; average diameter 0·0185 m.m. (0·00073 inch); a few exceptionally large granules may be found measuring as much as 0·07 m.m. Shape, slightly angular circles. Concentric rings and hilum either invisible or only seen with difficulty.

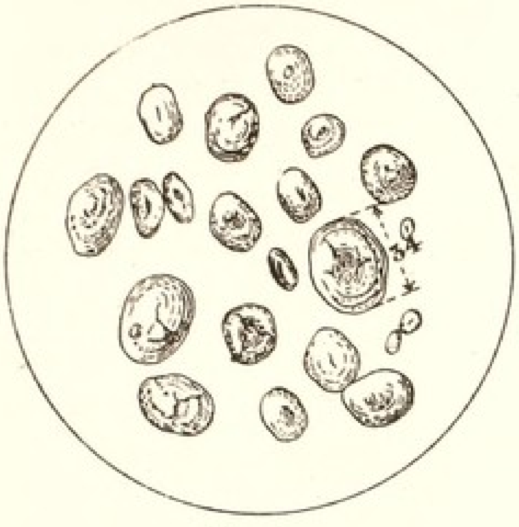
144. Rye.—Diameter of granules from 0·0022 to 0·0375 m.m. (0·00009 to 0·00148 inch). Taking a whole field, the average size of granules is usually somewhat higher than those of wheat. Shape, granules are almost perfectly round, here and there show cracks. Concentric rings and hilum only seen with difficulty.

145. Oats.—Diameter of granules, 0·0044 to 0·03 m.m. (0·00017 to 0·00118 inch). Granules are angular in outline, varying from three to six-sided.

146. Maize.—Diameter of granules, average size, 0·0188 m.m. (0·00074 inch). Shape, from round to polyhedral, mostly elongated hexagons, with angles more or less rounded. Concentric rings scarcely visible, hilum star-shaped.

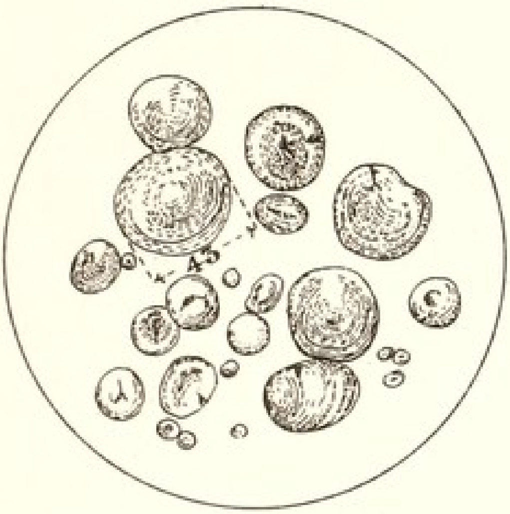
147. Rice.—Diameter of granules from 0·0050 to 0·0076 m.m. (0·0002 to 0·0003 inch). Granules are polygonal in shape, mostly either five or six-sided, but occasionally three-sided. Are usually

PLATE I.

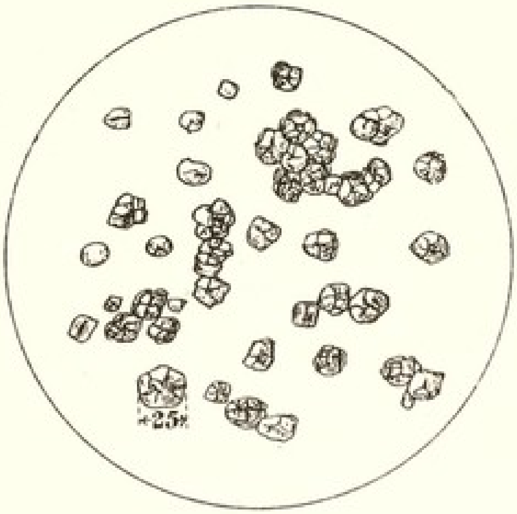


Barley.

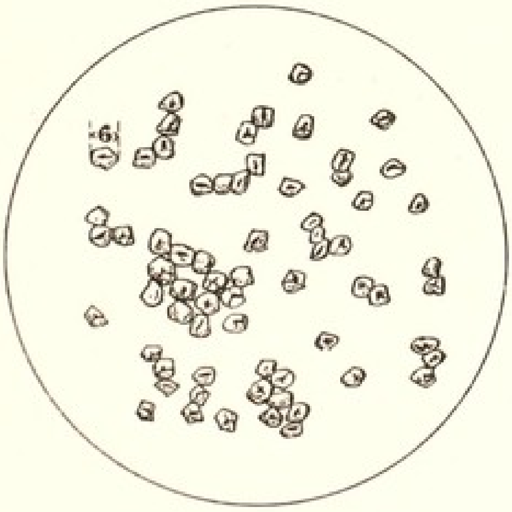
Wheat.



Rye.



Maize.



Rice.

Potato.

MICROSCOPIC SKETCHES OF VARIOUS STARCHES.

Magnified about 100 diameters.

P.E. Fuller

seen in clusters of several joined together. A very high magnifying power shows a starred hilum.

148. Potatoes.—Diameter of granules from 0·06 to 0·10 m.m. (0·0024 to 0·0039 inch). The granules vary greatly in shape and size; the smaller ones are frequently circular; the larger grains are mussel or oyster shaped. The hilum is annular, and the concentric rings incomplete, but, especially in the larger granules, clear and distinct. The rings are distributed round the hilum in very much the same way as the markings show on the outside of a mussel shell. With polarised light a very distinct dark cross is seen, the centre of which passes through the hilum.

149. Canna Arrowroot, or Tous les mois.—Diameter of granules varies from 0·0469 to 0·132 m.m. (0·0018 to 0·0052 inch). The shapes differ considerably, from round to more or less elongated ovals. The hilum is eccentric; the rings are incomplete, extremely fine, narrow and regular. Under polarised light a more distinct cross is seen than with the potatoes.

150. Preparation and Manufacture of Starch.—For experimental purposes, starch can readily be obtained from wheaten flour by first preparing a small quantity of dough; this is then wrapped up in a piece of fine muslin, or bolting silk, and kneaded between the fingers in a basin of water. The milky fluid thus produced deposits a white layer of starch on the bottom of the vessel, which may be carefully air-dried. The starch of barley and the other cereals may be obtained in a sufficiently pure form for microscopic study in the same manner. Potatoes require to be first scraped, or rubbed through a grater, into a pulp; this pulp must then be enclosed in the muslin and the starch washed out.

On the manufacturing scale, starch is obtained from wheat and other grains by first coarsely grinding and then moistening the meal with water. This is allowed to stand, and after three or four days fermentation sets in, more water is then added and the putrefactive fermentation allowed to proceed for some three or four weeks. By the end of this time the glutten and other nitrogenous matters are dissolved. They are then readily separated from the starch by washing, after which the starch is dried. Starch is now largely manufactured from rice by a process in which the grain is subjected to the action of very dilute caustic soda, containing about 0·3 per cent. of the alkali; this reagent dissolves the nitrogenous bodies and leaves the starch unaltered. The so-called "corn flour" is the starch of maize prepared after the same fashion. Potato starch is obtained by first rasping the washed potatoes into a pulp by machinery; the pulp is next washed in a sieve, the starch is carried through by the water, and after being allowed to subside is dried on a tile floor at a gentle heat.

151. Gelatinisation of Starch.—Starch is insoluble in cold water, and cannot be dissolved by any known liquid without change; this follows from its having a definite organic structure; when this is destroyed, as must of necessity be the case whenever a solid is rendered liquid, it cannot by any artificial means be again built up in the same form.

As previously stated, the starch granules consist of an outer envelope of cellulose, enclosing what is termed "amylose," or starch proper. This latter body is soluble, and although pure starch in the granular form yields no soluble substance to water, yet if the cellulose envelopes be ruptured by mechanical means, it is then found that on treatment with water at ordinary temperatures a soluble extract is obtained. When, however, starch is subjected to the action of boiling water a marked change ensues: under the influence of heat the little particles in the interior, by swelling, burst the containing envelope, and dissolving in the water form a thick and viscous liquid, which on cooling, if sufficiently concentrated, solidifies into a gelatinous mass. This solution of starch is somewhat cloudy, owing to the undissolved particles of starch cellulose remaining in suspension. These may be, in great part, removed by filtration.

This bursting of the starch granules is frequently spoken of as the "gelatinisation" of starch, and the resulting substance as "starch-paste." The temperature at which this change occurs varies with the nature and origin of the starch.

The following table gives particulars as to the gelatinising temperatures of starch from different sources. The figures to the left are those of Lippman, while to the right are given the results of a series of later determinations made by Lintner, and published in 1889. It may be taken that Lintner's temperatures are for complete gelatinisation.

TEMPERATURE OF GELATINISATION OF STARCH.

SOURCE OF STARCH.	Granules Swollen.		GELATINISATION.				Complete Gelatinisation, Lintner.	
			Commenced.		Completed.			
	°C.	°F.	°C.	°F.	°C.	°F.	°C.	F°.
Barley, ...	37·5	99·5	57·2	135	62·2	144	80	176
Maize, ...	50·0	122·0	55·0	131	62·2	144	75	167
Rye, ...	45·0	113·0	50·0	122	55·0	131	80	176
Potato, ...	46·1	115·0	58·3	137	62·2	144	65	149
Rice, ...	53·8	129·0	58·3	137	62·2	144	80	176
Wheat, ...	50·0	122·0	65·0	149	67·2	153	80	176
Green Malt,	...	...	...	...	...	...	85	185
Kilned Malt,	...	...	...	...	...	...	80	176
Oat, ...	...	...	...	...	...	...	85	185

These temperatures of gelatinisation assume that the walls of the starch containing cells have been broken down, and that excess of water is present; otherwise the temperature of gelatinisation is considerably higher: thus, in stiff biscuit doughs, and even in bread, much of the starch remains ungelatinised even after being baked.

There is doubt as to whether or not gelatinised starch is in a state of true solution. When filtered, the clear filtrate gives a blue coloration with iodine (a characteristic reaction of starch), but on dialysis through an animal or vegetable membrane, or even filtration through porous earthenware, the starch is removed. This has led to the view that the starch in starch-paste is simply in a state of extremely fine division, but more probably the state is one of true solution, and the removal by filtration is due to the highly colloid nature of starch.

152. Soluble Starch.—On treating starch with dilute acids in the cold, the starch loses its power of gelatinisation, and becomes what is known as "soluble starch." In this form no change of appearance is observed in the granules, but the starch readily dissolves in hot water to a clear limpid liquid. Lintner directs soluble starch to be prepared in the following manner:—Pure potato starch of commerce is taken and mixed with a sufficient quantity of 7·5 per cent. hydrochloric acid to cover it, and allowed to stand either at ordinary temperatures for seven days, or for three days at 40° C. By that time the starch will have lost the power of gelatinisation, and is repeatedly washed with cold water until every trace of acid is removed. It is then air-dried, and is readily and completely soluble in hot water to a bright and limpid solution.

Soluble starch is probably a polymeride of ordinary starch, and when dissolved, then known as "starch solution," closely resembles "starch-paste" in its chemical behaviour.

153. Action of Caustic Alkalies on Starch.—Treatment with cold dilute solutions of potash or soda causes starch granules to swell enormously; the volume of starch grains may thus be made to increase 125-fold. This reaction also serves for the differentiation of the various starches. H. Symons recommends the use of soda solutions of different strengths: a small quantity of the starch is shaken up in a test-tube for ten minutes with one of the soda solutions, and then a drop of the liquid is examined under the microscope. The following is a table of results thus obtained:—

	A few starch granules dissolved in a solution of	The greater number dissolved in a solution of	All dissolved in a solution of
Potato,	0·6 per cent.	0·7 per cent.	0·8 per cent.
Oats,	0·6 ,,	0·8 ,,	1·0 ,,
Wheat,	0·7 ,,	0·9 ,,	1·0 ,,
Maize,	0·8 ,,	1·0 ,,	1·1 ,,
Rice,	1·0 ,,	1·1 ,,	1·3 ,,

154. Action of Zinc Chloride.—Treatment with zinc chloride also causes a remarkable swelling of the granules of starch; this reaction, when viewed under the microscope, serves admirably to show the structure of the corpuscles. Some concentrated solution of zinc chloride is tinged with a trace of free iodine. A few grains of the starch are placed on a glass slide, together with a small drop of this solution. No change is observed until a little water is also added. They then assume a deep blue tint, caused by the iodine, as explained in a subsequent paragraph, and gradually expand. A frill-like margin developes round the granule, the foldings of this frill open out in their turn, until the granules at last swell up to some twenty or thirty times the original volume, and then appear as limp looking sacs. These changes, so far as can be seen, are not accompanied by any expulsion of the inner contents of the cell.

155. Properties of Starch in Solution.—A solution of starch is colourless, odourless, tasteless, and perfectly neutral to litmus. Starch is a highly colloid body, and can be readily separated by dialysis from crystalline substances. On evaporating a solution of starch, it does not recover its original insolubility. Starch solution causes right handed rotation of polarised light. Starch amylose is insoluble in alcohol, and may be entirely precipitated from its aqueous solution by the addition of alcohol in sufficient quantity. Tannin precipitates both starch-paste and soluble starch, the precipitate being re-dissolved on heating. Barium hydrate gives an insoluble compound with solution of starch, and is used in this way in some processes of starch estimation.

Soluble starch, owing to the formation of a hydriodide of starch, $(C_{24}H_{40}O_{20}I)_4HI$, is coloured an intense blue by the addition of iodine in extremely small quantities. This blue colouration disappears on heating the solution, but reappears on its being cooled. This reaction is exceedingly delicate, and is practically characteristic of starch. For the purpose of this test, the iodine may be dissolved in either alcohol or an aqueous solution of potassium iodide; for most purposes preferably the latter. For the occurrence of this reaction, the presence of water is apparently essential; for if wheaten flour be moistened with an alcoholic solution of iodine no colouration is produced other than the natural brownish yellow tint of tincture of iodine. But with a potassium iodide solution the flour assumes a blue colour so intense as to be almost black. The iodine colouration of starch is only caused by free iodine, not by iodine compounds; and is not produced except in the presence of hydriodic acid or an iodide. Potash or soda in solution, when added to dissolved iodine, immediately combine therewith to form iodides and iodates; consequently, the iodine test for starch is inapplicable in an alkaline medium. In case a solution to be tested for starch, is alkaline to litmus, cautiously add dilute sulphuric acid, until neutral or very slightly acid; the test for starch may then be made. The only compounds usually likely to interfere with the iodine reaction for starch are some of the dextrins; these bodies combine with iodine, forming either colourless or brown compounds; but unless present in large quantities do not prevent the detection of starch. Iodine combines with starch more readily than with dextrin, consequently the iodine should in such cases be added in very small quantities at a time, when the blue colouration due to the starch will appear before the brown tint produced by dextrin. In testing for starch the addition of iodine solution should be continued until an excess of iodine is present in the solution. Kraus has recently discovered a substance in the epidermis of some of the *Arums* which strikes a blue colour with iodine. This body is not a starch, and the discoverer has come to the conclusion that it is allied to the tannins. In ordinary work, however, this substance is not likely to interfere with the iodine test for starch.

In recently examining some starchless biscuits, the author found, on dropping a solution of iodine on the broken surface of the biscuit, that a blue colouration was produced, but that prolonged boiling failed to yield a solution which gave an iodine colouration. The probable explanation seems to be that under the influence of heat traces of starch cellulose in the biscuit products are converted into the soluble variety, and hence give a colouration *in situ*, but are in such small quantity and so firmly imprisoned within the cellulose as not to be liberated by boiling. It is not sufficient in making starch tests on solid substances to trust to adding iodine to the substance itself: the substance should also be extracted with boiling water, and the test made on the filtered solution.

Starch does not cause a precipitate with Fehling's solution, that is, it does not reduce an alkaline solution of copper sulphate in potassium sodium tartrate. (See paragraph 161 on maltose.)

Starch under the influence of heat, and readily when treated with certain other bodies, is transformed into others of the carbohydrates.

DEXTRIN, $20C_{12}H_{20}O_{10}$.

156. Occurrence.—Dextrin is principally known as a manufactured article, but also occurs in small quantities as a natural constituent of wheat and most bodies containing starch.

157. Physical Character.—In appearance, dextrin is a brittle transparent solid, very much resembling the natural gums, as gum arabic. It is colourless, tasteless, and odourless. Dextrin is a colloid body, and is very soluble in water, and also in dilute alcohol: it is insoluble in absolute alcohol, by means of which it may be precipitated from its solutions. Dextrin is also insoluble in ether. Surfaces moistened with a solution of dextrin, and then allowed to dry in contact with each other, adhere firmly. Commercial dextrin has usually a more or less brown tint from the presence of caramel in small quantity.

158. Preparation.—Dextrin is usually prepared by the action of heat, with or without certain reagents, on starch. The starch may be maintained at a temperature of about 150° C. until it assumes a brown colour: treatment with water then dissolves out dextrin in an impure form. If the starch be first moistened with water containing a minute quantity of nitric acid, the change proceeds much more rapidly; the starch should in this case be heated to about 200° C. The substance thus yielded is that known as British gum, and is largely used for sizing calicoes and other purposes in commerce. If starch solution be boiled with dilute sulphuric acid until it no longer gives a blue colouration with iodine, dextrin will be found in the solution, but mixed with maltose. Certain nitrogenous bodies also possess the power of converting starch into dextrin and maltose.

159. Chemical Character.—Until recently, dextrin was supposed to consist of a mixture of polymeric bodies of closely similar chemical character. These several dextrins were separated into two groups by their difference in behaviour when treated with iodine solution. The members of one of these groups, known as "erythro-dextrins," were found to strike a reddish-brown colouration on treatment with iodine; while the others, which were classified as "achroo-dextrins," yielded no colouration when iodine was added. It has already been stated that Brown and Morris in 1889 investigated the molecular weights of the carbohydrates, and that they found the results given by the various dextrins were practically identical. The formerly held theory assumed that the erythro-dextrins contained in the molecule 8 and 9 respectively of the group $C_{12}H_{20}O_{10}$; while the molecular formula of the achroo-dextrins included from 2 to 7 of the $C_{12}H_{20}O_{10}$ group. In face of Raoult's method, giving identical molecular weights for the whole of the dextrins, the view of their being polymeric bodies is no longer tenable. The iodine colouration, produced by the so-called erythro-dextrins, is due to the presence of certain other bodies, termed "amyloïns," which will subsequently be described.

Dextrin has a powerful action on polarised light, twisting the ray to the right: its name is derived from this property. A solution of dextrin in some respects resembles one of starch; they are, however, distinguished by the dextrin giving no blue colour when treated with iodine. Dextrin exercises no reducing action on Fehling's solution: in this respect its behaviour is similar to that of starch.

THE SUGARS—*Maltose, Cane Sugar, Milk Sugar, and Glucose.*

160. General Properties.—The sugars are a subdivision of the class of bodies known as carbohydrates; they are characterised by having a more or less sweet taste, and are soluble in water. Many are natural products occurring both in the animal and vegetable kingdom.

161. Maltose, $C_{12}H_{22}O_{11}$.—This body occurs in company with dextrin in starch solutions, which have been treated with dilute sulphuric acid until the solution no longer yields a blue colouration with iodine. It forms a most important constituent of malt extract, amounting to from 60 to 65 per cent. of the total solid matter. In the pure state, maltose consists of small hard crystalline masses or minute needles, which are soluble in water and dilute alcohol. Maltose, being a crystalline body, may be separated from dextrin by dialysis, and also by precipitating the dextrin by means of strong alcohol. A solution of maltose causes a right-handed rotation of a ray of polarised light. Maltose gives no colouration with iodine, but, in common with certain other of the sugars, exercises a reducing or deoxidising action on some metallic salts. This reducing action is most commonly tested by means of the reagent known as "Fehling's solution." This consists of sulphate of copper, tartrate of potassium and sodium, and sodium hydrate. If sodium hydrate be added to a solution of copper sulphate, a precipitate of copper oxide, CuO, combined with water, is thrown down; the sodium and potassium tartrates redissolve this and form a deep blue solution, which may be boiled for some minutes without alteration. Now certain varieties of sugar reduce the CuO to Cu_2O; that is, they take away oxygen, the change being represented by $2CuO = Cu_2O + O$. The oxygen is taken by the sugar, and for our present purpose need not be traced further. The Cu_2O, or copper sub-oxide, thus formed is insoluble in the Fehling's solution, and hence is precipitated, first as a yellow and then as a brick red powder.

162. Cane Sugar, $C_{12}H_{22}O_{11}$.—Cane sugar is widely spread in nature: it is found in certain roots, as beet-root, in the sap of trees, as the maple, and in the juice of the sugar cane. These natural solutions are first purified, and then the sugar obtained by crystallisation. The sugar found in perfectly sound wheat is either identical with, or closely allied to, cane sugar. Pure cane sugar is colourless, odourless, and soluble in water, to which it imparts a sweet taste. Boiling water dissolves sugar in all proportions, while cold water dissolves about three times its weight. Sugar is insoluble in absolute alcohol, ether, chloroform, and petroleum spirit, but is sparingly soluble in rectified spirits of wine. The purest commercial form of sugar is that sold by the grocers as "coffee sugar," and consists of well defined crystals about three-sixteenths of an inch across. This, when dried at 100° C. to expel any water that may be present, is sufficiently pure for most experimental work with sugar. A solution of cane sugar exercises a right-handed rotation on a polarised ray of light. Cane sugar produces no colouration with iodine, neither does it cause any precipitate in Fehling's solution. By the action of heat, cane sugar melts, and if then allowed to cool, forms the solid termed "barley-sugar;" a prolongation of the heat results in giving the sugar a deeper colour. Many sweetmeats consist of sugar thus treated. The darkening in colour is due to the fact that at moderately high temperatures (210° C. = 410° F.) sugar begins to undergo decomposition. Watery vapour and traces of oily matter are evolved, leaving behind a substance soluble in water, to which it imparts a rich brown tint. The characteristic sweet taste of sugar has then disappeared, and the liquid is no longer capable of fermentation by yeast. The change has resulted in the formation of a brown substance, termed caramel, to which the formula $C_{12}H_{18}O_9$ has been given Caramel is, however, rather a mixture of bodies, than a definite chemical compound. The browning of dextrin and starch when heated is also due to the formation of caramel.

163. Milk Sugar or Lactose, $C_{12}H_{22}O_{11}$.—This sugar is principally of interest as being that present in milk, which contains quantities of it, varying from 4 to 5 per cent.

It will be noticed that the three sugars—maltose, cane sugar, and milk sugar—have all the same formula.

164. Glucose or Grape Sugar, $C_6H_{12}O_6$.—Several modifications of glucose exist; of these, two only are of importance in connection with the present subject, viz., dextrose or dextro-glucose, and lævulose or lævo-glucose.

165. Dextrose or Dextro-Glucose.—This form of sugar exists as a natural product in the juices of many fruits, notably the grape and sweet cherry. The former yields about 15 per cent. of grape sugar. Dextrose is also found in large quantity in the urine of diabetic patients; some doubt exists as to whether this sugar is absolutely identical with the dextrose of fruits. Dextrose, when pure, occurs in crystalline masses: it has a sweet taste; but, weight for weight, possesses much less sweetening action than does cane sugar. A solution of dextrose exercises a right-handed rotation on a ray of polarised light. Among the sugars, dextrose is specially noticeable for the great ease with which it undergoes alcoholic fermentation. Like maltose, dextrose exercises a reducing action on Fehling's solution, producing a red precipitate of cuprous oxide.

166. Lævulose or Lævo-Glucose.—This sugar occurs in company with dextrose in certain fruits, and also in honey. Lævulose is non-crystallisable, possesses greater sweetening power than dextrose, and offers more resistance to alcoholic fermentation. A solution of lævo-glucose exercises a left-handed rotation on a ray of polarised light, thus distinguishing it from dextro glucose; the two names are based on the respective right and left handed rotary power of these glucoses. Lævo- and dextro-glucose both act similarly on Fehling's solution.

167. Commercial Glucose.—Glucose, in a more or less pure form, is largely manufactured for commercial purposes. Under the names of "saccharum," "invert sugar," &c., it is used as a substitute for malt by brewers and distillers. Various forms of confectionery and fruit jams contain glucose as an important constituent. Glucose occurs in two forms in commerce: the one is a thick and almost colourless syrup, the other is a hard crystalline body, varying in colour from almost white to pale brown. Glucose is usually made from starch by the action of heating with dilute sulphuric or oxalic acid. For the purpose, either maize or rice is usually selected. Subjoined are some analyses of commercial glucose, which were quoted at a lecture given before the Society of Arts by W. G. Valentin:—

	Brown, very hard English.	Soft, straw-coloured French.
Glucose, $C_6H_{12}O_6$, … … …	80·0	58·85
Maltose, $C_{12}H_{22}O_{11}$, … …	none.	14·11
Dextrin, $C_6H_{10}O_5$, … …	none.	1·70
Other carbohydrates and traces of albuminoids, …	8·20	9·38
Mineral matter, … … …	1·30	1·40
Water, … … … …	10·50	14·56
	100·00	100·00

The glucose in these commercial products is a mixture of dextrose and lævulose. The author has recently examined a number of the sirupy glucoses: these he finds to consist principally of maltose and dextrin.

Cane sugar is also converted into a mixture of dextrose and lævulose by the action of acids; it is then sold under the name of "invert sugar;" the reason for this name is that such sugar rotates the ray of polarised light to the left instead of to the right, as does normal cane sugar.

THE AMYLOÏNS.—*Amylo-dextrin, Malto-dextrin.*

168. Constitution.—The term "amyloïns" was proposed by Armstrong as a convenient name for a group of bodies which are compounds of varying proportions of the amylin or dextrin group, $C_{12}H_{20}O_{10}$, with the amylon or maltose molecule, $C_{12}H_{22}O_{11}$. That these bodies are compounds and not mixtures is proved by their being incapable of separation by the action of alcohol, whereas mixtures of dextrin and maltose in the same proportions are readily so separated. Further, the amyloïns are unacted on by ordinary yeast, *Saccharomyces cerevisiæ*, while the maltose of a *mixture* is readily so fermented. They are completely converted by diastase into maltose.

169. Amylo-dextrin, $\left\{\begin{matrix} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_6 \end{matrix}\right.$—This body is produced by the action of dilute acids on starch granules in the cold. After some weeks' treatment the corpuscles become completely disintegrated, and then consist largely of amylo-dextrin ; this is dissolved in hot water and purified by precipitation with alcohol. This substance is a definite chemical compound, having the formula above assigned to it as the result of a determination by Raoult's method ; and is produced by the hydrolysis of starch. Amylo dextrin gives an intense reddish-brown colouration with iodine, and its presence is the cause of the chemical properties hitherto ascribed to erythro-dextrin.

170. Malto-dextrin, $\left\{\begin{matrix} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{matrix}\right.$.—When starch is converted by diastase, malto-dextrin is found to a greater or lesser extent in the products, especially when the converting action is not very prolonged. Malto-dextrin is unfermentable by ordinary yeast, *Saccharomyces cerevisiæ*, by the action of which it may be distinguished, and separated, from maltose. Malto-dextrin is, however, slowly fermented by certain secondary yeasts. Diastase completely and readily converts malto-dextrin into maltose.

171. Other Carbohydrates of Cereals.—There are certain other bodies, of which small quantities are found in wheat and other grains ; among these are :

Raffinose, $C_{18}H_{32}O_{16},5H_2O$, is a sugar somewhat resembling cane sugar in character, but less easily inverted. Found by O'Sullivan in barley.

α and β Amylan, $nC_6H_{10}O_5$, are two bodies having the same empiric formula, which are found in the mucilaginous portions of grains. They are almost insoluble in cold water, dissolve in hot water, and gelatinise on cooling. These substances, when treated with dilute acids, are converted into dextrose without the production of intermediate bodies. Wheat contains from 0·1 to 0·05 per cent. of α amylan, and from 2·0 to 2·5 per cent. of β amylan.

Extractive Matters.—Under this heading are included certain substances which cannot be readily identified in the same manner as starch, maltose, and other bodies. This is in consequence of their possessing no very definite chemical reactions. Recently, Lintner has obtained from barley a white amorphous substance, which he provisionally calls barley-gum, and to which he gives the formula $nC_6H_{10}O_5$, and suggests its identity with O'Sullivan's amylan.

EXPERIMENTAL WORK.

172. Cellulose.—Mix in a moderate sized beaker about 5 grams of wheat meal, with 150 c.c. of water, and 50 c.c. of a five per cent. solution of sulphuric acid; and set the beaker in a hot water bath for half-an-hour, giving its contents an occasional stir. At the end of that time add 50 c.c. of a twelve per cent. potash solution, and set the beaker in the bath for another half-hour. Observe that a residue remains; allow this to subside, and wash it by decantation. Finally, transfer it to a filter, and let it drain. The substance thus obtained consists of the cellulose or woody fibre of the wheat. Add iodine solution to a portion, and notice that it produces no blue colouration.

It is assumed that most of the students who go systematically through this course of experimental work will do so in a regularly appointed laboratory: they will there find the solutions of sulphuric acid and potash above referred to ready made up for use. Full directions for their preparation, and also of other special reagents required, are given in the chapters on analytic work toward the end of the book. Unless he has not access to such solutions, the student need not at this stage of his work trouble to specially prepare them.

173. Microscopic Examination of Starches.—Take a small quantity of either wheat meal or flour and make it into a dough. Tie this up into a piece of muslin or bolting silk, and knead in a small cup or glass with water; the starch escapes, giving the water a milky appearance, while the gluten and bran remain behind in the muslin. Clean an ordinary microscopic glass slide and cover, shake the starchy water and place a minute drop on the slide, lay on the cover, press it down gently, and soak up any moisture round its edge with a fragment of blotting paper. Place the slide on the microscopic stage, and focus the instrument, using first the inch and then the quarter or eighth objective. The separate starch cells are then plainly seen. Trace in a few of the cells on paper, with a camera lucida, and sketch in any points of detail. Measure one or two of the cells with the eye-piece micrometer, and mark their dimensions on the drawing.

Take a small quantity of the flours respectively of barley, rye, rice, and maize, wash out the starch from each, and examine microscopically in precisely the same manner as with the wheat, making drawings in each case. A little corn flour, being practically pure maize starch, may be used instead of maize flour. Cut a potato in halves, and with a sharp knive scrape off a little pulpy matter from the cut surface, transfer to a slide, and examine with the microscope.

Notice in each case the relative sizes of the granules, and compare their shapes. Examine for the hilum and also observe the rings. If the microscope be fitted with polarising apparatus, study the various starches under polarised light.

174. Examination of Mixed Starches.—With separate portions of wheat flour, mix respectively small quantities of rice meal and corn flour. As before, knead the starch out of each, and examine the milky fluid for the foreign starches. Notice in the one case the very small rice starch granules, and in the other the somewhat larger maize starch granules interspersed among those of the wheat.

175. Gelatinisation of Starch.—Heat separate quantities of one gram of the starches of wheat, rye, maize, rice, and potato in 50 c.c. of water; and notice the temperature at which the liquids commence to thicken through gelatinisation of the starch. The experiment is conducted in the following manner.

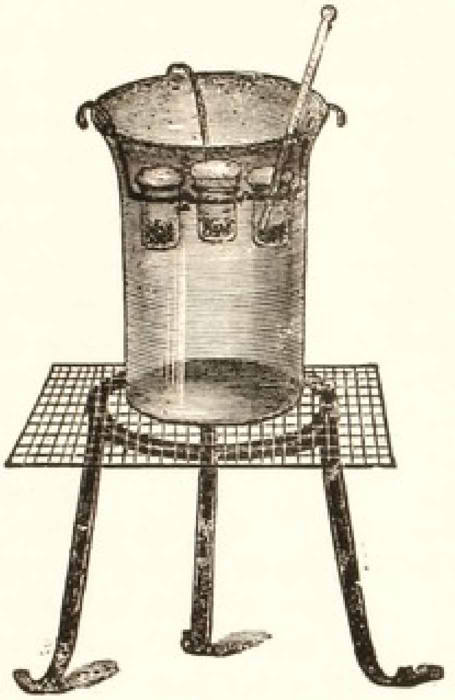


FIG. 7.—APPARATUS FOR DETERMINING TEMPERATURE OF GELATINISATION OF STARCH.

Place a moderately large beaker on a piece of wire gauze over a tripod, as in figure 7. Take several small beakers or test tubes, and attach to each a wire hook, so that they may be hung over the edge of the large beaker. Fill this large beaker with water, and use it as a water bath. Put the starch to be tested, together with the requisite quantity of water, in one of the small beakers, and suspend it in the water bath; under which place a lighted bunsen. While the small beaker is thus being heated, stir its contents with a thermometer, and note the temperature at which the first appearance of gelatinisation is detected; instantly remove the beaker and plunge it into a vessel of cold water. When cold, examine a little of the paste with the microscope, and notice whether or not many of the granules remain unaltered. Make a second experiment with the same starch, arresting the temperature at 2° hotter or colder, according to the degree of gelatinisation revealed by the microscope on the first trial. All the starches specified are to be tested in the same manner.

176. Reactions of Starch Solution.—Gelatinise a little starch by heating it with water in a test tube or small beaker placed in the hot-water bath; then let the solution cool.

Dissolve some iodine in alcohol, and aqueous solution of potassium iodide, respectively. In each case use sufficient iodine to just give a sherry tint to the solution. Add some of either of these solutions (that in alcohol is commonly a "tincture") to a small quantity of the solution of starch; notice the blue colour produced. Heat the solution, and then allow it to cool; observe the disappearance and gradual reappearance of the colour.

Render a portion of the starch solution alkaline by the addition of caustic soda or potash: to one portion of this solution add iodine; notice that no colouration is produced. To the other, add dilute sulphuric acid until the solution is slightly acid to litmus paper. Then add some iodine solution, and observe that the normal blue colour is produced. Add respectively solution of iodine in potassium iodide, and the tincture of iodine, to separate small portions of flour; notice the dark blue colour produced in the first instance, and the sherry tint in the second. To the second portion add a little water; the dark blue colour at once appears. Mount a minute portion of flour on a slide with iodine solution; examine under the microscope and notice the blue colouration of the starch granules, while other constituents of the flour remain comparatively uncoloured.

177. Dextrin.—Render some water faintly acid by the addition of a small quantity of nitric acid; with this, moisten some starch in a porcelain dish, and maintain it at a temperature of 200° C. in a hot-air oven for about two hours. The hot-air oven is usually made of copper, and is heated by means of a bunsen placed underneath; through a hole in the top a thermometer is fixed so as to show the temperature. Before using the oven, regulate the temperature by turning the bunsen partly on or off until the thermometer remains steadily within say 10 degrees of 200. The moistened starch must not rest direct on the bottom of the oven: it may be placed on a small tripod made by turning down the wires of an ordinary pipe-clay triangle.

Treat this heated starch with hot water, and filter; a yellowish-brown gummy solution is obtained. To a portion, add iodine solution; notice that no blue colouration is produced, but instead a reddish-brown tint; starch, therefore, is absent. The reddish-brown colour is due to the presence of amylo-dextrin. From another portion of the solution, precipitate the dextrin by adding strong alcohol; filter and wash the precipitate with alcohol, dissolve in a little water and reserve for a future experiment. Use a little of the solution for fastening together pieces of paper; notice that it exhibits the ordinary properties of gum.

178. Maltose and other Sugars.—Take from 5 to 10 grams of ground malt, and mix with ten times the quantity of water, place the mixture in a beaker arranged in a hot-water bath, and keep it at a temperature of 60° C. for half-an-hour: this may be done by turning down the flame, or altogether removing it from time to time. The temperature may range from 55 to 65° C., but must not be allowed to go above the latter. At the end of the half-hour, raise the temperature to the boiling point for five minutes, and then filter; the resultant liquid is a solution of maltose and dextrin, and may be used for experiments on maltose.

Prepare solutions of the following substances, and test them with Fehling's solution—(1), starch; (2), the re-dissolved alcoholic precipitate of dextrin; (3), aqueous extract of malt; (4), cane sugar; and (5), commercial glucose.

Set some distilled water boiling in a flask or large beaker for half-an-hour. Take 20 c.c. of the mixed Fehling's solution (see Chapter XXIV.), add equal quantity of the boiled distilled water, and set in the boiling hot-water bath for ten minutes; notice that no precipitate is produced. Heat five separate portions of 20 c.c. of Fehling's solution, and 20 c.c. of water to the boiling point, and add respectively 20 c.c. of the starch and other solutions previously prepared. Let them all stand in the hot-water bath for ten minutes: at the end of that time some of the solutions will probably be decolourised with the deposition of a copious red precipitate, while others will remain unchanged. The results should be as follows :—

Starch—No precipitate.
Dextrin—No precipitate. (Practically, there is usually a very slight precipitate, owing to difficulty in thoroughly washing the dextrin free from maltose).
Maltose—Red precipitate.
Cane sugar—No precipitate.
Glucose—Red precipitate.

CHAPTER VII.

THE PROTEIDS.

179. Character of Proteids.—The proteids, while not the most abundant constituents of wheat and flour, are yet among the most important. In whatever life exists, and in that physical basis of life, protoplasm, proteids are constantly and invariably present. In matters of animal origin, such as muscle, blood, milk, the proteids constitute a larger proportion of the water-free material than in most vegetable bodies, and much of the work of examining and classifying proteids has been first done on those derived from animal sources. All animal proteids are, however, derived either directly, or indirectly through the body of some other animal, from the proteids of the vegetable kingdom. The name proteid is derived from the Greek (*πρωτεῖον*, pre-eminence), and has been given to these bodies because of their great importance in the animal economy. Typical among the proteid bodies is albumin, the essential constituent of the white of egg; so much so that the term "albuminous" substance is often used as a synonym of proteid. With a more minute classification of the proteids, the term albumin is restricted to one particular proteid group; and the term "albuminoid," commonly employed as bearing the same meaning as "proteid," should be restricted to gelatin and certain other bodies which are not proteids, but bodies bearing a resemblance or relationship to the group of which albumin is the typical member.

180. Composition of Proteids.—The proteids are distinguished in composition from the carbohydrates by their containing nitrogen and sulphur as essential constituents, in addition to carbon, hydrogen, and oxygen. They are substances of extremely complex constitution, and have very high molecular weights. They are highly colloid bodies, and for the most part uncrystallisable. The various proteids differ somewhat in composition: the following table, on the authority of Hoppe-Seyler, gives the ranges of variation in percentages:—

	C	H	N	S	O
From	51·5	6·9	15·2	0·3	20·9
To	54·5	7·3	17·0	2·0	23·5

From these figures various observers have attempted to assign empiric formulæ to the proteids; thus, Lieberkühn and Loew both give for albumin the formula $C_{72}H_{112}N_{18}SO_{22}$, while Schutzenberger suggests $C_{240}H_{392}N_{65}S_3O_{75}$: in the present state of our knowledge, however, such formulæ are of necessity almost purely speculative.

181. Reactions of Proteids.—Proteid substances are distinguished by their evolving ammonia on being strongly heated. This is at once noticed on burning pieces of quill or dried gluten, both of which consist largely of proteid bodies. If the suspected substance be heated to near the boiling point of concentrated sulphuric acid, to which a little potassium sulphate has been added, the whole of its nitrogen is converted into ammonium sulphate, from which free ammonia is obtained by adding caustic soda in excess, and subjecting the liquid to distillation. This reaction forms the basis of what is known as Kjeldahl's method for the determination of nitrogen in organic compounds. In examining substances for proteids, and especially in discriminating the various proteids from each other, their following characters are of importance—solubility, heat coagulation, indiffusibility, action on polarised light, and colour reactions.

Solubility.—All proteids are insoluble in absolute alcohol and in ether. Some are soluble in water, others insoluble; among the latter, many are soluble in weak saline solutions. Some proteids are soluble and others insoluble in strong or saturated saline solutions.

Mineral and acetic acids, and also caustic alkalies, dissolve all proteids by the aid of heat, such solution being, however, accompanied by decomposition. The gastric and pancreatic juices also dissolve proteids, but, in so doing, change them into a sub-class of proteids, known as peptones.

Heat-coagulation.—This is a very familiar characteristic of some proteids, chief among them being albumin from the white of egg, which on being plunged into boiling water assumes an insoluble form. Many proteids when dissolved either in water or dilute saline solutions are coagulated by the action of heat. The temperature at which coagulation occurs affords one method of determining the nature of the particular proteid in the solution. Distinct from heat coagulation is what is known as ferment-coagulation, an instance of which is the coagulation of milk by rennet.

Indiffusibility.—All the proteids (with the exception of the peptones) are highly colloid bodies, and when in solution may consequently be separated from crystalline bodies by dialysis.

Action on Polarised Light.—All proteids turn a ray of polarised light to the left, or are lævorotatory.

Colour Reactions—Xanthoproteic Reaction.—These are very useful methods of detecting and recognising proteids. The Xanthoproteic reaction is obtained in the following manner:—Add to the solution under examination a few drops of strong nitric acid; a white precipitate may or may not be produced, according to the nature and degree of concentration of the proteid. (Peptones and some varieties of albumose give no precipitate.) Boil; the precipitate or liquid turns yellow, with usually some solution of any precipitate. Cool and add ammonia; the yellow liquid or precipitate turns orange. This colouration is the essential part of the reaction, and is the most delicate test for proteids we possess.

Millon's Reaction.—Dissolve, by the aid of gentle heat, one part by weight of mercury in two of strong nitric acid; dilute with twice its volume of water, and allow the precipitate to settle; the clear supernatant liquid is Millon's reagent. On the addition of a few drops of this to a solution of proteid, a white precipitate forms, which, on being heated, assumes a brick-red colour. The reaction is prevented by the presence of sodium chloride. Other substances are precipitated by Millon's reagent, but the precipitate does not turn red on boiling.

Piotrowski's or "Biuret" Reaction.—Add to the solution of albumin or similar proteid a few drops of dilute solution of copper sulphate; a precipitate of copper albuminate is formed, except with deutero-albumose and peptone. Add excess of caustic potash or soda, a violet solution is produced. Ammonia gives a blue solution.

In the case of albumoses and peptones, the result is, instead, a rose-red solution with potash, and a reddish-violet with ammonia. Care must be taken not to add excess of sulphate, as so doing gives a reddish-violet colour, very difficult to distinguish from this peptone reaction. When this test is applied in the presence of salt solutions it may be somewhat modified; thus, magnesium sulphate is precipitated as magnesia by potash; before the colour can be observed the precipitate must be allowed to subside. If ammonium sulphate is present, a large quantity of potash is necessary before the colour appears; sodium chloride does not affect the reaction.

182. Precipitation of Proteids.—The preceding note on the solubility of proteids affords some clue to their various modes of precipitation, the peptones and albumoses being much more soluble than other proteids.

Solutions of the proteids may be precipitated by the following bodies:—Strong mineral acids, especially nitric acid; acetic acid; and also with excess of sodium sulphate, sodium chloride, or magnesium sulphate. Salts of the heavy metals, as mercuric chloride or basic lead acetate, also precipitate proteids; on suspending the precipitate in water, and passing a stream of sulphuretted hydrogen, the metal is precipitated and the proteid recovered in an unchanged form. In addition, proteids are precipitated by tannin, or tannin and sodium chloride together: by saturation with ammonium sulphate: by picric acid: and by alcohol in faintly acid solutions.

Among these the following are convenient methods of removing proteids from a solution, either as a part of the process for their own isolation, or as a prior step toward examining the liquid for other substances:—

1. The solution is mixed with half its volume of a saturated solution of common salt, tannin is added in slight excess, and the proteids are entirely separated.

2. The solution is saturated with ammonium sulphate, which precipitates all proteids but peptones.

3. The solution is rendered faintly acid with acetic acid, several times its volume of absolute alcohol added, and allowed to stand twenty-four hours. The whole of the proteids are thus precipitated.

4. When proteids of the albumin or globulin group only are present, simple acidulating and boiling the solution precipitates the proteids.

183. Classification of Proteids.—Proteids are commonly divided into animal and vegetable proteids, according to their origin. Strictly speaking, the animal proteids have but little to do with the present work, but as their classification is largely that on which the classification of those from vegetable bodies is also based, a short account of the animal proteids is here inserted.

184. Animal Proteids.—These are conveniently arranged in the following groups :—

Class 1. *Albumins*, soluble in water, in dilute saline solutions, and saturated solutions of sodium chloride and magnesium sulphate. Precipitated from their solutions by saturation with ammonium sulphate. Coagulated by heat, usually about 70°—73° C.

Members of class—Serum albumin, egg-albumin, cell-albumin, muscle-albumin, lact-albumin.

Class 2. *Globulins*, soluble in dilute saline solutions ; insoluble in water, concentrated solutions of sodium chloride, magnesium sulphate, and ammonium sulphate. Coagulated by heat, temperature varying considerably.

Members of class—Fibrinogen, serum globulin, crystallin ; vitellin, in the yolk of egg, not precipitable by sodium chloride.

Class 3. *Albuminates, or Derived Albumins*, derived from either albumins or globulins by the action of weak acids or alkalies. On heating a solution of egg albumin to about 40° C. with a few drops of 0·1 per cent. sulphuric acid or 0·1 per cent. potash solution, the solution loses its properties and becomes converted into acid-albumin or syntonin, and alkali albumin respectively.

Albuminates are soluble in acid or alkaline solutions or in weak saline solutions ; insoluble in pure water, precipitated like globulins by saturation with sodium chloride, magnesium sulphate, or ammonium sulphate. Solutions not coagulated by heat.

Caseinogen, the chief proteid constituent of milk, is an albuminate.

Class 4. *Proteoses*, intermediate products in the hydration of proteids, formed in the body by the action of the gastric and pancreatic juices, artificially by heating with water, and more readily by dilute mineral acids. Are not coagulated by heat, precipitated by alcohol, all give the biuret reaction. Precipitated by nitric acid, precipitate soluble on heating, and reappearing as the liquid cools.

The proteoses are subdivided into albumoses, globuloses, &c., according to the original proteid from which derived, albumin, globulin, &c. Each group of proteoses may be further subdivided in a similar manner ; taking albumose, there are two varieties, *hemi-albumose* and *anti albumose*, which on further digestion are converted into hemi-peptone and anti-peptone respectively. Classified according to their solubilities, they are divided into—

Proto-albumose, soluble in cold and hot water and in saline solutions ; precipitated like globulins by saturation with sodium chloride or magnesium sulphate.

Hetero-albumose, insoluble in water ; soluble in 0·5—15 per cent. sodium chloride solution in the cold, but precipitated by heating to 65°. Precipitated from its solutions by dialysing out the salt, like globulins. Precipitated by saturation with salts. Proto- and hetero-albumose are often called primary albumoses, because they are the first products of hydration of proteids.

Deutero-albumose, soluble in hot and cold water, not precipitated from its solutions by saturating with sodium chloride or magnesium sulphate, but precipitated by ammonium sulphate, is an intermediate stage in the conversion of the primary albumoses into peptone.

Class 5. *Peptones* are the final product of the hydration of proteids; further hydration splits up the peptone into simpler bodies, which are no longer proteids. The peptones are soluble in water, not coagulated by heat, and are not precipitated by nitric acid, copper sulphate, ammonium sulphate, and a number of other precipitants of proteids. Precipitated, but not coagulated, by alcohol. Precipitated by tannin, picric acid, and other substances. They give the biuret reaction.

Pure peptone may be separated from all other proteids by ammonium sulphate; the solution is then subjected to dialysis in order to remove the sulphate, and the peptone precipitated by alcohol. It may then be dried by washing with absolute alcohol, ether, and finally standing in desiccator over sulphuric acid, a vacuum being maintained in the desiccator by a sprengel or other air-pump. Peptone thus prepared hisses and froths on being dissolved in water with evolution of heat.

Peptone is somewhat cheesy in taste, but not unpleasant. Artificially prepared peptones, as peptonised milk or beef extract, have a bitter taste. This is due, however, to some bitter substance not yet separated; native peptones and albumoses being almost tasteless.

Hemi-peptones are split up by the pancreatic juice into simpler products, as leucine and tyrosine. Antipeptone is not decomposed in this manner.

Both varieties of peptone are readily dialysable; albumoses are only slightly diffusible under similar conditions, while the albumins and globulins are highly colloid.

Class 6. *Coagulated Proteids.—(a)* Coagulated by heat, are insoluble in water, weak acids, and alkalies. Soluble after prolonged boiling in concentrated mineral acids, also in gastric and pancreatic juice with formation of peptones. *(b)* Coagulated by ferments, fibrin from blood, myosin from muscle, casein from milk.

185. Vegetable Proteids.—As previously stated, plants contain a less proportion of proteid matter than animals. They may be found in solution in the sap or juice of plants, or in the solid state in the protoplasm of the plant cells, and in a comparatively dry condition in the ripe seeds. Proteid is often found in granules (aleurone grains). Some of the vegetable proteids are obtainable in a crystalline form. The same classification may be applied to the vegetable proteids as has been adopted for those of animal derivation.

Class 1. *Vegetable Albumins* answer to the same reactions as animal albumins—small quantities are found in wheat and flour.

Class 2. *Globulins.*—Most of the soluble proteids present in plants belong to this class—a small quantity is found in wheat and flour.

Some observers (Weyl and Bischoff) state that they find the proteid matter of wheat to consist largely of a globulin like myosin, but this view is negatived by more recent researches, which go to show that the body so described is another proteid to which the name of gliadin has been given.

A plant-vitellin occurs in aleurone grains, and is distinctly crystalline. Certain vegetable para-globulins (analagous to the globulin of blood-serum) are found in abrus and other seeds.

Class 3. *Albuminates.*—Both acid- and alkali-albumin are readily produced by the action of acids and alkalies on the albumins and globulins of plants.

So-called legumin is alkali-albumin formed by the caustic potash employed in its extraction from plants.

Class 4. *Proteoses* are present in small quantity in wheaten flour: their nature, however, is but little known. Hemi-albumose has been found in aleurone grains, while Martin considers the two proteids of gluten to be forms of phyt-albumose.

Class 5. *Peptones* do not apparently occur in plants. They may be formed from vegetable proteids by boiling with dilute mineral acids, or treatment with gastric or pancreatic juices. Animal proteids are, as a rule, more easily peptonised than those of vegetable origin; thus papain, a vegetable ferment, converts animal proteids into peptones, but carries the change of vegetable proteids no further than proteoses.

Class 6. *Coagulated Proteids.*—Plant albumin and globulin are coagulated by heat. Martin and others argue that certain ferment-actions produce coagulation of vegetable proteids.

186. Albuminoids.—With the proposal to restrict this term to a series of bodies outside the proteid group, it will be well to briefly state the character of albuminoids in this more restricted sense. The tendons of animals contain a body known as "collagen," which is insoluble in water. By the action of dilute acids or boiling water, collagen is transformed into gelatin: the process is one of hydration, represented, according to Hofmeister, by the following equation:—

$$\begin{array}{ccccc} C_{102}H_{149}N_{31}O_{28} & + & H_2O & = & C_{102}H_{151}N_{31}O_{29}. \\ \text{Collagen.} & & \text{Water.} & & \text{Gelatin.} \end{array}$$

The albuminoids, as thus classified, differ from the proteids in that they contain no sulphur. Gelatin is insoluble in cold water, but dissolves in hot, gelatinising, or forming a jelly, on cooling.

187. Proteids of Wheat.—It is a fact too familiar to need experimental demonstration, that the white of egg coagulates on being heated; but it will be found on further experiment, as may in fact be gathered from the preceding description, that if the white of egg be shaken up with considerable quantities of water and then heated, the albumin separates out in coagulated flocks. Similarly on making a cold aqueous infusion of flour, or, still better, of the germ of wheat, and then filtering the solution until perfectly clear, a liquid is obtained which, on being raised to the boiling point, throws down abundant flocks of albumin and globulin. The coagulated proteid thus obtained is as white and pure in appearance as that from the white of egg, and is, to all intents and purposes, identical with that of mixtures of albumin and globulin of animal origin. While the egg albumin always occurs in an alkaline liquid, that of vegetables is always found either in acid or neutral liquids.

Further, every miller and baker knows that flour, on being moistened, forms a stiff, tenacious paste or dough; he also knows that the flour of wheat is distinguished in a remarkable manner from other flours by this character; for oatmeal, when similarly treated, simply produces a damp mass, having little or no tenacity. On kneading a mass of wheaten dough, enclosed within a piece of muslin, with water, until the starch is separated, there remains behind a greyish-white sticky elastic mass, to which the name of "crude gluten" is applied. This substance consists of the insoluble proteids of the wheat, together with a portion of the ash, and also of the oily matter. Although this gluten, when in the flour, existed as a powder, yet, on the addition of water, it thus swells up into a tough mass. Gluten is practically insoluble in water, and without taste; on being dried by exposure to the heat of the hot-water oven, it changes into a hard horny mass. Gluten which has been thus moistened with water, provided it is dried at a low temperature, swells up again on being wetted, although not usually to such a tough mass as when first extracted. Osborne, with whom recently has been associated Voorhees, has for some years been engaged in a systematic investigation of the vegetable proteids; in 1893 they conjointly communicated to the American Chemical Journal an article of great importance on "The Proteids of the Wheat Kernel." This article contains a historical resumé of the work previously done on these compounds, and also includes the results of their own elaborate investigations on wheat proteids, conducted on the lines of the most recent knowledge of the constitution of proteids generally. The following description is very largely based on Osborne and Voorhees' article.

188. Earlier Researches.—After recounting the results of the researches of Taddei, Berzelius, Mulder, Gunnsberg, and others, Ritthausen's conclusions are mentioned, in which that chemist recognised in 1872 that wheat contains five proteid bodies, to which he gave the names of gluten casein, gluten fibrin, plant gelatin or gliadin, mucedin, and albumin. He expressed a doubt as to the presence of albumin, as what was viewed as this body might possibly be a mixture of mucedin and gliadin.

In 1880, Weyl and Bischoff published the view that the proteid matter of wheat is principally a myosin like globulin, which they call vegetable myosin, and, if this view be correct, they further assume that it is from this substance that gluten is derived, other proteids only being present in small quantity. They extracted flour with a 15 per cent. salt solution, and found that the residue yielded no gluten; they consequently assumed that gluten is formed from myosin as a result of a ferment action similarly to the formation of fibrin from fibrinogen. No ferment possessing such properties could, however, be detected. Large quantities of sodium chloride and other salts prevent the formation of gluten in the same way as these salts also prevent the formation of fibrin. On first heating flour with alcohol, they found that subsequently no gluten could be obtained on washing, and so assumed that the myosin had been coagulated. Also, on warming flour for from 48 to 96 hours, keeping the temperature below 60° C., the coagulation point of myosin, and then adding a little unwarmed flour and extracting gluten from the mixture, no gluten is obtained beyond that present in the added flour, showing in Weyl and Bischoff's opinion that the gluten-forming substance had suffered coagulation.

Martin in 1886 examined gluten by extraction with alcohol—he found but one proteid substance so extracted. This body is soluble in hot water, but is insoluble in cold, and so is insoluble phyt-albumose. The residue insoluble in alcohol is uncoagulated proteid, soluble in dilute acids and alkalies; this he terms gluten fibrin. The insoluble phyt-albumose is not present as such in flour, as direct extraction of the meal with 75 per cent. alcohol removes no proteid. Martin concluded that the insoluble phyt-albumose is formed from the soluble by the action of water, the gluten fibrin being formed by a similar action of water on the globulin, that is, conversion into an albuminate. The albuminate and insoluble phyt-albumose together constitute gluten.

Johannsen, 1889, combats the ferment theory of the production of gluten. He found that a normal dough was obtained by grinding dried gluten and mixing with starch, and also by mixing moist gluten with starch.

189. Osborne and Voorhees' Experiments, Wheats Used.—One of these was a Minnesota spring wheat, Scotch Fife, milled under chemical supervision into "patent" flour from finest and purest middlings, and "straights" from the coarser middlings. The "shorts" (red-dog?), chiefly composed of inner portions of the bran, with adhering portions of the endosperm, was also examined. Samples of whole wheat flour were prepared direct from the wheat by grinding in the laboratory when required. A variety of winter wheat, known as "Fultz," was also examined, but only as whole wheat flour. Preliminary investigations showed that all these different flours yielded proteid matter to

Diluted alcohol,
Water,
10 per cent. sodium chloride solution,
And after complete and successive extractions with these reagents, to dilute potash water.

The bodies extracted by these various reagents will be examined separately.

190. Proteids Soluble in Water.—In the course of some preliminary experiments, 200 grams of spring wheat straight flour were mixed with 800 c.c. of distilled water. No coherent gluten formed, the undissolved flour settling down as a non-coherent mass. After a few hours' digestion the solution was filtered; the filtrate was straw-yellow in colour, becoming red-brown on standing, and had a *very* slight acid reaction.

Saturation with ammonium sulphate gave a bulky precipitate, which contracted on standing, showing the solution to contain but little proteid matter. After 24 hours this precipitate was completely soluble in water, giving no evidence of the formation of so-called albuminates. Saturation with sodium chloride gave a small precipitate. Acetic acid in the cold gave no precipitate until sodium chloride was added.

On slowly heating, the solution gave a turbidity at 48° C., and a flocculent coagulation at 52°. After heating to 65° for some time and filtering, the solution became turbid again at 73°, flocks forming in very small amount at 82°. Heating to boiling caused no further separation ; but the addition of a little acetic acid and sodium chloride gave a small precipitate. The body coagulating at 52° formed the greater part of the proteid in solution. The complete coagulation of this required a temperature of 65°, but was greatly facilitated by the addition of sodium chloride.

Further experiments showed that extraction of the flour with 10 per cent. salt (sodium chloride) solution yielded the same proteids, so that the subsequent examination of the water-soluble substances was confined to extracts originally made with 10 per cent. salt solution after separation of the globulins by dialysis.

Again, 4000 grams of straight flour were treated with 8 litres of 10 per cent. brine, allowed to subside over night, and the supernatant liquid filtered off. Another 2 litres of the brine were added to the residue, which was stirred up, allowed to settle, and again filtered. The filtrate was saturated with ammonium sulphate as rapidly as collected. The precipitate thus procured was filtered and redissolved in 10 per cent. brine, filtered clear, and dialysed until the chloride had disappeared. This resulted in the precipitation of a globulin, which was filtered off, and the solution again dialysed for 14 days, but with no further production of globulin.

The globulin-free solution was next examined by slowly heating a portion—turbidity occurred at 48°, flocks separating at 55°. After heating at 65°, the coagulum was filtered off. Further heating resulted in a minute amount of coagulum being formed at 80° : after filtering, there was no further precipitate on boiling, and nothing was obtained by adding a *little* salt and acetic acid. On adding 20 per cent. salt solution and a little acetic acid to the original solution, a precipitate was caused ; another portion was first heated to 65°, and a third to 95°, and filtered before adding the salt solution and acetic acid. The second gave less, and the third least precipitate. The filtrate from the first of these portions, when neutralised and boiled, gave no precipitate, showing that, as was to be expected, the separation of albumin by precipitation with salt and acid was complete.

This globulin-free solution gave a precipitate on saturation with sodium chloride, the filtrate became flocculent at 56°, with no further precipitate on further heating, showing that the higher coagulating proteid had been thus removed. Treatment of the globulin-free solution with nitric acid yielded a precipitate, a portion of which dissolved on heating, the rest remaining insoluble : after filtration, the filtrate deposited a precipitate on cooling, which again dissolved on re-application of heat. The filtrate from the salt and acid precipitate did not give this reaction, which is characteristic of certain proteoses, and shows that the salt and acid precipitate contains a proteose, together with the albumins. Three distinct proteid substances are thus recognised which are soluble in pure water; two coagulable, one at a higher temperature than the other, and presumably both albumins and a proteose.

To make sure that the body, which was apparently an albumin, was not a myosin-like globulin held in solution by the salts naturally present in river water used for dialysis, a strong aqueous solution of winter wheat meal was dialysed into distilled water in the outer vessel. The solution still coagulated at 54°, and contained in 250 c.c. only 0·0008 gram of mineral matter, proving the substance was an albumin.

191. Albumins.—The remainder of the globulin-free solution, after making foregoing tests, was heated to 61°, the precipitate filtered, washed with water, alcohol, absolute alcohol, and ether, dried over sulphuric acid, and heated to 110°; this was called Preparation 1.

A duplicate lot was prepared in the same way, and yielded 6·4 grams from 10,000 grams of flour; this was called Preparation 2.

The filtrate from Preparation 2 was further heated to 75°, and the small amount of precipitate washed with alcohol and dried as before; this was called Preparation 3.

Another preparation was made on the same flour by extracting 10 per cent. brine, and dialysing at once without precipitation by ammonium sulphate. After the separation of the globulins, the albumins were precipitated by at once raising the temperature to 90°; this, after drying, constituted the Preparation No. 4.

Another preparation was made on the spring wheat "shorts," by extracting with 10 per cent. salt solution, treatment with ammonium sulphate, dialysis, coagulating albumin at 65°, and drying; this was Preparation 5.

These substances gave on analysis the following results:—

ANALYSES OF COAGULATED WHEAT ALBUMIN.

	1	2	3	4	5	Average.
Carbon, ...	53·27	53·06	...	53·02	52·71	53·02
Hydrogen, ...	6·83	6·82	...	6·87	6·85	6·84
Nitrogen,	16·95	17·01	16·94	16·26	16·83	16·80
Sulphur, ...	1·27	1·30		1·20	1·34	1·28
Oxygen, ...	21·68	21·81	...	22·65	22·27	22·06
	100·00	100·00	...	100·00	100·00	100·00

These figures agree very closely, except that the nitrogen in No. 4 is low: as four determinations give concordant results, Osborne and Voorhees consider it possible that some of the nitrogen may be lost at the higher temperature.

192. Proteoses.—As already stated, there are found in the solution after separating the globulins by dialysis, and the albumins by heating, small quantities of one or more proteoses which are almost wholly precipitated by saturation with sodium chloride. On concentrating the filtered solution, after the removal of albumins by heat, a coagulum gradually develops, which must be derived from the proteose-like proteid still remaining in solution before concentration.

This body gave on analysis the following figures :—

Carbon,	51·86
Hydrogen,	6·82
Nitrogen,	17·32
Sulphur, Oxygen,	24·00
	100·00

The small quantity of proteose still remaining after removal of the coagulum was not separated for analysis. In analyses quoted later, paragraph 207, the amount of this proteose is seen to be as much or more than that of the coagulum.

193. Globulin.—The extraction of this body has already been referred to: in a direct experiment for the preparation of globulin, 10,000 grams of "straight" flour were extracted with 34 litres of 10 per cent. salt solution, stirred and allowed to stand over night. This was filtered, precipitated by saturation with ammonium sulphate, filtered and again dissolved in 10 per cent. brine. The solution produced was exceedingly viscid, and filtered with extreme difficulty; this was placed in a dialyser and left in a stream of running water until the chlorides were removed. The globulin gradually separated out in minute particles of spheroidal form. The precipitate was filtered, washed with water, alcohol, and ether, dried over sulphuric acid, and then weighed 5·8 grams. Globulin, thus prepared, dissolves in 10 per cent. salt solution, from which it is precipitated by the addition of water. Saturation with sodium chloride gives no precipitate, but saturation with magnesium sulphate, or ammonium sulphate, completely precipitates the globulin. The solution in 10 per cent. brine gives, on slow heating, a very slight turbidity at 87°, which increases slightly up to 99°. Dried at 110°, this globulin constituted Preparation 8.

A preparation was also made in the same way, except that the precipitation with ammonium sulphate was omitted. Again the solution was remarkably viscid, a property possibly due to the presence of gum, for the pure solution of globulin in 10 per cent. brine showed no trace of it, neither did an aqueous solution of the flour. On dissolving up the globulin obtained by dialysis in 10 per cent. salt solution, a residue remains, consisting of an "albuminate" derived from the globulin. This globulin constituted Preparation 9.

The globulin was also extracted from the "shorts," and its total quantity amounted to nearly twice as much as was similarly obtained from a like quantity of flour. This globulin was Preparation 10.

The globulins gave on analysis the following results :—

ANALYSES OF WHEAT GLOBULINS.

	8	9	10	Average.
Carbon, ...	51 07	51·01	51·00	51·03
Hydrogen, ...	6·75	6·97	6·83	6·85
Nitrogen, ...	18·27	18·48	18·26	18·39
Sulphur, ...	23·91	0·71	0·66	0·69
Oxygen, ...		22·83	23·25	23 04
	100·00	100·00	100·00	100·00

In contradistinction to the views held by Weyl and Bischoff, and Martin, Osborne and Voorhees have only found in extracts of wheat meal, either spring or winter wheat, the one globulin just described; which in properties and composition closely resembles those globulins found in other seeds, and assigned to the class of vegetable vitellins.

194. Proteid Soluble in Dilute Alcohol; Gliadin.—Whether wheat flour be extracted direct with dilute alcohol, or after treatment with 10 per cent. salt solution, a considerable amount of proteid is obtained. The same is the case if the previously extracted gluten be subjected to alcohol extraction. Extracts were made by alcohol under all these conditions, and subjected to repeated fractional precipitations, in order to learn whether a single proteid body or a mixture had been obtained.

195. Direct Alcoholic Extraction.—In direct treatment with alcohol, 5000 grams of "straight" flour were extracted with 10 litres of alcohol, 0·90 specific gravity, and allowed to soak over night. The mixture was then stirred, allowed to settle, and the supernatant liquid poured off. Three litres more of alcohol of the same strength were added, and presumably stirred in; after standing, the clear liquid was poured off, and the residue put in a screw press and squeezed nearly dry. The whole of the liquid thus obtained was mixed, and constituted "Extract 1." The residue was again treated with 4 litres of 0·90 alcohol, and once more pressed nearly dry; this liquid was "Extract 2." The same process was twice more repeated, and the two extracts mixed, which gave "Extract 3." Each of the three extracts was filtered clear, and concentrated separately to one-third its volume, and after cooling decanted from the very glutinous viscid mass which had separated. This precipitated mass was in each case dissolved in a small amount of hot alcohol, sp. gr. 0·90, and the solution allowed to cool over night: most of the substance separated on cooling, and the liquid was decanted from it. The solutions were treated with a quantity of distilled water and a little sodium chloride added, the proteid was thus precipitated, washed with water, absolute alcohol, and ether, and dried. The residue was subjected to a series of fractional precipitations based on the principle of partially dissolving with alcohol of 0·820 sp. gr., and precipitating from the solution by the addition of small quantities of sodium chloride solution, which precipitate was washed, dehydrated with absolute alcohol, digested with ether, and dried over sulphuric acid. A portion of the principal fraction was again divided by solution in 250 c.c. of 0·90 alcohol, and partial precipitation by pouring the solution into 800 c.c. of absolute alcohol; precipitate and solution were again treated separately. As the result of a series of fractional precipitations, altogether 13 fractions were prepared and then analysed. These constituted Preparations 11 to 23. The results of the whole series are given by Osborne and Voorhees, but 5 of the fractions are discarded from the final comparison, because of their being impure, for obvious reasons. Some, for example, contain fat, while others have concentrated in them the solid matter which in a series of filtrations has passed through the filter papers. Subjoined is given the results of these various analyses, and the weight of each fraction which was obtained :—

ANALYSES OF "FRACTIONS" OF THE WHEAT PROTEID OBTAINED BY DIRECT EXTRACTION WITH DILUTE ALCOHOL.

	15	16	17	18	19	21	24	25	26
Carbon, ...	52·52	52·77	52·67	52·55	52·74	52·82	...	52·33	52·38
Hydrogen,	6·78	6·78	6·70	6·85	6·77	6·81	..	6·91	7·13
Nitrogen, ...	17·64	17·77	17·66	17·94	17·62	17·67	17·69	17·70	17·82
Sulphur, ...	1·08	1·26	1·22	1·21	1·23	1·11	...	23·06	22·67
Oyxgen, ...	21·98	21·42	21·75	21·45	21·64	21·57			
	100·00	100·00	100·00	100·00	100·00	100·00	...	100·00	100·00
Weight of fraction in grams	12·40	8·60	32·26	5·34	17·43	63·0	...		

Nos. 24, 25, 26 are fractional re-precipitations of fraction No. 21.

A study of this series of analyses shows that the whole of the fractions are in remarkable agreement, and that no fractional separation of the extracted proteid has been effected. For example, Nos. 15 and 16, which are aqueous solutions, have the same composition as those from solution in 0·820 alcohol, and also as the residue remaining after treatment with these reagents. Osborne and Voorhees draw the conclusion that it may be safely concluded that wheat contains but one proteid soluble in dilute alcohol. The total amount of proteid contained in the whole of these preparations is 207·83 grams, being equal to 4·16 per cent. of the flour.

196. Alcoholic Extraction after Salt Solution Extraction.—For this purpose 4000 grams of "straight" flour were taken, extracted with 10 per cent. salt solution so long as anything was removed, and then the residue squeezed as dry as possible in a screw-press This residue was then treated with alcohol of such a strength as to yield with the water retained in the flour as nearly as possible a solution containing 75 per cent. of alcohol. Digestion with this solvent was continued for two days; the extract was squeezed in a press, and the process repeated three times, giving altogether four extracts. These were concentrated to small bulk, and the solution decanted from the separated mass, which was washed with distilled water, re-precipitated by sodium chloride, washed with absolute alcohol, digested with ether, and dried over sulphuric acid. The precipitates obtained from the water washings by adding salt were treated in the same way. The total weight of these preparations was 157·45 grams, equal to 3·94 per cent. of flour, as against 4·16 per cent. obtained by direct extraction, showing that the dilute alcohol extract is different and distinct from the proteids soluble in water. These constituted Preparations 27—31. The following table gives the result of their analyses:—

ANALYSES OF "FRACTIONS" OF WHEAT PROTEID OBTAINED BY EXTRACTION WITH DILUTE ALCOHOL AFTER SODIUM CHLORIDE EXTRACTION.

	27	28	29	30	31
Carbon, ...	52·69	52·72	52·71	...	52·65
Hydrogen, ...	6·84	6·86	6·81	...	6·83
Nitrogen, ...	17·73	17·89	17·75	17·08	17·79
Sulphur, ...	1·02	0·95	1·10	...	1·08
Oxygen, ...	21·72	21·58	21·63	...	21·65
	100·00	100·00	100·00	...	100·00
Weight of fraction in grams, ...	82·0	57·0	11·3	1·35	5·8

Nos. 27-30 are the precipitates obtained from the four extracts; No. 31 is obtained from the water washings of 27 and 28.

The results of these analyses agree very closely among themselves, and also with the series obtained by direct alcoholic extraction.

197. Extraction of Gluten with Dilute Alcohol.—For the preparation of gluten, 2000 grams of "straight" flour were made into dough with distilled water at 20°, and then washed in a stream of river water at 5° C. When nearly the whole of the starch had thus been removed, the gluten was chopped fine and digested with alcohol of 0·90 sp. gr. at a temperature of about 20°. This extraction was repeated with fresh portions of alcohol of the same strength so long as anything was removed. The extracts were united, filtered clear, and evaporated down to one-fourth their original volume This was allowed to stand over night, and the supernatant liquid decanted from the separated proteid. This latter was then dehydrated with absolute alcohol. The original mother-liquor from which the proteid had separated, and also the absolute alcohol used for dehydrating, were each precipitated by a small quantity of sodium-chloride solution. The three products were united, digested with absolute alcohol, and then with absolute ether. After drying over sulphuric acid, the Preparation No. 32 weighed 82·0 grams, and formed 4·10 per cent. of the flour taken. In order to determine whether this substance was a single proteid or a mixture of more than one, the process of fractional precipitation was again employed. Thirty grams of Preparation 32 were dissolved in 0·90 alcohol, concentrated to small volume, and then strong alcohol added till about half the substance taken had been precipitated. The precipitate was treated with absolute alcohol, dried over sulphuric acid, and found to weigh 12 grams; this constituted Preparation 33. The solution was precipitated with water, dehydrated and dried over sulphuric acid; it weighed 16 grams, and was marked Preparation 34. These substances had the following composition:—

ANALYSES OF "FRACTIONS" OF THE WHEAT PROTEID OBTAINED BY EXTRACTION OF GLUTEN WITH DILUTE ALCOHOL.

	32	33	34
Carbon, ...	52·58	52·68	52·84
Hydrogen, ...	6·67	6·78	7·18
Nitrogen, ...	17·65	17·65	17·57
Sulphur, ...	1·08	1·09	22·41
Oxygen, ...	22·02	21·80	
	100·00	100·00	100·00

In this case also the analyses show clearly that no separation into proteids of differing composition had thus been effected.

198. Extraction of "Shorts" with Dilute Alcohol.—In order to determine whether the "shorts" or bran flour yielded the same body to dilute alcohol, 2000 grams were taken and subjected to much the same process of extraction as was flour, except that greater precautions were necessary in order to remove impurities. Two Preparations, Nos 36 and 37, were obtained, which had the following composition:—

ANALYSES OF FRACTIONS OF WHEAT PROTEID OBTAINED BY EXTRACTION OF "SHORTS" WITH DILUTE ALCOHOL.

	36	37
Carbon, ...	52·85	52·74
Hydrogen, ...	6·81	6·87
Nitrogen, ...	17·48	17·67
Sulphur, ...	22·86	22·72
Oxygen, ...		
	100·00	100·00

A comparison of these figures with those which have preceded shows that the proteid extracted from the bran has a similar composition to that obtained from the flour.

199. Extraction of Whole Wheat Meal with Dilute Alcohol.—In view of the fact that Ritthausen, and probably others, employed whole wheat meal in their investigations of the composition of wheat proteids, Osborne and Voorhees decided to make some experiments on wheat meals, in addition to those previously described. Accordingly, 1000 grams of freshly ground whole spring wheat meal were taken, made into a dough, and the gluten extracted. This was chopped fine, thoroughly extracted with 0·90 alcohol, the extract concentrated, and the proteid separated by cooling. This deposit was dissolved as far as possible in dilute alcohol, and the insoluble substance washed with absolute alcohol, and ether, and dried over sulphuric acid. This was Preparation 38. The solution was precipitated with absolute alcohol, dried as usual, and constituted Preparation 39; the filtrate from this was concentrated to small volume, poured into absolute alcohol, and the precipitate washed and dried as before, giving Preparation 40.

In a similar manner, Preparations were made from winter wheat meal; the coagulated proteid was labelled 41, and that obtained by further digestion, 42. These had the following composition:—

ANALYSES OF WHEAT PROTEIDS OBTAINED BY EXTRACTION OF WHOLE WHEAT MEAL WITH DILUTE ALCOHOL.

	Spring Wheat.			Winter Wheat.	
	38	39	40	41	42
Carbon, ...	52·90	52·89	53·16	52·82	52·68
Hydrogen, ...	6·99	6·87	6·83	6·88	6·81
Nitrogen, ...	17·52	18·06	17·75	17·55	17·63
Sulphur, ...	1·43	0·92	0·96	22·75	22·88
Oxygen, ...	21·16	21·26	21·30		
	100·00	100·00	100·00	100·00	100·00

Throughout the whole series there is no essential difference in composition, nor in physical properties; nor was the proteid altered in composition by solution in dilute caustic potash, and re-precipitation by an equivalent quantity of hydrochloric acid; neither, so far as it could be observed, was its solubility altered.

The composition of this proteid, as obtained by averaging the preceding figures, is the following:—

Carbon, ...	52·72
Hydrogen, ...	6·86
Nitrogen, ...	17·66
Sulphur, ...	1·14
Oxygen, ...	21·62
	100·00

200. Properties of Proteid extracted by Dilute Alcohol.—If this proteid be dehydrated by absolute alcohol, and thoroughly dried over sulphuric acid, it forms a snow-white friable mass easily reduced to powder. When dried from weak alcohol or water, it forms an amorphous transparent substance, closely resembling pure gelatin in appearance, being, however, rather more brittle than that body. In the cold, distilled water turns the substance sticky, and a part dissolves. As the water is warmed, the degree of solubility increases, and with boiling, a considerable quantity goes into solution. A portion of this is re-deposited on cooling. **The solution in pure water is instantly precipitated by adding a very minute amount of sodium chloride.** In absolute alcohol this proteid is perfectly insoluble, but dissolves on the addition of water, being very soluble in 70 to 75 per cent. alcohol. From alcoholic solutions, minute quantities of salt readily precipitate the proteid. Exceedingly dilute acids and alkalies readily dissolve this proteid, which is again precipitated apparently unchanged in appearance and composition by neutralisation.

This proteid has been obtained in a more or less pure form by earlier observers; Taddei first gave it the name of "gliadin." Ritthausen and others assumed that it consisted of a mixture of two or more substances, to which the names of mucin or mucedin, and gliadin or vegetable gelatin have been given. Among recent observers, Martin found in gluten only one proteid soluble in dilute alcohol, to which he gave the name of "insoluble phyt-albumose," but, curiously enough, stated that flour extracted direct with 76 to 80 per cent. alcohol yielded no soluble proteid. This is in direct opposition to the results of Osborne and Voorhees, and also, it may be added, to those of the author of the present work, who, prior to seeing Osborne and Voorhees' paper, made a series of analyses of various flours, in which a direct gliadin estimation by alcohol was included. These results are given in Chapter XXIII. Osborne and Voorhees adopt **gliadin as the original and appropriate name for the wheat proteid soluble in dilute alcohol.** They point out that gliadin is absolutely distinct in properties and composition from the alcohol-soluble proteids obtained from the kernel of oats and maize.

201. Proteid Insoluble in Water, Saline Solutions, and Alcohol; Glutenin.—After treatment with the series of previously described solvents, a proteid body remains in wheat flour and gluten, which is soluble only in dilute acids and alkalies. **This proteid being especially characteristic of gluten, Osborne and Voorhees have given it the name Glutenin.**

In the following accounts of extraction of glutenin, it is throughout understood that the separations are made on flour or meal which has previously been exhausted with one or more of the following solvents:—Water, 10 per cent. salt solution, and dilute alcohol.

202. Extraction of Glutenin from "Straight" Flour after Treatment with Brine and Dilute Alcohol.—After completely exhausting 4000 grams of straight flour successively with 10 per cent. brine and 0·90 sp. gr. alcohol, the residue was extracted twice with 0·1 per cent. potash solution. The residual proteid was soluble in this, and after standing three days at a temperature of 5°, with frequent stirring, the extract was filtered off and allowed to stand in a cold room until most of the finer solid impurities had subsided. The still turbid solution was then decanted and neutralised with 0·2 per cent. hydrochloric acid, thereby producing a precipitate which subsided rapidly, leaving a milky filtrate. This precipitate was redissolved in the dilute potash, allowed to stand in order to deposit impurities, and again precipitated with 0·2 per cent. hydrochloric acid. The proteid was washed with water, dilute alcohol, absolute alcohol, and ether. This preparation was found to be far from pure, and accordingly a portion of it was again dissolved in 0·2 per cent. potash, and repeatedly filtered through very dense filter paper till perfectly clear. As this filtration proceeded very slowly the operation was conducted in a refrigerator at a temperature near 0° C. Two successsive portions of the filtrate obtained were reprecipitated with 0·2 per cent. hydrochloric acid, washed with water, alcohol, ether, and dried over sulphuric acid, and then at 110°. These gave Preparations 45 and 46. It was found absolutely necessary to filter the potash solution *perfectly clear*, as otherwise considerable amounts of non-nitrogenous matter are subsequently carried down with the precipitate.

203. Extraction of Glutenin after Treatment of Dough with Water and Exhaustion with Dilute Alcohol.—A dough was made with 2000 grams of spring wheat "straight" flour and distilled water; this was washed with river water till freed so far as possible from starch. The gluten was exhausted with 75 per cent. alcohol, and the insoluble residue dissolved in 0·15 per cent. potash solution, and allowed to stand in a cold room for 48 hours. The solution was decanted, precipitated with dilute hydrochloric acid, washed thoroughly with water, absolute alcohol, and ether. It was then again dissolved in 0·1 per cent. potash, allowed to stand over night, filtered till perfectly clear, and a part of the filtrate precipitated by neutralising with 0·2 per cent. hydrochloric acid. This precipitate and dried as usual, and constituted Preparation 48.

Another lot of gluten was prepared in the same way from 1000 grams of "straight" flour, extracted with alcohol and then dissolved in potash water. After standing this was precipitated by adding acetic acid to slightly acid reaction. The precipitate was washed with water, alcohol, and ether, and again dissolved in potash water, reprecipitated with hydrochloric acid, and again washed and dried as usual over sulphuric acid. A pure white light mass was obtained, which was marked Preparation 51.

In order to determine whether the proteid lost any nitrogen by prolonged solution in potash water, another lot of gluten was similarly treated, and the potash solution kept in an ice-chest for 20 hours, and then precipitated and treated in the usual manner. This constituted Preparation 52, and had evidently lost but exceedingly little nitrogen.

204. Extraction of Glutenin after Direct Exhaustion of Flour with Alcohol, Water Treatment Omitted.—Another preparation was made by extracting 200 grams of spring patent flour with large quantities of alcohol of 0·90 sp. gr., then washing the flour with absolute alcohol and drying and air-drying. The dry flour was then made into a dough, which possessed considerable coherence, showing that the proteid insoluble in alcohol has an important function in dough production. The dough was washed on a hair-sieve under a stream of water, but yielded no coherent gluten. The washings were allowed to settle, and the sediment treated with 0·2 per cent. potash. After standing, the supernatant liquid was decanted, precipitated with dilute hydrochloric acid, and the precipitate allowed to settle. It was then again dissolved in dilute potash, filtered perfectly clear while in the ice chest, reprecipitated, and washed and dried in the usual manner. This constituted Preparation 56.

Another experiment was made by direct alcohol treatment, in which 1000 grams of "straight" flour were exhausted with 0·90 alcohol, and the residue squeezed in a screw-press. This was then extracted with 0·2 per cent. potash, but filtration was impossible owing to the gummy nature of the liquid. An equal volume of alcohol, sp. gr. 0·820, was then added, and after long standing a comparatively clear yellow solution was syphoned off and filtered clear. This was precipitated with hydrochloric acid, and the precipitate filtered off and again dissolved in potash, filtered perfectly clear, reprecipitated, washed with water, dilute and then absolute alcohol, and ether. This yielded Preparation 57, the analysis of which shows that the same proteid is extracted by potash water from the flour which has not been in contact with water as was obtained in other experiments.

205. Extraction of Glutenin from Gluten of Whole Wheat Flour.—A dough was made from 1000 grams of whole spring wheat meal, washed till free from starch, and the gluten exhausted with dilute alcohol. The residue was dissolved in dilute potash, allowed to stand, decanted, reprecipitated, and the precipitate washed with water, dilute alcohol, absolute alcohol, and ether, and then re-dissolved in 0·2 per cent. potash water. This was filtered perfectly clear, and precipitated and treated in the usual way. The dry proteid was Preparation 58.

A preparation was made in the same manner from whole winter wheat meal, which constituted Preparation 60. In the following table, analyses are given of the whole of the glutenin preparations which have been described.

ANALYSES OF PROTEID OF WHEAT SOLUBLE ONLY IN DILUTE ACIDS AND ALKALIES—GLUTENIN.

	45	46	48	51	52	56	57	58	60
Carbon, ...	52·29	...	52 32	52·54	52·38	...	52·19	52·19	52·03
Hydrogen,	6·61	...	6·82	6·85	6·81	...	6·92	6·93	6·83
Nitrogen, ..	17·41	17·33	17·61	17·46	17·59	17·20	17·56	17·45	17·48
Sulphur, ...	0·94	...	23·25	1·07	1·24	...	23·33	23·43	23·66
Oxygen, ...	22·75	...		22·08	21·98	...			
	100·00	...	100·00	100·00	100·00	...	100·00	100·00	100·00

206. Properties of Glutenin.—The characteristic reactions of glutenin, owing to its comparative insolubility, are not numerous. A minute quantity is dissolved by cold water, and more on slightly warming. Diluted alcohol also dissolves a small quantity of proteid in the cold, and a larger quantity on boiling, which again precipitates as the liquid cools. It is just possible that this is due to the presence of traces of gliadin, but in face of the very careful exhaustion by alcohol previous to preparation of glutenin, it is more probable that glutenin itself is slightly soluble both in warm alcohol and warm water.

When freshly precipitated and hydrated, glutenin is soluble in 0·1 per cent. potash solution, and 0·2 per cent. hydrochloric acid. In this condition it is also soluble in the slightest excess of sodium carbonate solution or ammonia. After drying over sulphuric acid, it becomes rather less soluble in all these reagents. On comparing the analyses of gliadin and glutenin, a very close agreement is observed. It is well known that many proteids pass readily into conditions in which their solubility is changed without any alteration in their composition, capable of detection by analysis. Glutenin may therefore be considered as an altered form of gliadin, in which the solubility has been changed in much the same way as in the case of albuminates derived from the globulins. Osborne and Voorhees are of opinion that gluten is made up of two forms of the same proteid, one being soluble in cold dilute alcohol, and the other not soluble.

207. Amount of the various Proteids contained in Wheat.—The percentage of each proteid present in whole-wheat meal was determined by an analysis on 1000 grams of meal from spring and winter wheats respectively. The following is an outline of the analytic method adopted, which was the same in each case. To 1000 grams of the fine meal were added 4000 c.c. of 10 per cent. salt solution, and the extract filtered; 2500 c.c. of clear extract were obtained from the spring meal, and 2600 from the winter wheat meal. As 100 c.c. of solution were used to each 25 grams of flour,

2500 c.c. = extract from 625 grams spring meal, and
2600 c.c. = „ 650 „ winter meal.

The extracts were dialysed for five days, at the end of which time they were free from chloride. The precipitated globulin was filtered, washed with distilled water, alcohol, absolute alcohol, and ether, and dried at 110°. The following weights were obtained:—

3·8398 grams = 0·624 per cent. globulin in spring wheat.
3·9265 „ = 0·625 „ „ winter „

The filtrates from the globulin were heated to 65°, and the coagula formed at that temperature removed by filtration, washed as usual, dried at 110°, and weighed with the following results:—

1·9714 grams = 0·315 per cent. No. 1 albumin in spring wheat.
1·9614 „ = 0·302 „ „ winter „

The filtrates from these were heated to boiling, and the second coagula similarly treated. The weights obtained were:—

0·4743 grams = 0·076 per cent. No. 2 albumin in spring wheat.
0·3680 ,, = 0·057 ,, ,, winter ,,

The filtrates were evaporated nearly to dryness, and two crops of coagulated proteid removed, washed, dried, and weighed—together they amounted to :—

1·6886 grams = 0·269 per cent. coagulum in spring wheat.
1·4516 ,, = 0·223 ,, ,, winter ,,

The filtrates from the coagula were next again evaporated to a syrup, and, as no insoluble matter separated, were precipitated by pouring into strong alcohol, the precipitates were washed, dissolved in water and reprecipitated, washed with absolute alcohol and ether, and dried at 110°. They were evidently very impure, and the amount of proteid present in each was estimated by determining the nitrogen and multiplying by 6·25. They gave in this way the following results :—

1·3297 grams = 0·213 per cent proteose and peptone in spring wheat.
2·8063 ,, = 0·432 ,, ,, ,, winter ,,

Collecting these figures, the sodium-chloride solution contained the following amounts of proteid matter :—

	Spring Wheat.	Winter Wheat.
Globulin, ...	0·624 per cent.	0·625 per cent.
Two Albumins together,	0·391 ,,	0·359 ,,
Coagulum, ...	0·269 ,,	0·223 ,,
Proteose, ...	0·213 ,,	0·432 ,,
Total, ...	1·497 ,,	1·639 ,,

The remainder of the proteid matter constitutes the gluten, and was determined in the following manner—200 grams of each meal were made into a dough, and washed free from starch. The wet gluten, freed from adhering moisture, was then weighed, and exactly one half dried at 110° to constant weight.

Spring wheat yielded 12·685 per cent. dry gluten.
Winter ,, 11·858 ,, ,,

The other half of the gluten was cut up fine, and extracted with alcohol of 0·90 sp. gr. The extract was concentrated, and the precipitated proteid extracted with ether and dried at 110°. Reckoned on the whole meal,

Spring wheat gluten yielded 4·3379 per cent. gliadin.
Winter ,, ,, 4·2454 ,, ,,

The residues, after exhaustion with alcohol, were then dried at 110° and weighed. Reckoned on the whole meal,

Spring wheat gluten yielded 7·800 per cent. matter insoluble in alcohol.
Winter ,, ,, 7·504 ,, ,, ,,

Nitrogen determinations were then made in the following bodies—the whole meal insoluble alcohol residues, dried gluten, and the sediments of the water used for washing out gluten, after being washed with strong alcohol, dried and weighed. The following is the tabulated result of the various determinations :—

PROXIMATE ANALYSIS OF PROTEIDS OF WHEAT.

	Spring.	Winter.
Total nitrogen in the meal, ...	1·950 per cent.	1·940 per cent.
Total gluten in the meal,... ...	12·685 ,,	11·858 ,,
Part of gluten insoluble in alcohol,	7·800 ,,	7·504 ,,
Per cent. of nitrogen in gluten, ...	12·010 ,,	12·000 ,,
Total nitrogen in gluten in per cent. of flour, ...	1·5222 ,,	1·4230 ,,
Total nitrogen in residue of gluten insoluble in alcohol, ...	0·8245 ,,	0·7346 ,,
Total nitrogen extracted by alcohol,	0·6977 ,,	0·6884 ,,
Gliadin (N × 5·68, assuming 17·60 per cent. of N in gliadin), ...	3·9630 ,,	3·9100 ,,
Gliadin by direct weighing, ...	4·3379 ,,	4·2454 ,,
Nitrogen in sediment from washing gluten, ...	0·2239 ,,	0·1552 ,,

	SPRING WHEAT.		WINTER WHEAT.	
	Nitrogen.	Proteid.	Nitrogen.	Proteid.
Glutenin, ...	0·8245 × 5·68 =	4·683	0·7346 × 5·68 =	4·173
Gliadin, ...	0·6977 × 5·68 =	3·963	0·6884 × 5·68 =	3·910
Globulin, ...	0·1148 =	0·624	0·1148 =	0·625
Albumin, ...	0·0657 =	0·391	0·0603 =	0·359
Coagulum, ...	0·0453 =	0·269	0·0379 =	0·223
Proteose, ...	0·0341 =	0·213	0·0791 =	0·432
From Water Washings of Gluten, ...	0·2239 × 5·68 =	1·272	0·1552 × 5·68 =	0·881
Total, ...	2·0050	11·415	1·8703	10·603
Meal, ...	2·10 × 5·68 =	11·93	1·94 × 5·68 =	10·96

Inspection of the above figures shows that the gliadin by direct weighing agrees fairly well with that estimated from a nitrogen determination. The residue insoluble in alcohol is, however, very much more than the true glutenin: thus, in the spring wheat the insoluble residue weighed 7·80 per cent. of the meal, whereas the glutenin calculated from nitrogen amounted to only 4·683, leaving 3·117 of foreign matter in the residue insoluble in alcohol. The total proteid agrees in each case very closely with the whole found by direct estimation on the meal.

208. The Formation of Gluten.—So far as is known, wheat is the only plant whose seeds contain proteids in such a form as to enable them to be separated in a coherent mass from the other constituents by washing with water. Osborne and Voorhees have examined very carefully the views promulgated on this point by previous observers; prominent among these is the "ferment" hypothesis of Weyl and Bischoff, who, as previously stated, considered the proteids of wheat meal to consist principally of a globulin very similar in character to myosin, and which they therefore termed "vegetable myosin." This they regarded as the mother-substance of gluten, which on the addition of water is changed by a ferment, hitherto unisolated, into gluten, "as other proteids, if present at all, exist only in small amount" (Weyl and Bischoff). The exhaustive analyses previously quoted show that globulin and also gliadin form only about half the total proteid of the grain. Osborne and Voorhees point out that gliadin is extracted in similar quantity from dry flour direct by alcohol, as is yielded after treatment with 10 per cent. sodium chloride solution, or by direct extraction of the previously washed out gluten. Weyl and Bischoff state that with the aid of a 15 per cent. salt solution the flour was extracted till no proteid could be detected in the extract; the residue of the meal kneaded with water then gave no gluten. "*If the globulin substance is extracted, no formation of gluten takes place.*" Osborne and Voorhees confirm this if the flour is stirred up with a large quantity of salt solution, and then extracted repeatedly with fresh quantities of the solution. But they say, "If, however, wheat flour is mixed at first with just sufficient salt solution to make a firm dough, this dough may then be washed indefinitely with salt solution, and will yield gluten as well and as much as if washed with water alone."

This statement alone is scarcely a sufficient disproof of Weyl and Bischoff's position. In a firm dough made with 15 per cent. salt solution, the quantity of salt will only amount to 5 per cent. of the dough. As nothing has been removed in the act of making dough, it may be reasonably claimed that this quantity of salt is insufficient to prevent the ferment performing its function, and thus producing gluten; while further, the gluten once formed is able to withstand the action of the salt solution which is unable to decompose it. Osborne and Voorhees go on to state that "when large quantities of salt solution are applied at once, the flour fails to unite to a coherent mass, and cannot afterwards be brought together." This action of salt solution in large quantities is explained by subsequent experiments, in which it is shown that such solution materially modifies the adhesive nature of gliadin.

Weyl and Bischoff's experiment in which they extracted the flour with 90 per cent. alcohol is scarcely conclusive, because according to both hypotheses this would result in the non-formation of gluten. In the one case globulin would be coagulated, and in the other gliadin would be removed, and so according to both reasoners no gluten could be produced.

More recently, Martin has advanced a somewhat similar theory of gluten formation; he finds one proteid in gluten soluble in alcohol, and in hot water, but not in cold, which proteid he calls an insoluble phyt-albumose. The gluten is termed by him "gluten-fibrin." Martin next inquires: Does flour contain gluten-fibrin? Does it contain insoluble phyt-albumose? He states that the first question cannot be answered directly, and that, if phyt-albumose originally existed in the flour, it should be extracted by 76-80 per cent. alcohol, which, however, extracts only fat. There is here direct conflict of experimental evidence, as the analyses previously quoted show that considerable quantities of a proteid are thus extracted. Martin next points out that 10 per cent. sodium chloride solution extracts a large quantity of globulin of the myosin type and of albumose. Osborne and Voorhees consider that Martin has made the mistake of taking albumin for a myosin-like globulin, and, owing to the voluminous nature of the body when coagulated, have been misled as to its amount. Martin further looks upon the insoluble albumose as formed from the soluble, and that the globulin is transformed into gluten-fibrin. That a body should be obtained from a solution of globulin, which gave the same reactions as gluten-fibrin, is not surprising, as so-called albuminates, having no characteristic reactions, are derived from nearly all globulins. Martin tabulates his theory as follows :—

$$\text{Gluten} = \begin{cases} \text{Gluten-fibrin} & \text{—precursor, globulin.} \\ \text{Insoluble albumose—} & \text{,, \quad soluble albumose.} \end{cases}$$

Osborne and Voorhees cannot admit this theory, because it is founded on two erroneous observations : 1st. that 80 per cent. alcohol does not extract proteid from flour ; 2nd. that at least one half the proteid of the seed is a myosin-like globulin

Osborne and Voorhees conclude that no ferment action is involved in the formation of gluten, and that it contains but two proteid substances, glutenin and gliadin, and that these exist in the wheat kernel in the same form as in the gluten, except that in the latter they are combined with about thrice their weight of water. This opinion is based on the following reasons :—

1st. Alcohol extracts the same gliadin in the same amount, whether applied directly to the flour, to the gluten, or to the flour previously extracted with 10 per cent. sodium chloride solution.

2nd. Dilute potash solution extracts glutenin of uniform composition and properties from flour which has been extracted with alcohol, or with 10 per cent. sodium chloride solution and then with alcohol, as it extracts from gluten which has been exhausted with alcohol.

Viewed as a refutation of the ferment theory, the weak point of this statement is that in order to prepare gliadin the flour is in all cases treated with water, as even the alcohol used contains water to the extent of 30 per cent. (although extraction with 70 per cent. alcohol is a condition the reverse of favourable to ferment action). The advocates of the ferment theory might adduce the fact that small quantities of ferment substance are capable of changing very large quantities of the body on which they act, and further might suggest that the small quantity of globulin which is removed by treatment with sodium chloride solution is the ferment in question. It is well known that flour contains a diastase precipitated by alcohol, which presumably belongs to the albumins or globulins : it is therefore conceivable that among the globulin, albumin, and indefinite proteoses of wheat, a ferment may exist capable in the presence of water of producing gliadin from some other pre-existing substance. It is difficult, however, to prove a negative, and the onus of proving the existence of ferment action lies rather with those who are advocates of that hypothesis than with those who view it as unnecessary. Osborne and Voorhees, without actually absolutely disproving the existence of a gluten-ferment, account rationally and scientifically for the production of gluten on the assumption of the pre-existence of its constituents as such in the grain ; the balance of evidence is certainly at present strongly in favour of the latter hypothesis.

The following experiments are adduced to show that both glutenin and gliadin are necessary for the production of gluten. A portion of flour was washed free from gliadin by alcohol of 0·90 sp. gr., and next with stronger alcohol, and finally with absolute alcohol, and air dried. The residue made a tolerably coherent dough, but much less tough and elastic than that obtained from the untreated flour. On washing this dough most carefully, not a trace of gluten could be obtained.

In another experiment 7·5 grams of finely ground air-dried gliadin were mixed with 70 grams of starch, and distilled water added. A plastic dough was formed, but it had no toughness. On adding a little 10 per cent. sodium chloride solution the dough became tough and elastic. This was washed with great care with cold water, a little salt solution being added from time to time; no gluten was, however, obtained.

The following experiment shows that additional gluten is formed when glutenin is present, by the adding of gliadin. Two portions of 100 grams each of flour were taken, and to one of them 5 grams of gliadin added. Both were made into dough with the same quantity of water. The two doughs exhibited considerable differences, that containing the extra gliadin being the yellower and tougher of the two. Gluten was extracted from each by washing, after which each was weighed in the wet condition, that containing the added gliadin weighed 44·55 grams, and the other 27·65 grams. On drying at 110° the yield of dry gluten was respectively 15·41 grams and 9·56 grams ; the difference being 5·85 grams, which amount more than covers the added gliadin.

On heating finely ground air-dried gliadin with a small quantity of distilled water, a sticky mass is formed which, on the addition of more distilled water, forms a turbid solution. But, if to the gliadin moistened with distilled water a very dilute solution of salt in distilled water is added, the gliadin is changed into a very coherent viscid mass which adheres to everything it touches, and can be drawn out into long threads. Treatment of gliadin with 10 per cent. salt solution, first to moisten it, and afterward in larger quantity, serves to cause the substance to unite in a plastic mass which can be drawn out into sheets and strings, but is not adhesive. This explains the non-success of Weyl and Bischoff's experiment before referred to. The gliadin is the binding material which causes the particles of flour to adhere together, thus forming a dough. But the gliadin alone is not sufficient to form gluten, for it yields a soft and fluid mass which breaks up entirely on washing with water. The insoluble glutenin is probably essential as affording a nucleus to which the gliadin adheres, and from which it is not mechanically carried away by the wash water.

209. Summary.—The following are the properties and composition of the proteids of the wheat grain :—

1. A *globulin*, belonging to the vegetable vitellins, soluble in saline solutions, precipitated therefrom by dilution, and also by saturation with magnesium sulphate or ammonium sulphate, but not by saturation with sodium chloride. Partly precipitated by boiling, but not coagulated at temperatures below 100°. The grain contains between 0·6 and 0·7 per cent. of globulin.

2. An *albumin*, coagulating at 52°, which differs from animal albumin in being precipitated on saturating its solutions with sodium chloride, or with magnesium sulphate, but not precipitated by completely removing salts by dialysis in distilled water. The grain contains between 0·3 and 0·4 per cent. of albumin.

3. A *proteose*, precipitated (after removing globulin by dialysis, and the albumin by coagulation) by saturating the solution with sodium chloride, or by adding 20 per cent. of sodium chloride and acidulating with acetic acid. Separates as a coagulum on concentrating the solution, and thus yields about 0·3 per cent. of the grain.

The solution from this coagulum still contained a proteose-like body which was not obtainable in a pure state. By indirect methods it is assumed to amount to from 0·2 to 0·4 per cent. of the grain. Both these substances, the coagulum and the proteose-like body, are derivations of some other proteid in the seed, presumably the proteose first mentioned.

4. *Gliadin*, soluble in dilute alcohol, and soluble in distilled water to opalescent solutions, which are precipitated by adding a little sodium chloride. Completely insoluble in absolute alcohol, but slightly soluble in 90 per cent. alcohol, and very soluble in 70—80 per cent. alcohol, and is precipitated from these solutions on adding either much water or strong alcohol, especially in the presence of much salts; soluble in very dilute acids and alkalies, precipitated from these solutions by neutralisation, unchanged in properties and composition. The formation of gluten is largely dependent on this proteid. The grain contains about 4·25 per cent. of gliadin.

5. *Glutenin*, a proteid insoluble in water, saline solutions, and dilute alcohol, which forms the remainder of the proteids of the grain. Soluble in dilute acids and alkalies, and re-precipitated from such solutions by neutralisation.

The following is the composition of these bodies:—

ANALYSES OF PROTEIDS OF WHEAT.

	Globulin.	Albumin.	Coagulum.	Gliadin.	Glutenin.
Carbon, ...	51·03	53·02	51·86	52·72	52·34
Hydrogen, ...	6·85	6·84	6·82	6·86	6·83
Nitrogen, ...	18·39	16·80	17·32	17·66	17·49
Sulphur, ...	0·69	1·28	24·00	1·14	1·08
Oxygen, ...	23·04	22·06		21·62	22·26
	100·00	100·00	100·00	100·00	100·00

Wheat gluten is composed of gliadin and glutenin, both being necessary for its formation. Gliadin forms with water a sticky medium which, by the presence of salts, is prevented from becoming wholly soluble. This medium binds together the particles of flour, rendering the dough and gluten tough and coherent. Glutenin imparts solidity to the gluten, and forms the nucleus to which gliadin so adheres that it cannot be washed away with water. Gliadin and starch form a dough which yields no gluten, as the gliadin is washed away with the starch. Flour freed from gliadin gives no gluten, as there is no binding material to hold the particles together so that they be brought into a coherent mass.

Soluble salts are also necessary in forming gluten, as in distilled water gliadin is readily soluble. The mineral constituents of the flour are sufficient for this purpose, as gluten can be obtained by washing a dough in distilled water.

No ferment action occurs in the formation of gluten, for its constituents are found in the flour having the same composition and properties as in the gluten, even under those conditions which would be supposed to completely remove antecedent proteids, or to prevent ferment-action. All the phenomena which have been attributed to ferment-action are explained by the properties of the proteids themselves, as they exist in the seed and in the gluten.

The conclusions of Osborne and Voorhees agree well with the following opinions on a gluten-ferment expressed by the present author in a previous work on this subject :—" The existence of this body cannot as yet, however, be recognised as proved. While the formation of gluten may be due to the intervention of such a body, yet there is nothing remarkable in considering it to be a simple and direct hydration, by water, of the gluten compounds existent in the grain. The effect of heating the flour, and of treatment with salt solution, are fairly accounted for by their well-known coagulating action on the albuminous matters. So, too, those wheats whose flours hydrate slowly are grown under conditions which favour the proteids being in a difficultly soluble condition."

210. Proteids of the Oat-Kernel.—For purposes of comparison the following statement by Osborne of the composition of the proteids of oats is given. When oat-meal is extracted with 10 per cent. sodium chloride solution, two portions of uncoagulated proteid were obtained ; after which alcohol extracted another uncoagulated proteid. Two distinct proteids are thus obtained from oats—that extracted from untreated oats readily coagulates and becomes insoluble in alcohol, and when wet with absolute alcohol does not absorb moisture from the air ; whilst that obtained from oats after treatment with salt solution has no tendency to coagulate, is freely soluble in cold alcohol of 0·90 sp. gr., and when wet with absolute alcohol absorbs moisture from the air and becomes gummy. Both substances, when washed with absolute alcohol and dried, are light yellowish powders, soluble in dilute acids and alkalies, and reprecipitated on neutralising their solutions *(American Chemical Journal).*

211. Distribution of Proteids in Wheat.—The proteids of wheat are not distributed equally throughout the whole seed, there being certain portions of the wheat grain which are specially rich in soluble proteids; the bran and germ are particularly so. Starting from the outside of the seed, the interior portions become less and less nitrogenous, until the kernel of the grain is found to consist much more largely of starch.

212. Decomposition of Proteids.—Soluble albumin, or the white of egg, on being allowed to stand, putrefies, with the evolution of sulphuretted hydrogen and other gases. The odour of sulphuretted hydrogen is almost invariably described by comparison to that of rotten eggs. Coagulated albumin, when dry, is a fairly stable body; but, when left in contact with water, putrefies, yielding valeric and butyric acids, together with other bodies. The oxygen of the air has no action on albumin.

Dry gluten may be kept indefinitely without change, but if when wet it is exposed, in masses too large to dry quickly, to air at ordinary temperatures, it gives off a quantity of gas, and at last evolves a strong putrescent odour. At the same time, the insoluble gluten breaks down into a thick creamy mass.

It is necessary to get accurate ideas of what putrefaction really is. Every one knows the results of putrefaction in their last or extreme stages; animal and vegetable substances both give off gases having most disgusting odours, and yield a variety of offensive products. These gases consist of compounds of hydrogen with carbon, and also with sulphur; this latter gas, termed by the chemist sulphuretted hydrogen, is, as just stated, responsible for the odour so characteristic of rotten eggs. In the earlier stages, however, of putrefaction, the changes do not result in the production of such disagreeable bodies; gases are evolved, but these are either inodorous or at most possess only slight smells. Speaking broadly, putrefaction consists of the breaking down or degrading of the complex molecules of animal and vegetable structures into compounds of a more simple character, and ultimately into inorganic compounds, such as carbon dioxide, water, and sulphuretted hydrogen; which latter, in its turn, deposits its sulphur, and forms water by the action of atmospheric oxygen. Bodies in the first stage of putrefying absorb more or less oxygen; when this element has been removed from the supernatant air, a species of fermentation, known as putrefactive fermentation, proceeds. When dealing with the whole question of fermention this change must be viewed more closely. At present there is one particular point that should, however, be mentioned, and that is, that by heating any organic liquid, as a solution of hay, white of egg, or proteids of flour, under pressure at a temperature of about 266° F. for some time, and then boiling the liquid in a flask whose neck is loosely plugged with cotton wool until the whole of the air is expelled, the liquid acquires the property of resisting putrefactive action. Solutions preserved in this manner may be kept for an indefinite length of time; on being once more exposed to the air they again are subject to putrefaction. It would thus appear that putrefaction is not a process appertaining exclusively to the grain itself, but is in some way dependent on the action and presence of air.

EXPERIMENTAL WORK.

213. Reactions of Proteids.—Separate a little gluten from flour by kneading dough, enclosed in muslin, in water. Dry a little of this, and heat strongly in a test-tube; notice that an odour is evolved similar to that of burning hair or feathers. Water also condenses in the cooler parts of the tube: test this water with a strip of red litmus paper, and notice that it has an alkaline reaction; this alkalinity is caused by the presence of ammonia. Make a precisely similar experiment with some white of egg, and observe that the same reactions occur.

Solubility.—Mix some white of egg with about four times its volume of water. Place a portion of this solution in a test-tube, float it in a beaker of cold water, and heat gently. Test the temperature at which coagulation ensues. To successive portions of the albumin solution, add alcohol, ether, mercuric chloride, and picric acid solutions, and dilute nitric acid: notice the formation of a precipitate. To the portions precipitated by acid, add caustic soda or potash solution: the precipitates are re-dissolved.

Colour Reactions.—Test the Xanthoproteic and Millon's colour reactions, as described in paragraph 181.

Precipitation.—Precipitate proteids from solutions by the various methods given in paragraph 182.

Production of Peptones.—Take some of the white of a hard-boiled egg, and rub it through a fine sieve. Add to it some dilute hydrochloric acid (0·2 per cent.) and a little prepared pepsin. Gently warm the whole to a temperature of about 40° C., and notice that the white of egg dissolves. The albumin has then been converted into peptone.

Soluble Flour Proteids.—Weigh out 50 grams of flour, and mix with 250 c.c. of water in a large flask, shake up thoroughly several times during half-an-hour, and then set aside for a few hours, or even overnight. Filter the supernatant liquid through a French filter paper until bright. Heat a portion of this solution in a small beaker placed in a water-bath: notice the coagulation of vegetable albumin.

214. Gluten and its Constituents.—The separation of gluten will have been illustrated in the preceding experiments. Moisten flour with alcohol and fold up in muslin; knead in a small vessel also containing alcohol: notice that no gluten is yielded. Make a similar experiment with a 15 per cent. salt solution: place a sample of flour for the night in the hot water oven, and treat with ordinary water in the morning: observe in each case that no gluten is produced.

Place aside some moist gluten and water in an outhouse: notice day after day the changes which occur in the appearance and physical properties of the gluten as putrefaction sets in.

Take some carefully washed gluten and grind it up in a mortar with a little 80 per cent. alcohol. Transfer to a flask and keep at a temperature of 40° C. for some hours; filter, and again grind the undissolved residuum with more alcohol in the mortar. Again digest in the flask, and once more repeat this treatment. Evaporate down the mixed filtrates over a water-bath, and notice the transparent yellow gliadin thus obtained. Carefully dry the insoluble portion, which consists of more or less pure glutenin.

The extent to which this series of experiments is carried must depend on the time and opportunities of the student, and also the laboratory facilities at his disposal.

CHAPTER VIII.

ENZYMES AND DIASTASIS.

215. Hydrolysis.—It has already been incidentally mentioned that starch may readily be converted into dextrin and maltose; with regard to the carbohydrates generally, one of their special characteristics is, that the less hydrated members of the series are easily changed to those containing a higher proportion of hydrogen and oxygen. In consequence of the great importance of these transformations, they will require to be dealt with fully. The present chapter will, therefore, give particulars of the nature of these changes, the agents by which they are effected, and the conditions which are favourable or unfavourable to their occurrence. As the mutations of the carbohydrates consist of the addition of the elements of water to the atoms previously present in the molecule, it has been proposed to include these changes under the general term "hydrolysis." **Hydrolysis is, therefore, defined as a chemical change, consisting of the assimilation, by the molecule of hydrogen and oxygen in the same proportions as they exist in water; and resulting in the production of a new chemical compound or compounds.** Those bodies capable of producing hydrolysis are termed "hydrolysing agents" or "hydrolytics."

216. Hydrolytic Agents.—These bodies include oxalic and dilute hydrochloric and sulphuric acids. Commencing with soluble starch, the acids mentioned possess the power of converting that body first into dextrin and maltose, then into glucose. The acid hydrolytics also transform cane sugar into glucose. It will be noticed that the ultimate products of hydrolysis of starch are sugars of various descriptions, hence this operation is frequently termed the "saccharification" of starch.

217. Saccharification of Starch by Acids.—This operation is carried on as a commercial process for the manufacture of glucose for use in brewing. The starch is boiled, either in open vessels or under pressure, with dilute sulphuric acid. If the operation be stopped as soon as a portion of the solution gives no blue colouration when tested with iodine, it will be found that dextrin and maltose are the chief products. Continued boiling results in the transformation of most of the dextrin and maltose into glucose. The sulphuric or oxalic acid, whichever is used, is next removed by the addition of calcium carbonate in slight excess. This reagent forms an insoluble oxalate with the latter acid, and with the former, calcium sulphate, which is only very slightly soluble. The precipitate is allowed to subside and the supernatant liquid evaporated under diminished pressure.

218. Enzymes or Soluble-Ferments.—There is yet another most important group of hydrolysing agents, namely, those which consist of certain soluble bodies of organic origin. Among such substances, which possess a very marked hydrolytic action, are human saliva, filtered aqueous infusions of yeast, flour, bran, and malt. Chemical research shows that in each case hydrolysis is due to the nitrogenous constituents of these various agents. In several instances the active principle has either been isolated or obtained in a very concentrated form; it is not known, however, with certainty whether these bodies are definite chemical compounds, or whether they are only mixtures of certain nitrogenous bodies in a particularly active state.

These substances form part of a yet larger group of bodies which formerly were indiscriminately classed together as "ferments," that is, bodies which were capable of inducing fermentation. At present this latter term, as is explained in a subsequent chapter, is confined to those chemical actions which are the work of certain micro-organisms; and the changes, such as hydrolysis, that are due to active principles which are not organised or living, form a separate class. These active principles have been termed soluble-ferments; but, as in order to avoid confusion with micro-organisms and fermentation, it is well to dissever them entirely from the idea of fermentation, the term "enzyme" has been proposed, and is being generally adopted. It has also been proposed to group together all the chemical changes due to enzymes under the generic term of "enzymosis."

A number of chemical reactions are brought about by enzymes, most of which, however, are instances of hydration of the bodies acted on. Enzymosis occurs usually most readily at temperatures about 40° C., and is characterised by the fact that a minute quantity of the enzyme is capable of causing the characteristic chemical change in a comparatively enormous quantity of the substance acted on, without itself apparently undergoing change. **An enzyme may therefore be defined as a nitrogenous organic substance capable, under favourable conditions, of inducing chemical changes in enormously large quantities of contiguous compounds without itself necessarily undergoing change.**

219. Chemical Properties of Enzymes.—These substances can be extracted from the bodies containing them by the action of water, dilute alcohol, salt solutions, or glycerin. From these solutions they may be precipitated by strong alcohol, lead acetate, or saturation with ammonium sulphate. This precipitate, on being washed with absolute alcohol and dried in vacuo, yields a friable mass easily reduced to a white powder, and in composition either proteid or closely allied to proteid matter. The enzymes act most vigorously at a temperature of from 40 to 45° C., and are, in the moist state, destroyed by a temperature of from 50 to 75° C., according to the nature of the enzyme. (Certain enzymes when absolutely dry withstand a temperature of as much as 170° C.) The presence of free acid or alkali, and also small quantities of certain neutral salts, as ammonium sulphate, are inimical to enzymosis.

220. Classification of Enzymes.—Among the number of enzymic actions, comparatively few are of importance in the study of the present subject; these are placed first in the accompanying table, while others of less immediate value, but still of interest as illustrative of the whole scheme of enzymosis, follow.

CLASSIFIED LIST OF ENZYMES.

Name of Group.	Function.	Principal Members.	Bodies from which derived.
1. Cellulolytic.	Solution of cellulose walls of grain.	Cytase.	Green malt.
2. Amylolytic.	Conversion of starch-paste into soluble starch (liquefaction).—Conversion of soluble starch into maltose and dextrin (saccharification).	Diastase. Ptyalin. Amylopsin.	Malt. Saliva. Pancreatic juice.
	Saccharification only, not liquefaction.	Barley diastase. Wheat diastase. Reychler's "Artificial diastase" (?)	Raw grain. Raw grain or flour. Wheat gluten.
3. Inversive.	Conversion of sucrose into glucose.	Invertase. Invertin.	Yeast. Intestinal juice.
4. Proteolytic.	Conversion of proteids into peptones.	Pepsin. Trypsin. Proteolytic enzyme of Diastase (?)	Gastric juice. Pancreatic juice. Germinating grain.
5. Coagulative.	Coagulation of proteid matter.	Fibrin-ferment. Myosin-ferment. Weyl and Bischoff's Vegetable myosin (?) Rennet.	Blood. Muscle. Wheat flour (?) Gastric juice.
6. Emulsive.	Conversion of glucosides into glucose and other compounds.	Emulsin. Myrosin.	Almonds. Mustard.
7. Steatolytic.	Separation of fats into fatty acids and glycerin.	Steapsin.	Pancreatic juice.

In class 4 of the preceding table a note of interrogation is placed against diastase. The subject has not as yet been examined very minutely, but there is considerable evidence that the gluten of wheat flour is attacked during fermentation in the presence of diastase. Osborne and Voorhees' researches throw considerable doubt on the existence of Weyl and Bischoff's vegetable myosin ; but, if the contrary were the case, the natural place of this enzyme would be as shown in class 5. The fact that there are members of this class which can perform analogous functions in blood and muscle has done much toward paving the way for the acceptance of the hypothesis of there being a gluten-forming enzyme.

221. Cytase.—As early as 1879, Brown and Heron mentioned that during the germination of grain the cellulose cell-walls, and also the cellulose of the starch granules, are broken down. Brown and Morris again call attention to the same fact in their paper on the *Germination of some of the Gramineæ*, Journ. Chem. Soc., 1890, p. 458. As germination proceeds, the parenchymatous cell-walls of the endosperm are gradually dissolved, and ultimately leave no sign of separation between the contents of the contiguous cells. During the progress of these changes the endosperm is much softened, and attains the condition of "mealiness" aimed at by the maltster in course of the germination of barley in malt manufacture. Brown and Morris find that this production of mealiness is undoubtedly co-terminous with the dissolution of the cell-wall, and, contrary to what is usually believed, is entirely independent of the disintegration of the starch-granule. **The enzyme, which thus dissolves the parenchymatous cell-walls of the endosperm, has received the name Cytase.** Cytase is secreted by the embryo during germination, and is found in considerable quantity in green- or air-dried malt, but is readily destroyed by the action of heat, and so is found in only very limited quantity in kiln-dried malt, especially that which has been subjected to a somewhat high temperature. That cytase is not identical with diastase is demonstrated by the fact that, whereas a filtered aqueous extract of air-dried malt dissolves the cell-walls of the endosperm, this power is lost on subjecting the liquid to a temperature of 60° C., which temperature does not destroy the vitality of diastase.

222. Diastase.—Since the "mashing" or maceration of malt with water at about a temperature of 60° C. has been employed as one of the operations in the brewing of beer, it has been well known that during this process the starch of the malt is converted into some form of sugar. Payen and Persoz, in 1833, stated that the action of an infusion of malt on starch was due to the presence of a particular transforming agent, to which they gave the name of diastase.

Investigation shows that diastase is secreted by the embryo of such plants as wheat and barley during germination—in a subsequent chapter the physiology of its production and action is dealt with somewhat fully. Diastase is present in large quantity in air-dried malt, and to a lesser but still considerable extent in the malt after kiln drying.

For its extraction in a concentrated form, Lintner recommends the following method :—1 part of green malt or sifted air-dried malt is extracted with 2 to 4 parts of 20 per cent. alcohol for 24 hours. At the end of this time as much as possible of the liquid is filtered off by means of a press, then filtered through paper until bright. To this filtered extract 2½ times its volume of absolute alcohol is added, resulting in the production of a precipitate, which is allowed to settle, and washed in a filter with absolute alcohol. The precipitate is then transferred to a mortar and rubbed down with absolute alcohol, once more transferred to a filter and washed with absolute alcohol, and ether. Finally it is dried in vacuo over sulphuric acid. Prepared in this manner, diastase consists of a yellowish-white powder of great diastasic activity. Its purification is effected by repeatedly dissolving in water and re-precipitating by alcohol. Subjecting the aqueous solution to dialysis reduces the quantity of ash (which consists of normal calcium phosphate), and also increases the percentage of nitrogen. A purified diastase gave the following numbers on analysis calculated on the ash-free substance. Results of analyses of other enzymes are also given.

COMPOSITION OF VARIOUS ENZYMES.

	Diastase.	Pancreatic Enzyme.	Invertase.	Emulsin.
Carbon, ...	46·66	46·57	43·90	43·50
Hydrogen, ...	7·35	7·17	8·40	7·00
Nitrogen, ...	10·42	14·95	9·50	11·60
Sulphur, ...	1·12	0·95	0·60	1·30
Oxygen, ...	34·45	30·36	37·60	36·60
	100·00	100·00	100·00	100·00
Authority, ...	Lintner.	Hüfner.	Barth.	Bull.

Diastase gives all the reactions of the proteids, but not the characteristic biuret reaction of the peptones. It gives with tincture of guaiacum and hydrogen peroxide a blue colouration, which is soluble in ether, benzene, chloroform, and carbon disulphide, but not in alcohol. This reaction is characteristic of diastase, and is given by no other enzyme or proteid substance.

Diastase in the pure form does not reduce Fehling's solution, and, as may be judged from its very nature, is marked by a great capacity for liquefying starch paste and saccharifying it into dextrin and maltose. Unlike the acids, diastase, however, is incapable of converting starch further than into dextrin and maltose. Diastase readily changes amylodextrin and maltodextrin completely into maltose, but does not under any circumstances further hydrolyse maltose.

Under favourable circumstances, one part of well prepared diastase is stated to suffice for the conversion of 2000 parts of starch. A dilute solution of diastase is exceedingly unstable, rapidly becoming acid, and losing its power of starch conversion. This does not apply to concentrated solutions of diastase in the presence of sugars such as are obtained by concentrating in vacuo cold-water extracts of malt to the consistency of a syrup.

223. Diastasic Action or Diastasis.—The action of diastase, being of such great importance in brewing operations, has been studied closely. The term "diastase" is occasionally used in a generic sense, and is then applied to the hydrolysing agents of the cereals generally; thus cerealin is at times referred to as the "diastase" of bran. **Hydrolysis, when effected by diastase or its congeners, is often termed diastasic action, for which the shorter term "diastasis" is proposed.**

224. Measurement of Diastasic Capacity.—The activity of malt extract, or of the purer forms of diastase, depends on the degree of concentration, temperature, and other conditions. Kjeldahl has enunciated what is known as the law of proportionality. The amount of diastase in two malt extracts is proportional to the reducing power which they effect, providing that both act on the same quantity of starch during the same period of time, and that the cupric oxide reducing power[1] (K) does not surpass 25—30. If the whole of the starch present were converted into maltose, K would be 62·5; according to this stipulation, therefore, somewhat less than half the starch must undergo conversion into maltose, or, in other words, starch must be to that extent in excess of the amount hydrolysed by the diastase. Unless the starch is thus largely in excess, the diastasic action will not be proportional to the amount of diastase.

Lintner measures the diastasic capacity on soluble starch, prepared as directed in Chapter VI., paragraph 152, and terms the diastasic activity of the precipitated diastases as 100, when 3 c.c. of a solution of 0·1 gram of diastase in 250 c.c. of water, added to 10 c.c. of a 2 per cent. starch solution, produces in one hour, at the ordinary temperature, sufficient sugar to reduce 5 c.c. of Fehling's solution. These quantities amount to 0·0012 gram of diastase, acting on 0·2 gram of soluble starch, while the maltose necessary to reduce 5 c.c. of Fehling's solution is 0·0400 grams. This quantity of maltose produced is approximately equal to 0·05 grams of starch reduced, and the diastase will have hydrolysed about 41 times its weight of starch in the time and under the conditions specified. Directions for the determination of diastase

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[1] The cupric oxide reducing power, or, more shortly, the cupric reducing power of a substance, has been defined by O'Sullivan as "the amount of cupric oxide calculated as dextrose, which 100 parts reduce" from Fehling's solution under usual conditions of analysis. By careful experiment it has been found that

100 grams of dextrose reduce 220·5 grams of CuO.
100 ,, maltose ,, 137·8 ,,

If in the case of maltose the reduced CuO be assumed to be caused by dextrose, and calculated as such, then

$$\frac{137 \cdot 8 \times 100}{220 \cdot 5} = 62 \cdot 5 = \text{cupric reducing power of maltose.}$$

Another way of expressing the same thing is—The cupric oxide reduced by a given weight of dextrose being 100, the amount reduced by the same weight of any other body is taken as the cupric oxide reducing power of that body.

For cupric reducing power the symbol K or κ is employed.

by methods based on this principle are given in the analytic section of this work. The above is simply a mode of determining diastasic activity, everything else being equal. The consideration of how diastasic capacity is affected by changes of temperature and other conditions is described in detail in subsequent paragraphs.

225. Nature of Diastase.—The effects of diastase on starch have already been spoken of as including two distinct actions; first, the liquefying of starch paste, converting it, in fact, into soluble starch; and second, the saccharifying of this previously liquefied starch. Certain forms of diastase possess this latter power only; but it is usually assumed that malt diastase possesses the two properties. More recently, the opinion has been growing that malt diastase consists of two distinct enzymes—the one a liquefying, and the other a saccharifying agent. More will be said on this matter when dealing with the diastase of unmalted grain.

There naturally arises, in conjunction with the study of diastase, the speculation whether diastase is a distinct chemical compound of nature allied to the proteids, or a property or function certain proteid bodies are capable of exercising under special conditions. Certainly, in the purest form hitherto isolated, diastase is obtained by processes which secure soluble proteids in the purest state; and, practically, any substance called diastase is unobtainable as distinct and separate from soluble proteids.

Brown and Heron finding that, on heating malt extract to a temperature of about 46° C., the soluble proteids commence to coagulate; a continuance of this temperature for some 15 to 20 minutes effects the maximum amount of coagulation possible at 46° C. On raising the temperature a few degrees, an additional quantity of proteids coagulate; this further increase of coagulation continues, as the temperature rises, up to about 95° C. The proteids of malt extract may be viewed as being composed of distinct fractions, each of which has a definite coagulating point, varying from 46° to 95° C. With the coagulation of the proteids, the diastasic power of the malt extract diminishes; also, no diminution of starch converting power has been observed without a coagulation of proteids. Further, at the point at which the diastasic power of malt extract is destroyed (80—81° C.), nearly the whole of the coagulable proteids have been precipitated. Brown and Heron "are consequently led to conclude that **the diastasic power is a function of the coagulable proteids themselves, and is not due, as has been generally supposed, to the presence of a distinctive transforming agent.**" They further find that filtration through a porcelain diaphragm results in the production of a liquid which, on being heated to the boiling point, throws down no proteids. This filtered malt extract they find to be incompetent to produce diastasis, possessing "absolutely no transforming power." It is therefore possible to remove the diastasic agent from the malt extract without the application of heat.

226. Action of Diastase on Starch.—This reaction may first be summed up briefly by stating that if a cold infusion of malt be made, and then filtered; it, the infusion, on being added to a solution of starch in water, at temperatures from 15° to about 70° C., more or less rapidly hydrolyses the starch into a mixture of dextrin and maltose. The longer the operation is continued, the higher is the proportion of maltose produced; but even prolonged action does not result in any further hydrolysis of the maltose into glucose. The investigation of starch and its transformation products has for many years occupied the close attention of what may be called the Burton School of Chemists. Prominent among these are the names of O'Sullivan, Brown, Heron, and Morris. By these and other writers, a number of papers of singular interest and value have been contributed to the Journal of the Chemical Society. Appended is a list of the principal papers of this series, arranged in the order of their appearance:—

"Contributions to the History of Starch and its Transformations." By Horace T. Brown and John Heron. Vol. XXXV., p. 596; year 1879.

"On the Transformation Products of Starch." By C. O'Sullivan. Vol. XXXV., p. 770; year 1879.

"α- and β-Amylan: Constituents of some Cereals." By C. O'Sullivan. Vol. XLI., p. 24; year 1882.

"On the Estimation of Starch." By C. O'Sullivan. Vol. XLV., p. 1; year 1884.

"On the Non-crystallisable Products of the Action of Diastase upon Starch." By Horace T. Brown and G. H. Morris. Vol. XLVII., p. 527; year 1885.

"On the Sugars of some Cereals and of Germinated Grain." By C. O'Sullivan. Vol. XLIX., p. 58; year 1886.

"The Determination of the Molecular Weights of the Carbohydrates." By Horace T. Brown and G. Harris Morris. Vol. LIII., p. 610; year 1888.

"Amylo-dextrin of W. Nägeli, and its Relations to Soluble Starch." By Horace T. Brown and G. Harris Morris. Vol. LV., p. 449; year 1889.

"Determination of the Molecular Weights of the Carbohydrates." By Horace T. Brown and G. Harris Morris. Vol. LV., p. 462; year 1889.

"Researches on the Germination of some of the Gramineæ." Part I. By Horace T. Brown and G. Harris Morris. Vol. LVII., p. 458; year 1890.

"Invertase: a Contribution to the History of an Unorganised Ferment." By C. O'Sullivan and F. W. Tompson. Vol. LVII., p. 834; year 1890.

"The Estimation of Cane-Sugar." By C. O'Sullivan and F. W. Tompson. Vol. LIX., p. 46; year 1891.

"On the Search for a Cellulose-dissolving Enzyme in the Digestive Tract of certain Grain-feeding Animals." By Horace T. Brown. Vol. LXI., p. 344; year 1892.

"The Hydrolytic Functions of Yeast." Part I. By James O'Sullivan. Vol. LXI., p. 593; year 1892. Part II. Vol. LXI., p. 926; year 1892.

The following paragraphs (227—233) consist largely of a summary of the conclusions arrived at and adduced in these papers, after careful collation with each other, and the work of other investigators.

BROWN, HERON, AND MORRIS' RESEARCHES.

227. Malt Extract employed.—It was found that a cold aqueous infusion of malt was the most convenient diastasic agent to employ, as diastase when employed in a pure state was liable to considerable variations in activity. With proper precautions, the aqueous infusion of malt admitted of any degree of accuracy. The infusion or malt extract was prepared by mixing 100 grams of finely ground pale malt with 250 c.c. of distilled water. This mixture was well stirred and then allowed to stand for from six to twelve hours, and then filtered bright. This extract had a specific gravity of 1036—1040.

228. Action of Malt Extract on Cane Sugar.—Malt extract is capable of "inverting" cane sugar, *i.e.*, changing it into glucose. The term "inverting" is derived from the fact that the resulting mixture of glucoses exerts a left handed rotary action on polarised light, while the original sugar is dextro rotary. The maximum effect is produced at about 55° C.; it is much weaker at 60°, almost destroyed at 66°, and entirely destroyed by boiling.

229. Action of Malt Extract on Ungelatinised Starch.—According to Brown and Heron's earlier researches, malt extract is incapable of acting on unaltered starch; and even when contact between the two is maintained for a considerable time, not the slightest action is perceptible at ordinary temperatures.

Notwithstanding this, it is well known that the starch of seeds is attacked and dissolved during the natural act of germination; but this action they viewed as being inseparable from the living functions of the vegetable cell.

This statement is at variance with that of Baranetzky, who avers that "the starch granules of different kinds are acted on with unequal rapidity by the diastasic ferments of plant juices, the strongest ferment of all, malt diastase, being well known to have no perceptible influence, even after long exposure, on solid potato-starch granules, while wheat and buck-wheat are dissolved with facility."

In a more recent paper on *Germination of some of the Gramineæ*, 1890, Brown and Morris refer to Brown and Heron's paper of 1879, and the conclusion therein expressed is that ungelatinised starch is not acted on by malt extract, no "pitting" of the granule or disintegration being produced by artificial means. They also refer to Baranetzky's memoir, and confirm his statement that solid potato-starch granules (which had been exclusively used by O'Sullivan and themselves in their previous researches) are highly resistant to diastase. They further find that well-washed and highly-purified barley-starch is in a few days "pitted," disintegrated, and dissolved by a cold-water extract of air-dried malt, the action being facilitated, as shown by Baranetzky, by the presence of a minute quantity of acid. They treated some well-purified ungelatinised *barley*-starch with a solution of precipitated malt diastase, to which 0·0065 per cent. of formic acid had been added (Acid of this degree of solution has no action on barley-starch.) A trace of chloroform had also been employed in order to prevent putrefactive changes. The starch was vigorously attacked, with the production of maltose as the only optically active substance produced.

At higher temperatures, diastase or malt extract acts on ungelatinised starch; thus Lovibond ("Brewing with Raw Grain") states that the diffusive action of the diastase through the starch cell-wall is sufficient, at high temperatures, to effect the hydrolysis of the starch granulose. The temperatures at which he worked were, however, not much below those given for incipient gelatinisation. The author also finds that on mashing wheat flour with malt extract for some time at temperatures below the gelatinising point, considerable quantities of starch suffer hydrolysis.

Lintner gives the following table of the quantities of ungelatinised starch dissolved by treatment with malt extract at various temperatures. The digestion was allowed to proceed for four hours, but in the case of the higher temperatures was practically complete in about twenty minutes. The results are given in percentages of the total starch taken for the experiments :—

ACTION OF MALT EXTRACT ON UNGELATINISED STARCH.

	50° C.	55° C.	60° C.	65° C.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Potato Starch, ...	0·13	5·03	52·68	90·34
Rice „	6·58	9·68	19·68	31·14
Wheat „		62·23	91·08	94·58
Maize „	2·70	...	18·50	54·60
Rye „	25·20	...	39·70	94·50
Oat „	9·40	48·5	92·50	93·40
Barley „	12·13	53·30	92·81	96·24
Green Malt Starch ...	29·70	58·56	92·13	96·26
Kilned „ ...	13·07	56·02	91·70	93·62

230. Action of Malt Extract on Bruised Starch.—As the next step in the investigation, some starch was next triturated in a mortar with powdered glass. This treatment results in cutting the cellulose envelopes of the granules. The starch granulose is then exposed, and on being treated with malt extract rapidly undergoes conversion. The product consists principally of maltose, the actual results obtained in one experiment being that, after remaining six hours, the clear solution contained—

Maltose, ...	86·3
Dextrin, ...	10·5
Cellulose, ...	3·2
	100·0

After twenty-four hours in the cold the maltose had suffered a slight increase :—

Maltose, ...	91·4
Dextrin, ...	7·0
Cellulose, ...	1·6
	100·0

It will be noticed that under these circumstances a small quantity of cellulose becomes dissolved.

231. Action of Malt Extract upon Starch Paste in the Cold.—At ordinary temperatures malt extract acts upon starch paste (gelatinised starch) with great rapidity and energy. In 100 c.c. of starch solution, containing between 3 and 4 per cent. of solid matter, the addition of from 5 to 10 c c. of the malt extract causes the starch to become perfectly limpid in from one to three minutes. Immediately after arriving at this point the solution ceases to give a blue colouration with iodine. Amyloïns are shown to be present by the brown reaction with iodine, and do not disappear within some five or six minutes from the commencement of the experiment. In this case also a small quantity of starch cellulose is dissolved, but is slowly re-deposited on the liquid standing. After remaining three hours, three experiments gave a mean of :—

Maltose, ...	80·4
Dextrin, ...	19·6
	100·0

as the composition of the solution, resulting from hydrolysis by malt extract.

232. Action of Malt Extract at higher temperatures.—At temperatures of 40° and 50° C., the ultimate products of the action of malt extract are found to be practically the same as in the cold, but the point of disappearance of amyloïns is reached somewhat less rapidly. At 60° C. the action is weakened, but still proceeds sufficiently far to produce practically the same amount of maltose. At still higher temperatures the transformation of the dextrin, first formed, into maltose goes on much more slowly. Also, the action of the diastase of the malt extract may be weakened by the addition to it of dilute alkalies. Such treatment results in limiting the extent to which the conversion of dextrin into maltose proceeds. The results may be summed up by stating that, by modifications of the treatment of starch paste with malt extract, certain fixed points may be obtained representing several different molecular transformations of starch.

233. Molecular Constitution of Starch, Dextrin, and Maltose.—The historical development of the modernly held hypothesis of the molecular constitution of starch is, in view of the importance of the subject, of considerable interest. Brown and Heron, in their paper on *Starch and its Transformations*, 1879, considered that the most natural conclusion that can be derived from the varying proportions of dextrin, obtained in modifications of the hydrolysis of starch paste by malt extract, is that there are several dextrins, and that these dextrins are polymeric, and not metameric bodies. Having adopted this view, Brown and Heron's results led them to the opinion that the simplest molecular formula for soluble starch is $10C_{12}H_{20}O_{10}$, which may also be written $C_{12\times10}H_{20\times10}O_{10\times10}$. The first change produced by the addition of malt extract would, then, be represented by

$$\underset{\text{Soluble Starch.}}{C_{12\times10}H_{20\times10}O_{10\times10}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Erythro-dextrin. }\alpha}{C_{12\times9}H_{20\times9}O_{10\times9}} + \underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}.$$

That is, one of the groups of $C_{12}H_{20}O_{10}$ having combined with water to form maltose, the remaining nine groups constitute the first or most complex dextrin. By the assimilation of another molecule of water, the nine-group dextrin breaks up into a second molecule of maltose and an eight-group dextrin. This reaction proceeds through successive stages until finally the one group dextrin, $C_{12}H_{20}O_{10}$, is in its turn transformed into maltose. There are thus theoretically possible nine polymeric modifications of dextrin; the two higher of these are erythro-dextrins; the remaining seven are achroo-dextrins. The most stable of the whole of these dextrins is that resulting from the eighth transformation, having the composition $C_{12\times2}H_{20\times2}O_{10\times2}$: the hydrolysis of starch, with the production of this dextrin, would then be represented by

$$\underset{\text{Soluble Starch.}}{C_{12\times10}H_{20\times10}O_{10\times10}} + 8H_2O = \underset{\text{Achroo-dextrin. }\zeta}{C_{12\times2}H_{20\times2}O_{10\times2}} + \underset{\text{Maltose.}}{8C_{12}H_{22}O_{11}}.$$

In the more recent paper by Brown and Morris (*The Non-crystallisable Products of the Action of Diastase upon Starch*, 1885), they adduce evidence in favour of a third body, maltodextrin, being formed as an intermediate product during the hydrolysis of starch; as previously mentioned, they ascribe to this body the formula, $\begin{cases} C_{12}H_{22}O_{11} \\ C_{12}H_{20}O_{10}. \\ C_{12}H_{20}O_{10} \end{cases}$ From this it will be seen that maltodextrin is composed of a molecule of maltose united with two of the one-group dextrin. Viewed in the light of the existence of this intermediate product, they then regarded the following as the simplest molecular formula for starch, capable of accounting for the various reactions observed during its hydrolysis—

$$\begin{cases} (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \end{cases}$$

In accordance with this hypothesis, the first step in hydrolysis consists in the lesion of one of the ternary groups, which is transformed into maltodextrin by the assimilation of a molecule of water, thus—

$$\underset{\substack{\text{One of the five ternary groups}\\\text{constituting the starch molecule.}}}{(C_{12}H_{20}O_{10})_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Maltodextrin.}}{\begin{cases} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{cases}}$$

Malt extract effects the complete conversion of maltodextrin into maltose—

$$\underset{\text{Maltodextrin.}}{\begin{cases} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{cases}} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Maltose.}}{3C_{12}H_{22}O_{11}}.$$

In the change producing maltodextrin, the remaining four ternary groups of $(C_{12}H_{20}O_{10})_3$ unite to form the most complex of the dextrins. As the hydrolysis continues, the remaining ternary groups undergo successively the same change until one only remains: this is identical with that before referred to as achroo-dextrin ζ. The view that the starch molecule contains fifteen of the $C_{12}H_{20}O_{10}$ group instead of ten, requires that this, which may be distinguished as "stable dextrin," shall consist of three groups of $C_{12}H_{20}O_{10}$ instead of two: this, of course, makes the formula the same as that of one of the ternary groups. The reaction for the production of stable dextrin is then represented by the following equation:—

$$\underset{\text{Soluble Starch.}}{\left\{\begin{array}{l}(C_{12}H_{20}O_{10})_3\\(C_{12}H_{20}O_{10})_3\\(C_{12}H_{20}O_{10})_3\\(C_{12}H_{20}O_{10})_3\\(C_{10}H_{20}O_{10})_3\end{array}\right.} + \underset{\text{Water.}}{12H_2O} = \underset{\text{Stable Dextrin.}}{\left\{\begin{array}{l}C_{12}H_{20}O_{10}\\C_{12}H_{20}O_{10}\\C_{12}H_{20}O_{10}\end{array}\right.} + \underset{\text{Maltose.}}{12C_{12}H_{22}O_{11}}.$$

Such, very briefly summarised, were the opinions advanced by Brown, Heron, and Morris, up to 1885, as to the relative molecular constitutions of starch, dextrin, and maltose.

In 1888 and 1889, Brown and Morris contributed to the Chemical Society's Journal two most important papers on *The Molecular Weights of the Carbohydrates.* To these papers reference has already been made in the commencement of Chapter VI. By the application of Raoult's method, the molecular weights of starch and the products of its hydrolysis were definitely determined. Among these determinations, probably the most important was that of dextrin. This was made as a preliminary to the estimation of that of soluble starch. It has been already shown that these chemists view starch as a compound of five dextrin groups. In their 1889 paper they say:—

"When the complex molecule of starch is broken down by diastase, under the conditions most favourable to its complete hydrolysis, we have shown that a point of equilibrium, or, speaking more strictly, a resting point in the reaction is reached, when the amount of dextrin produced corresponds to *one-fifth* by weight of the amount of starch taken; that is, when the mixed products have $[\alpha]\ j_{3·86} = 162·6°$ and $\kappa_{3·86} = 49·3$.

"This reaction is represented in the simplest form by

$$\underset{\text{Starch.}}{5C_{12}H_{20}O_{10}} + \underset{\text{Water.}}{4H_2O} = \underset{\text{Dextrin.}}{C_{12}H_{20}O_{10}} + \underset{\text{Maltose.}}{4C_{12}H_{22}O_{11}}.$$

"If the production of maltose and dextrin during hydrolysis is to be considered as due to a molecular degradation of the starch, and we think the evidence in favour of this is almost conclusive; then, no matter what view we may take of the actual manner in which this degradation takes place, we cannot escape from the conclusion that *the molecule of stable dextrin of the above equation is one-fifth of the size of the soluble starch molecule from which it has been derived.*"

Brown and Heron determined by Raoult's method the molecular weight of this dextrin, and thus indirectly that of starch. In the next place they proceeded to consider whether Raoult's method was capable of throwing any light on the relations of the dextrins to each other, it being a matter of the highest theoretical importance to determine whether these bodies constitute a series of polymers, or whether they stand merely in metameric relation to each other. Accordingly some of the so-called higher dextrins were prepared; that is, those which result from starch hydrolysis arrested at its earlier stages. A comparison of the results thus obtained afforded no evidence of there being any difference in the molecular weights of the higher and lower dextrins. Brown and Morris summarise their conclusions by saying that there being no differences in the various dextrins when treated by Raoult's method, "goes, in our opinion, a long way towards proving that, after all, the dextrins are metameric, and not polymeric. If this is admitted as even probably correct, it becomes necessary to consider how far our previous views on the breaking-down of the starch molecule must be modified in order to include the new facts." Brown and Morris enunciate the following hypothesis as being more in accord with the facts :—

"We may picture the starch-molecule as consisting of four complex amylin-groups arranged round a fifth similar group, constituting a molecular nucleus.

"The first action of hydrolysis by diastase is to break up this complex molecule, and to liberate all the five amylin-groups. Four of these groups when liberated are capable, by successive hydrolysations through malto-dextrins, of being rapidly and completely converted into maltose, whilst the central amylin nucleus, by a closing up of the molecule, withstands the influence of hydrolysing agents, and constitutes the stable dextrin of the low equation, which, as we know, is so slowly acted upon by subsequent treatment with diastase. The four readily hydrolysable amylin-groups we look upon as of equal value, and in their original state these constitute the so-called high dextrins, which can never be separated completely from the low dextrin by any ordinary means of fractionation.

"This hypothesis provides for intermediate maltodextrins or amylo-dextrins, whose number is only limited by the size of the original amylin-group.

"Each amylin-group of the five has a formula of $(C_{12}H_{20}O_{10})_{20}$, and a molecular weight of 6480 ; so that the entire starch-molecule, or, more correctly speaking, that of soluble starch, is represented by $5(C_{12}H_{20}O_{10})_{20}$, having a molecular weight of 32,400."

In their *Text Book of the Science of Brewing*, published in 1891, Moritz and Morris further explain that probably the outer amylin-groups cannot exist as such, but immediately on separation from the central nucleus are partially hydrolysed, yielding amyloïns of possibly the very highest type. These amyloïns are gradually hydrolysed, being split up into smaller aggregations, which constitute the various malto-dextrins.

234. Effect of Heat on Diastasis.—The rapidity of diastasic action is considerably influenced by variations of temperature ; extreme cold practically inhibits it. Starting from ordinary temperatures, diastasis rapidly increases as the temperature rises, until, according to Kjeldahl, 54° C. (129° F.) is reached—from that temperature until 63° C. (145° F.) it remains fairly constant, and then rapidly decreases with any further rise in temperature, being entirely destroyed at 80—81° C. (176—177·8° F.). Lintner, working with soluble starch, places the optimum temperature at 50—55° C. (122—131° F.).

Lintner carefully investigated the effect of heat on diastase itself by dissolving similar quantities of diastase in water, and then heating the various solutions to 55° C. (131° F.) for varying periods of time, and then determining the quantity of each solution requisite to convert the same amount of starch. He obtained the following results :—

Of the untreated solution 0·55 c.c. was required.
After heating 20 minutes at 55° C., 1·10 c.c. of solution was requisite.
" 40 " " 1·75 c.c. " "
" 60 " " 2·22 c.c. " "

By prolonged subjection to this temperature the diastase was much weakened; but, where starch and its transformation products are present, the diastase does not suffer to a like extent on subjection to this temperature, the strength being reduced by about only half the amount when heated in water alone. These results should be compared with those of Brown and Heron, quoted in paragraph 225, on Nature of Diastase.

235. Effect of Time and Concentration on Diastasis.—Other conditions being the same, the time occupied in producing a given amount of reaction depends on the quantity of diastase present. Concentration within wide limits has little effect on the rapidity of diastasic action; Kjeldahl states that equal quantities of diastase, acting at the same temperature and for the same period of time, effect the same amount of conversion in solutions differing widely in degree of concentration.

236. Other Conditions favourable and Inimical to Diastasis.—Kjeldahl states that very minute quantities of sulphuric, hydrochloric, and organic acids accelerate diastasis, but large quantities retard it. Lintner states that sulphuric acid, to the extent of 0·002 per cent., very slightly increases the activity of diastase; that 0·01 per cent. retards it, and 0·10 per cent. exercises a destructive action. He also finds that 0·001 per cent. of ammonia retards diastasis, 0·005 per cent. almost, and 0·2 per cent. entirely stops the reaction. The influence, not only of these, but, of course, other substances, depends on their degree of concentration. Speaking generally, acetic and hydrocyanic acids, strychnine, quinine, and the salts of these bases, very slighty retard the action of diastase. Alkaline carbonates, dilute caustic alkalies, ammonia, arsenious acid, and magnesia, exercise a somewhat greater retarding influence, depending on the amount of these bodies added. The following bodies completely prevent the action of diastase upon starch—nitric, sulphuric, phosphoric, hydrochloric, oxalic, tartaric, citric, and salicylic acids; caustic potash, soda, and lime; copper sulphate and acetate; mercury chloride, silver nitrate, iron persulphate, alum, and borax. On the other hand—alcohol, ether, chloroform, thymol, creosote, essence of turpentine, cloves, lemon, mustard, &c., exert no retarding influence.

In cases where it is desired to suddenly arrest the action of diastase in chemical changes, salicylic acid forms a convenient agent. In 100 c.c. of solution, 0·040 gram of salicylic acid almost destroys the activity of the diastase in 5 c.c. of 40 per cent. malt extract solution, while 0·050 gram completely arrests all action. In any material containing diastase and starch, treatment with *boiling* 80 per cent. alcohol completely paralyses any subsequent action of the diastase without gelatinising the starch.

Where it is wished to prevent fermentation or putrefaction without retarding diastasis, the addition of small quantities of chloroform or thymol produces the desired effect. Chloroform is conveniently used in the form of chloroform water, containing 5 c.c. of chloroform to the litre.

237. Ptyalin and Amylopsin.—Ptyalin is found in human saliva, and at an optimum temperature of 35° C. converts starch paste into dextrin and maltose; the reaction being identical with that produced by diastase. Ptyalin acts best in a neutral medium, but is but little affected by small amounts of alkali; a very small quantity of acid, however, arrests its activity, consequently the diastasic action of ptyalin is destroyed on the mixture of food and saliva encountering the acid gastric juice of the stomach. Ptyalin is without effect on cellulose, and hence intact starch granules are not digested by its action.

Amylopsin is an enzyme, very similar to ptyalin, found in the pancreatic juice, where it performs important digestive functions on starchy foods.

238. Raw Grain Diastases.—Earlier observers have pointed out that barley contains more coagulable proteids than does malt, yet fresh barley extract exerts but little diastasic action. Experiments, on which these observations were based, were made with starch-paste, but more recent investigations in which soluble starch is employed show that in some cases raw barley is more actively diastasic than is the green malt prepared from it. Both from barley and wheat a diastase may be obtained by the same methods as is employed for its extraction from malt, that is, by treatment with 20 per cent. alcohol, subsequent precipitation of the filtered alcoholic extract with absolute alcohol, and drying in vacuo over sulphuric acid. Lintner and Eckhardt have examined this enzyme in order to determine whether or not it is identical with malt diastase. For this purpose they took quantities of malt and barley extracts respectively, having the same diastasic value as determined by Lintner's method, and subjected soluble starch to their action at varying temperatures. They found that malt diastase had the greatest activity at 50° C., and the most favourable period at 50—55°. Raw grain diastase, on the other hand, showed the greatest activity at 50, and the most favourable period at 45—50°. At 4° the raw grain diastase had as high a reducing power as was possessed by that of malt at 14·5°. The conclusion is that the two forms of diastase are distinct from each other.

A more marked and important distinction between these two enzymes is the inability of that from raw grain to effect liquefaction of starch-paste, while if by some other means such liquefaction is effected, raw grain diastase energetically converts the soluble-starch into dextrin and maltose. Brown and Morris notice that the power to liquefy starch-paste and to erode the starch-granule go hand in hand; the observed presence or absence of either property affords safe ground for predicting the presence or absence of the other of the two. The raw grain diastase is probably an unused residue of an enzyme produced during the previous history of the plant.

239. "Artificial Diastase" of Reychler.—This worker digested freshly prepared wheat gluten at 30—40° for a few hours with very dilute acids, and thus formed an opalescent solution containing considerable quantities of proteids. The solution is not coagulated by boiling; it gives a precipitate with a few drops of very dilute potash, soluble in excess. Tincture of guaiacum and hydrogen peroxide produce an intense blue colouration, but not if the solution has been previously boiled or treated with too much acid. A solution of the gluten from 10 grams of wheat flour in 50 c.c. of dilute acetic acid (1 in 10,000) gives this reaction, which according to Lintner is characteristic of diastase most distinctly. Reychler finds such solutions to possess a similar hydrolytic action to that possessed by diastase, and states that they saccharify starch-*paste*. Reychler finds also that the soluble proteids of wheaten flour give Lintner's diastase reaction and hydrolyse starch.

Brown and Morris refer to Reychler's researches on artificial diastase, but point out that the starch transforming powers of the product are essentially different from those of malt diastase. Lintner and Eckhardt doubt the existence of Reychler's "artificial diastase," and consider it probably identical with the enzyme of ungerminated grain, and not a conversion-product of the gluten. This view is based on the fact of a close examination by them of the product of the action of dilute acid upon the gluten of wheat. They found the gluten itself to possess diastasic power, which power was greatly increased by the action of acids, the resultant enzyme closely agreeing with raw grain diastase in its optimum temperature of activity and general character. They conclude that gluten contains a *zymogen* (enzyme generating substance), from which the artificial diastase is produced by the action of the dilute acid. Egoroff experimented by dissolving gluten in 0·1 per cent. acetic acid, but found no fresh diastase to be formed, and enunciated the opinion that the greater power possessed by these and aqueous solutions of converting starch into maltose is probably due to the development of a bacterium capable of effecting this transformation. Moritz and Morris practically endorse Lintner's view on this matter, and suggest the identity of "artificial diastase" with that of raw grain. There are two points of discrepancy here: first, the enzyme of ungerminated grain is soluble in water, and must be entirely washed away in the preparation of gluten; second, Reychler distinctly states that his artificial diastase acts upon starch-*paste*, and describes how he prepares the same, namely, by making 2 grams of starch into a "paste" with 250 c.c. of water.

It is interesting to note that as early as 1879, Brown and Heron pointed out that the comparatively inactive proteids of barley, and also wheat, may be rendered more efficient as diastasic bodies, after being obtained in solution; and, consequently, independently of germination. If cold aqueous infusions of barley and wheaten flours, respectively, have a little compressed yeast added to them, and then are allowed to stand for a few hours at 30° C., the solution in each case will be found to have considerably increased in diastasic power. A mixture of yeast and cane sugar, under the same conditions, has no action whatever on starch: therefore, growing yeast must be considered as capable of producing certain changes in the inactive proteids of wheat and barley, by means of which they are enabled to act on starch. Such action on starch is, however, caused by the affected proteids, and not by the yeast itself. While *saccharomyces* act thus on wheat proteids, the *schizomycetes* not merely confer no diastasic power, but rapidly destroy that which the solutions may have originally possessed. It is possible that the action here ascribed to yeast may be due to acidity formed by its action.

The following experiments were undertaken by the author with the view of further elucidating the problem of artificial diastase. A filtered extract of flour was prepared by taking 50 grams of high-class English flour of medium strength, and shaking up with 500 c.c. distilled water, in which had been dissolved 2·5 c.c. of chloroform. (The object of the addition of chloroform was the inhibition of any bacterial action, without hindering in any way the effects of diastase.) This solution was allowed to stand for half-an-hour, filtered and divided into two portions—A and B.

A.—To portion A, an equal volume of chloroform water was added, and the diastasic value on soluble starch by Lintner's scale determined immediately in a part of the solution, according to the method described in the analytic section of this work. Another portion of this diluted solution was treated precisely similarly, except that freshly prepared starch paste was substituted for Lintner's soluble starch.

A1.—The diastasic action reckoned on the flour was—

With soluble starch, ... 9·4° Lintner.
With starch paste, ... 5·0° ,,

B.—To portion B, an equal volume of 0·2 per cent. hydrochloric acid in chloroform water was added, and another pair of similar determinations to those preceding made immediately, with the following results:—

B1.—The diastasic action reckoned on the flour was—

With soluble starch, } less than 2·5° Lintner, there being
With starch paste, } practically no action whatever.

The plain 5 per cent. solution A, and the 5 per cent. solution in 0·1 per cent. hydrochloric acid, B, were then digested twenty hours at 30—35° C., and the diastasic capacity again measured with results as follows:—

A2, with soluble starch, ... 14·3° Lintner.
,, with starch paste, ... 4·5° ,,
B2, with soluble starch, } less than 2·5° ,, practically no
,, with starch paste, } action.

In the next place, 25 grams of flour were taken with 250 c.c. chloroform water, shaken and digested together for twenty hours at 30—35° C., giving preparation C. Another 25 grams were similarly treated with 250 c.c. of 0·1 per cent. hydrochloric acid in chloroform water, and digested, being preparation D. After digestion, diastasic measurements were made in the clear filtrate, with the following results:—

C, with soluble starch, ... 10·0° Lintner.
,, with starch paste, ... 4·0° ,,
D, with soluble starch, } less than 2·5° ,,
,, with starch paste, }

Digestion with 0·1 per cent. hydrochloric acid not only does not confer additional diastasic capacity, but practically inhibits any such power the flour naturally possessed.

A series of experiments was next made, in which 0·01 per cent. acetic acid was substituted for the hydrochloric acid. As previously, all solutions were treated with chloroform to prevent any action of bacteria. Of the same flour as before, 25 grams were taken, shaken up with 250 c.c. of water, and filtered after half-an-hour standing. An equal volume of 0·02 per cent. acetic acid was added, making a 0·01 per cent. acetic acid solution, called E. Preparation F consisted of 25 grams of flour with 250 c.c. of 0·01 per cent. acetic acid, shaken up and not filtered. These were digested for twenty hours at 30—35° C., and the mixture F filtered. In each, diastase determinations were then made, both with soluble starch and starch paste.

E, with soluble starch,	...	26·3° Lintner.
,, with starch paste,	...	15·1° ,,
F, with soluble starch,	...	29·4° ,,
,, with starch paste,	...	16·6° ,,

These experiments show that very dilute acid (0·01 per cent. acetic) considerably increases diastasic activity, even when any possible bacterial action is prevented, by the presence of chloroform, throughout the whole course of the experiment. Comparing A2, which was a plain solution of the flour, digested for twenty hours *after filtration*, with E, which was a solution of the same strength, acidulated to the extent of 0·01 per cent. with acetic acid, after filtration but before digestion, there is an increase in diastasic capacity from 14·3° to 26·3° Lintner on soluble starch, and from 4·5° to 15·1° on starch paste. The diastasic activity of the proteids actually in solution has been definitely increased by this treatment. It should be noticed also that the particular diastase present is not only capable of converting soluble starch, but also hydrolyses starch paste.

In C and F, the whole flour and water, and dilute acid respectively, were digested together *before* filtration. Again there is an increase in diastasic capacity. From a comparison of E and F, it would seem that very little of the increased diastasic action is due to any change in the insoluble proteid of the flour, as the F results are only slightly in excess of those in E. It is curious to note that in A2 and C, both experiments with plain water, digestion after filtration yields a more active product than digestion *before* filtration.

240. Invertase or Zymase.—Although diastase is unable to carry the hydrolysis of starch further than into maltose, yet, as already stated, there is evidence of malt extract containing an enzyme capable of converting cane sugar into glucose.[1] This enzyme has been termed zymase, but is now known more commonly as invertase. For practical purposes the principal source of invertase is beer-yeast, from which it may be separated in a fairly concentrated form. O'Sullivan and Tompson recommend for this purpose that sound brewers' yeast be pressed, and then kept at the ordinary temperature for a month or

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[1] Brown and Heron adduce experimental proof of this point in a contribution to the Journal of the Chemical Society, Vol. XXXV, 1879, page 609; they show that a cane-sugar solution, after being digested for 16 hours at 55° C. with cold water extract of malt, contained 20·4 per cent. of glucose. If, on the other hand, the malt extract were previously boiled for 15 minutes, the percentage of invert sugar was reduced to 0·2 per cent.

two, during which time it does not undergo putrefaction, but changes into a heavy yellow liquid. On filtering, this yields a clear solution of high hydrolytic power, containing all the invertase of the yeast in solution. This liquid has a specific gravity of about 1080, and is termed "yeast liquor" by O'Sullivan and Tompson. This liquor remains for a long time unaltered, except for a darkening of colour. On adding spirit to yeast liquor till it contains 47 per cent. of alcohol, the invertase is precipitated, and may be washed with spirit of the same strength and dried in vacuo, or preserved as a solution by extracting the precipitate with 20 per cent. alcohol, and filtering, when the filtrate contains the invertase.

Invertase acts rapidly on cane-sugar according to the equation :—

$$\underset{\text{Cane-Sugar.}}{C_{12}H_{22}O_{11}} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Lævulose.}}{C_6H_{12}O_6}.$$

This speed of inversion increases rapidly with the temperature until 55 - 60° is reached. At 65° invertase is slowly, and at 75° immediately destroyed. Minute quantities of sulphuric acid are exceedingly favourable to the action, but a slight increase of acidity beyond the favourable point is very detrimental. A sample of invertase which had produced inversion of 100,000 times its own weight of cane-sugar was still active; and further, invertase itself is not injured or destroyed by its action on cane-sugar. There is evidently no limit, therefore, to the amount of sugar which can be hydrolysed by a given amount of invertase. The caustic alkalies, even in very small proportions, are instantly and irretrievably destructive of invertase. Invertase is without action on starch, dextrin, maltose, dextrose, lævulose, and gum.

241. Intestinal Invertase.—The secretions of the small intestines contain an enzyme allied to the invertase of beer yeast, inasmuch as it inverts cane-sugar into dextrose and lævulose; it also inverts maltose into dextrose, thus differing from the invertase of yeast, which has no action on maltose. Brown and Heron state that it acts on starch, but Halliburton is of opinion that the bulk of evidence is against the presence of any such diastasic action.

242. Pepsin and Trypsin.—Collectively, the fluids of the stomach are known as gastric juice, and contain an active proteolytic enzyme termed pepsin. Pepsin may be obtained from the mucous membrane of the stomach by extraction with glycerin, in which pepsin is soluble. The pepsin is precipitated from its glycerin solution by alcohol, dissolved in water and freed from salts and peptones by dialysis. Pepsin is soluble in water to a mucous liquid, but is insoluble in alcohol or ether. Pepsin is either a proteid or proteid-like substance, and in the presence of an acid, preferably hydrochloric, attacks and rapidly dissolves insoluble proteid substances, as the white of hard-boiled eggs or lean beef, converting them into peptones. Pepsin is most active at about 40° C., and loses its power on exposure to 57—58°. The acid condition is necessary to its action, and is supplied in the gastric juice by the presence of hydrochloric acid, which in the gastric juice obtained from the human stomach amounts to 0·02 per cent., and in that of the dog to 0·30 per cent. The energy of pepsin is impaired, and at last arrested by the peptones produced. Dried pepsin may now be obtained as an article of commerce, being prepared by drying under 100° F. the fresh mucous lining of the stomach of the pig, sheep, or calf. In accordance with the scheme of nomenclature in which the names of the enzymes end in *ase*, the name of this body is frequently written peptase.

Trypsin occurs in the pancreatic juice, and is allied in its general behaviour to pepsin, possessing like it the power of converting proteids into peptones. It differs, however, in the fact that it acts only in an alkaline medium, and is destroyed by the presence of hydrochloric acid.

243. Proteolytic Enzyme of Resting and Germinating Seeds.—Seeds generally appear to contain a proteolytic enzyme in the form of a zymogen, which during the act of germination becomes active, probably through the agency of a small amount of acid produced while the seed is germinating. This body converts the proteids of the seed into peptones, leucin, and tyrosin. Very little is at present known as to its action, nor has it as yet been isolated. Malt extract and diastase in its various forms exert a marked physical effect on the proteids of flour during bread fermentation.

244. Other Enzymes.—Among other enzymes mentioned in the classified list previously given, a word should be said about those included in the group of coagulative enzymes. The coagulation of blood on leaving the body is due to an enzyme; so also is that of muscle at death, in the case of the stiffening termed *rigor mortis*, known in this instance as the myosin-ferment or enzyme. Interest attaches to this, as the animal analogue of Weyl and Bischoff's myosin, to which they ascribe the formation of gluten in the doughing of wheaten flour.

Space does not permit any further reference to the emulsive and steatolytic enzymes.

DETAILS OF APPLIED HYDROLYSIS.

245. Empirical Statement of Hydrolysis of Starch.—It will be seen that these formulæ, representing the probable constitution of the molecule, are much more complex than the empirical formulæ respectively of starch and dextrin. The following empirical equation represents in the simplest possible manner the above reaction; it must not, however, be viewed as representing the true nature of the molecular change involved :—

$$\underset{\text{Soluble Starch.}}{(C_6H_{10}O_5)_5} \quad + \quad \underset{\text{Water.}}{2H_2O} \quad = \quad \underset{\text{Dextrin.}}{C_6H_{10}O_5} \quad + \quad \underset{\text{Maltose.}}{2C_{12}H_{22}O_{11}}.$$

246. Hydrolysis of Cane Sugar.—This operation is slowly effected by the action of malt extract, or even by prolonged boiling with water, which effects the same change more or less completely. At ordinary temperatures, dilute sulphuric and hydrochloric acids are capable of slowly inverting cane sugar; at temperatures of from 65° to 70° C. the hydrolysis occurs with extreme rapidity. For laboratory purposes, complete inversion is effected by adding to the moderately strong sugar solution one-tenth its volume of strong hydrochloric acid, and then heating the mixture in a water-bath until the temperature reaches about 68° C. The change consists of the cane sugar molecule splitting up into two molecules of glucose, the one being dextro-, and the other lævo-rotary—

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextro-glucose.}}{C_6H_{12}O_6} + \underset{\text{Lævo-glucose.}}{C_6H_{12}O_6}.$$

Invertase also effects this change, and apparently is likely to be employed commercially for the purpose. O'Sullivan recommends its employment in the laboratory for the hydrolysis of cane sugar as a step towards its analytic estimation.

247. Hydrolysis of Dextrin.—By the action of acids, and also of malt extract, this body may be entirely converted into maltose: the nature of the chemical change has been described when treating of the hydrolysis of starch. Under ordinary conditions, neither invertase nor yeast itself is capable of effecting the hydrolysis of dextrin.

248. Hydrolysis of Maltodextrin.—This change is readily effected by the action of malt extract, but not by either invertase or yeast.

249. Hydrolysis of Maltose.—Maltose is a more stable sugar than is cane sugar: dilute acids effect its conversion with slowness; thus a maltose solution may be boiled for some minutes with dilute sulphuric acid without undergoing change. Complete inversion results from keeping the solution at a temperature of 100° C. for some six or eight hours. The principal product of inversion is probably either dextrose, or one or more closely allied dextro-glucoses. As has been previously stated, malt extract has no hydrolysing action on maltose. Invertase also is without action on maltose.

250. Composition of Malt.—Prior to dealing with the saccharification of malt, some information should be given of its composition. Treatment of the general questions of the transformation of barley into malt must be postponed until the subject of the physiology of grain life is being discussed. Malts differ from barley in that the proteid constituents show proofs of considerable degradation. Hilger and Van der Becke have examined barley, barley softened by steeping in water, fresh or green malt (unkilned), and kiln-dried malt. The following table gives the percentage of nitrogen, and of the various nitrogenous constituents:—

NITROGENOUS CONSTITUENTS OF BARLEY AND MALT.

	Barley.	Softened Barley.	Fresh Malt.	Dried Malt.
Total Nitrogen, ...	1·801	1·750	1·751	1·542
Nitrogen of insoluble constituents, ...	1·6789	1·6853	1·372	1·165
Nitrogen as albumin (soluble)	0·0600	0·0354	0·1571	0·1194
,, as peptone, ...	0·0046	0·0009	0·0058	0·0233
,, as ammonium salts,	0·0169	...	0·0290	0·0057
,, as amido-acids, ...	0·0417	0·0294	0·1417	0·2257
,, as amides, ...	...	...	0·0505	0·0029

It will be seen that the insoluble proteids have diminished in quantity, while the albumin has increased ; so also have the products of further degradation, peptone, amido-acids, and amides.

The starch in barley also suffers considerable diminution ; Brown and Morris found the quantities of starch in barley before and after germination to amount to

STARCH IN 1000 CORNS.

	Starch in Barley before Germination.	Starch in Barley after Six Days' Germination.	Loss of Starch.
Expt. 1., ...	20·0552 grams.	15·4398 grams.	4·6154 grams.
,, 2., ...	19·9158 ,,	15·3636 ,,	4·5522 ,,

Taking the mean of the two experiments, 22·5 per cent. of the starch has disappeared. A portion of this has been dissipated as carbon dioxide gas, a portion will have constituted the material from which the new parts of the plant have been formed, while a third portion will have been changed into sugars, which remain in the malt at the end of its manufacture. The increase of sugars is well shown in the following table, which gives in percentages the results of analyses of barley before and after germination, by O'Sullivan.

SUGARS IN BARLEY BEFORE AND AFTER GERMINATION.

SUGARS.	No. 1 Barley.		No. 2 Barley.	
	Before Germination.	After Germination.	Before Germination	After Germination.
Sucrose (Cane-Sugar),	0·9	4·5	1·39	4·5
Maltose, ...	1·1	1·2	0·62	1·98
Dextrose, ...		3·1		1·57
Lævulose		0·2		0·71

It will be seen that cane-sugar forms a very notable constituent of malt, and also that the other sugars are present in large quantity.

The percentage of acid considerably increases in grain during malting ; assuming acidity to be due to lactic acid, Bělohoubek gives the following :—

Barley, ...	0·338 per cent. as lactic acid.
Green Malt, ...	0·590 ,, ,,
Kilned Malt, ...	0.942 ,, ,,

In English malts, however, the percentage of acid is considerably less than this, being usually about 0·2 per cent ; so much as 0·4 per cent. is viewed as an indication of unsoundness.

The following table gives the approximate composition of malt, based principally on analyses by O'Sullivan :—

APPROXIMATE COMPOSITION OF MALT.

	Per Cent.		Per Cent.
Starch,	44·00	to	50·00
Sugars,	9·00	,,	16·00
,, These include, Sucrose, from	4·50	,,	16·00
,, Maltose, ,,	1·20		
,, Dextrose, ,,	1·65		
,, Lævulose, ,,	0·20		
Unfermentable Carbohydrates, not Dextrin,	5·00	,,	7·00
Cellular Matter (Cellulose),	10·00	,,	12·00
Proteids, soluble in cold water,	3·0	,,	4.50
,, insoluble ,,	8·00	,,	10·00
Fat,	1·50	,,	2·00
Ash,	1·90	,,	2·60
Water,	2·50	,,	7·00
Acid reckoned as Lactic Acid,	0·20	,,	0·40

251. Saccharification of Malt during the Mashing Process.—This process is of interest both from the technical point of view, as being largely used by the baker, and also scientifically, as representing an important example of hydrolysis by malt extract. Malt contains the active hydrolysing principle, diastase, and also from 44 to 50 per cent. of starch. In the operation of malting, the walls of the starch granules get more or less ruptured and fissured; hence the interior granulose is at the outset somewhat exposed to the action of the diastase. As a first step toward the preparation of beer, the brewer treats his ground malt with water at a temperature of from 65·5° C. (150° F.) to 71·1° C. (160° F.). This results in the conversion of the starch present into dextrin and maltose. This operation he terms "mashing." The first change is that the starch becomes gelatinised, and is then freely susceptible to the action of diastase. At temperatures below the gelatinising point of starch, diastasis also proceeds, but somewhat more slowly (comp. Lintner's table, par. 229). At a temperature of about 60° C. (140° F.) almost all the starch, and also the amyloïns, will have disappeared in about twenty minutes; this point may be ascertained by taking out a drop of the liquid and testing it with iodine. An increase of temperature weakens the action of the diastase; hence a mashing made at 60° C. (140° F.) yields in two hours, for the same malt, about 7 per cent. more dextrin and maltose than when mashed at 76·6° C. (170° F.). Further, as might be expected from the results already mentioned, the proportion of dextrin is much greater in the mashing made at 76·6° C. than at 60° C. The duration of the mashing operation has also an influence on the amount of dextrin and maltose produced. With a temperature of 62·7° C. (145° F.) most of the starch is converted into dextrin and maltose within thirty minutes, but for some time after, the yield of these continues to slightly increase. The proportion of maltose to dextrin also becomes higher with a longer mashing. The following is the result of an experiment by Graham:—

Length of Mashing.	Percentage of Maltose.	Percentage of Dextrin.	Total percentage of Maltose & Dextrin.	Ratio of Maltose to Dextrin.
½ hour.	48·60	14·61	63·21	3·3 : 1
1 ,,	52·35	12·26	64·61	4·2 : 1
2 hours.	53·56	11·39	64·95	4·7 : 1
3 ,,	54·60	11·05	64·65	4·9 : 1
7 ,,	61·47	3·53	65·00	17·4 : 1

It will be seen that by far the greatest proportion of the transformation is effected within the half hour, while for all practical purposes the hydrolysis is completed within two hours at the furthest.

252. Mashing Malt together with Unmalted Grain.—The diastase of good malt is not merely capable of saccharifying its own starch, but is competent also to hydrolyse in addition considerable quantities of starch from other sources; hence, in brewing operations, malt is frequently mixed with flour from other cereals, either rice or maize being commonly chosen. The diastase of the malt saccharifies the whole of the starch present; but with the proportion of malt unduly low, the ratio of maltose to dextrin produced is comparatively small.

EXPERIMENTAL WORK.

253. Hydrolysis of Starch.—Mix 10 grams of starch with 200 c.c. of water, and gelatinise by placing in the hot water-bath. Take 50 c.c. of this solution and add to them 10 c.c. of five per cent. sulphuric acid. Maintain at a temperature of 100° C. until a few drops, taken out with a glass rod or tube, and placed on a porcelain tile, give no blue colouration on addition of iodine. To the solution add precipitated calcium carbonate, or powdered marble, until it ceases to produce effervescence. Allow the precipitate to subside, and filter: taste the clear solution, notice its sweetness. Test a portion of this filtered solution with Fehling's solution, a red precipitate is produced, showing that either maltose or glucose is present.

To a test tube, containing another portion of the original starch solution, add some saliva, and stand it in a water-bath at a temperature of about 40° C. for some time: notice that the solution becomes more limpid, and ultimately that it gives no starch reaction, on a few drops being taken out and treated with iodine. Test now for maltose, by means of Fehling's solution; a red precipitate is produced. As a complement to this experiment, boil some corn-flour and water, allow the paste to cool, place a spoonful in the mouth, retaining it there for some fifty or sixty seconds, and mixing it with saliva by means of the tongue: notice that the paste becomes limpid, and acquires a sweet taste.

Take some fresh compressed yeast, mix a little with some of the starch solution and place in the water-bath at 40° C. Notice that after several hours the starch remains unaltered, giving a blue colouration with iodine, and little or no reaction with Fehling's solution. Prepare some "yeast-water" by shaking up about 50 grams of the compressed yeast with 150 c.c. of cold water; let this stand for from four to six hours, shaking occasionally, then allow to sudside and filter the supernatant liquid. Treat some starch solution with this yeast-water in the same way as with the yeast itself: notice that this also causes no alteration in the starch.

Make an aqueous extract of malt, as described in paragraph 227. Take some sound wheat starch, examine it under the microscope, to see that none of the granules are fissured or cracked. Add some of the malt extract to a portion of this starch, and allow it to remain for some hours at a temperature of 20° C. Maintain another similarly prepared sample at a temperature of 40° C. for from six to twelve hours. At intervals from the time of starting the experiment, and at the end of the time, examine the starch in each case carefully under the microscope, in order to see whether any of the granules show signs of cracking or pitting. Make a comparative series of experiments on potato starch. In every experiment, at the end test the starch granules with iodine, in order to see whether they still give the starch reaction.

Shake up some starch with water, and filter: notice that the clear filtrate gives no reaction with iodine. Rub a little of the starch in a mortar with powdered glass; this cuts the cellulose envelopes. Shake up with water, and filter; to the clear filtrate add iodine solution: a blue colouration shows the presence of soluble starch. To some of the bruised starch add malt extract, and allow to stand for twenty-four hours at 20° or 25° C., examine under the microscope, and notice that much of the interior of the cells is dissolved away. Treat a little with iodine, and examine under the microscope in order to determine how much unaltered starch remains. Make some starch paste, as described in paragraph 231; treat it with malt extract as there mentioned, and at intervals of a minute take out a drop of the solution by means of a glass rod, and test with iodine on a porcelain tile. Note the time when the starch and the amyloïns disappear. Make a series of similar experiments with varying temperatures, rising by 10° C. at a time, from 15° C. to the point at which diastasis ceases. The quantities of solution should be measured; and in each case, both the starch and the malt extract solutions should be allowed to stand in the water-bath, regulated to the desired temperature, until both have acquired that temperature, *then* mix the two and note the time. If desired, the bath may be regulated for this experiment by means of the regulator described and figured in Chapter XI.; in that case it is not absolutely necessary to get the temperature nearer than a degree, but the exact temperature, as read by a thermometer, should be noted.

Make a cold aqueous infusion of bran or pollard in the same way as described for malt, and treat starch solution with it, as was done with the malt extract, both in the cold and at higher temperatures. If separated wheat germ is obtainable, make a similar series of experiments with that substance.

254. Hydrolysis of Cane Sugar.—Mix cane sugar solution with strong hydrochloric acid, and heat to 68° or 70° C., as described in paragraph 246. After hydrolysis, test for reducing sugars by Fehling's solution. To another portion of the cane sugar solution add some yeast-water, and maintain for three or four hours at 40° C., after which test for maltose or glucose by means of Fehling's solution.

255. Mashing of Malt.—Take 100 grams of ground malt, and mix with 500 c.c. of water at 60° C. in a large beaker: weigh the beaker and its contents, and place it in a water-bath at 60° C. Stir occasionally, and from time to time take out small quantities of the well-stirred liquid, and test for starch by iodine solution. Note how long it is before the starch disappears; as soon as iodine produces no blue reaction, wipe the outside of the beaker, place it in the balance, and add distilled water until that lost by evaporation has been replaced: when this point is reached the beaker weighs just the same as before being placed in the bath. Then filter the clear solution, cool rapidly to 15° C., and take the density by means of a hydrometer. The method of using the hydrometer, and the conclusions to be drawn from the density of the wort, are described in the paragraph on "Specific Gravity of Worts" in Chapter XII. Make similar mashings at the temperatures respectively of 50° and 70° C.; note in each case the time requisite for saccharification, and the density of the wort. For the different experiments both the mashing liquor and the bath must be regulated to the temperature desired.

256. Substances inimical to Diastasis.—Prepare some starch solution and malt extract as in paragraph 253. To a portion of the malt extract add a small quantity of caustic potash, and note the time it takes to saccharify the starch, both starch and malt being used in the same proportions as before. Make similar tests with solutions of sulphuric, tartaric, and salicylic acids; lime, copper, sulphate, alum, borax, alcohol, and essence of turpentine.

CHAPTER IX.

FERMENTATION.

257. Origin of Term.—When a little of the substance called yeast is added to some wort (*i.e.*, the sweet liquid produced by the infusion of malt with warm water), at a temperature of about 18° C., it induces a most remarkable change. The quiescent liquid after a time becomes filled with bubbles ; these rise to the surface and form a scum there ; as the action proceeds these bubbles are produced with increased rapidity. Their continuous ascension gives the liquid a seething or boiling appearance, and from this has arisen the application of the term "fermentation" to this peculiar phenomenon ; that word being derived from the Latin, "*ferveo*," I boil. Fermentation results in a disappearance of the maltose present in the wort, together with the production of alcohol and carbon dioxide gas. The former remains in the liquid ; the latter rises to the surface and causes the before-mentioned boiling appearance. The carbon dioxide bubbles carry with them to the surface a peculiar sticky "scum ;" this substance has received the name of "Yeast," and on being added to a fresh quantity of wort, is capable of setting up fermentation therein. During the fermentation of wort, the quantity of this "scum" produced is many times in excess of that in the first place added to the wort.

258. History of the Views held of the Nature of Fermentation.—The earlier researches and published articles on fermentation regard that change as one of spontaneous decay. Yeast, with which fermentation is associated, was viewed as a peculiar condition which nitrogenous matter assumed during one of the phases of its decomposition. That in this state it was able to set up fermentation in a liquid, which was not at the time fermenting, was noticed as a remarkable property of yeast, which nevertheless was still considered as only nitrogenous matter in a particular stage of chemical change. One of these earlier views ascribed alcoholic fermentation to a vegeto-animal substance which resided in grapes as well as in corn. When the grapes were crushed, and the flour moistened, this fermentative agent commenced to produce active change. The body thus capable of inducing fermentation was termed a "ferment." The next step in investigation of this matter was that of Thénard, who observed that the ferment contained nitrogen, and that in distillation ammonia was yielded ; he therefore ascribed an animal nature to the ferment. (It should be explained that the older chemists were in the habit of looking on nitrogenous organic matter as animal, and the non-nitrogenous as vegetable ; no reference is intended to the peculiar organic structure of the ferment.) Opinion had settled down to the view that yeast was an immediate principle of plants, when the microscope, which had become such an important factor in scientific research, was brought to bear on the construction of yeast. Leuwenhoeck had, as early as 1680, discovered that yeast consisted of minute granules; but it was only in 1836 that de Latour again called attention to its microscopic structure. It was observed by him that yeast was a mass of little cells, and, further, that these were capable of reproduction by a process of budding. "Yeast, therefore," said the discoverer, "must be an organism which probably, by some effect of its growth, effects the decomposition of sugar into alcohol and carbon dioxide." This newly discovered form of life was, after some discussion, placed among the fungi, a new genus being created for it by Meyen, to which was given the name of Saccharomyces.

This view attracted considerable attention from scientists, and although the basis of that now almost universally accepted, encountered most uncompromising opposition. Prominent among its antagonists was Liebig, who in 1839 argued yeast to be a lifeless albuminous substance, and held that the cause of fermentation is the internal molecular motion which a body, in the course of decomposition, communicates to other matter in which the elements are connected by a very feeble affinity. Said Liebig, "yeast, and in general all animal and vegetable matter in a state of putrefaction, will communicate to other bodies the condition of decomposition in which they are themselves placed; the motion which is given to their own elements by the disturbance of equilibrium is also communicated to the elements of the bodies which come in contact with them." Amplifying this theory, Liebig asserted that the proteid bodies decomposed spontaneously, and the molecular disturbance resulting from this decomposition effected also the decomposition of such bodies as sugar, when placed in contact with the decomposing proteids.

For some years, de Latour's, or the vital hypothesis, Liebig's, or the mechanical hypothesis, and other views based on catalytic action, were three contending theories of fermentation.

The next great step was that the whole problem of fermentation received a most careful and exhaustive examination at the hands of Pasteur, who in 1857 gave as his "most decided opinion" that "the chemical action of fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it. I think that there is never any alcoholic fermentation without there being at the same time organization, development, multiplication of globules, or the continued consecutive life of globules already formed."

In 1870, Liebig published a long memoir on fermentation, in which he admitted that yeast was a living organism, but still maintained that fermentation was a mechanical act, pointing out that the quantity of sugar decomposed by yeast was out of all proportion to the amount of carbohydrate (cellulose) which the yeast had assimilated. To quote his own words—"Yeast consists of vegetable cells which develop and multiply in a solution containing sugar, and an albuminate, or a substance resulting from an albuminate . . . . It is possible that the physiological process stands in no other relation to the process of fermentation than that by means of it a substance is formed in the living cell, which, by an action peculiar to itself—resembling that of emulsin on salicin or amygdalin (enzyme)—determines the decomposition of sugar and other organic molecules." The admission of the physiological action of yeast being even indirectly associated with the decomposition of sugars during fermentation was an enormous concession by Liebig. A study of the action of enzymes shows that Liebig's position is partly justified: invertase can be separated from yeast, and afterwards is fully capable of performing its functions of inverting cane sugar, but such study does not lead us to observe a sufficiently close relationship between enzymic action and alcoholic fermentation as to prove their identity. Still in many respects there is great similarity. At present there is the marked distinction that alcoholic fermentation is inseparable from life, while enzymosis occurs in the absolute absence of living organisms. **As a result of prolonged research and investigation, the vitalistic theory of fermentation is now practically universally accepted.**

A careful study of the preceding sentence shows, however, that the statement of fermentation being a vitalistic act is not an explanation of fermentation. Granted that fermentation is a concomitant of vitality (*i.e.*, is due in some way to life), there must be some agent through which life acts in producing the chemical change of sugar into alcohol and carbon dioxide. In itself, this change is no more striking than the change of starch, by diastase, into dextrin and maltose; yet we know that diastase, although a direct product of life, is a soluble and absolutely unorganised body. Is there any such unorganised body through which yeast acts when effecting the decomposition of sugar? The answer is—no such substance has as yet been detected, to say nothing of its isolation.

Hoppe-Seyler and Halliburton incline to the hypothesis that the difference between organised ferment action and that of enzymes is this: an organised ferment is one which does not leave the living cell during the progress of the fermentation; an unorganised ferment, or enzyme, is one which is shed out from the cells, and then exerts its activity. Probably the chemical nature of the ferment is in the two cases the same, or nearly the same.

So far as we are acquainted with the nature of enzymes, they are either identical with, or closely allied to, the proteids. If fermentation be due to an enzyme-like body within the living cell, that body is of the nature of living proteids—like other proteids they are indiffusible, and consequently are not discoverable outside the cell wall. "Like all living things, their properties during life are different from those after death; this readily accounts for the fact that, with a few exceptions, they are not discoverable inside the cell wall after the cell has been killed by alcohol. The few exceptions are probably those which are more robust, and withstand the action of alcohol better." In this way does Halliburton endeavour to explain the difference between organised ferments and enzymes. The explanation, unfortunately, does not cover the whole problem. Even the more robust "ferments" cannot be said to have life in the ordinary sense of the term when extracted by dilute alcohol, and obtained in a state of perfect solution. Independently of any organism, the enzymes are able to prosecute their functions; but alcoholic fermentation cannot be induced by any substance contained by the yeast cell, unless that cell be living. If the protoplasm of yeast be liberated by crushing the cells, such extracted protoplasm does not cause fermentation. There is little doubt that fermentation does take place within the cell, and is in some way caused by some property of living proteid, *but it is an essential that the proteid be alive, and a part of a living organism.* This much may be conceded, that probably the living proteid acts in a more or less similar manner to an enzyme. In view of this it is interesting to note the agreement rather than the differences between the views promulgated by the illustrious *savants* Liebig and Pasteur; but, after all, there is the broad line of demarcation—enzymosis is independent of living organisms, while "fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it." The discussion of the nature of the vital act producing fermentation does not dispose of the fact of its being vital.

259. Definition of Fermentation.—The particular action produced by yeast on wort, and also on the sweet "must," or expressed juice of the grape, was found on investigation to be but one of many chemical actions which are associated with the life, growth, and development of microscopic organisms. Among these may be cited the souring of milk, also of wine into vinegar, and likewise the changes occurring during putrefaction. Consequently the term fermentation is no longer used in its original sense, as signifying a condition resulting in a peculiar seething or boiling appearance, but is applied to that group of chemical changes which are, in Pasteur's words, "correlative phenomena of vital acts beginning and ending with them." Used in its extended sense, **fermentation may be defined as a generic term applied to that group of chemical changes which are consequent on, and inseparable from, the life and development of certain minute microscopic organisms.**

In the chapter on the proteids, it was stated that putrefaction is regarded as a species of fermentation: equally, with the conversion of maltose into alcohol by yeast, it is a change inseparable from living organisms. This of itself is a conclusive answer to Liebig's earlier position, that fermentation is a secondary result of the spontaneous decomposition of proteids, inasmuch as that, in the absence of minute organisms, the decomposition of proteids does not occur: it is consequently not spontaneous, and therefore fermentation cannot be considered as a process dependent on spontaneous decomposition.

260. Modern Theory of Fermentation.—The following is a short statement of this theory. Maltose, proteids, and other fermentable substances do not decompose of themselves, even when subjected to favourable conditions of moisture, warmth, &c., provided that fermenting organisms are rigorously excluded. These, on their introduction, thrive and multiply; taking the nourishment requisite for their development from the substance which is fermented

A special feature characteristic of fermentation is that the amount of matter consumed and changed into other compounds is excessively great, compared with the size and weight of the consuming organisms; consequently a very few yeast globules decompose very many times their weight of sugar, and produce a relatively large quantity of alcohol and carbon dioxide. No very clear reason has as yet been given for this characteristic of fermentation, but the most feasible and probable explanation is that the decomposition of sugar furnishes not only material for the growth and development of cells, but also the heat necessary for the continuance of yeast life. It is this double function of sugar in fermentation which causes the enormous consumption of that compound. Fermentation is thus seen to be like enzymosis in that a small quantity of the active agent induces chemical change in much larger quantities of material; but fermentation goes further, inasmuch as the quantity of fermenting agent itself also increases during its continuance.

In alcoholic fermentation then, yeast, in order to obtain heat and nourishment, attacks glucose or maltose, and excretes or voids carbon dioxide gas, alcohol, and small quantities of other bodies. The assimilative power of yeast is limited to converting the sugar into these substances, which then become, so far as it is concerned, waste products. Other organisms attack the proteids and produce butyric acid and other compounds. Each particular organism has its special products of fermentation.

261. Experimental Basis of Modern Theory.—It is scarcely within the scope of the present work to trace step by step the nature of the various researches which have led to the adoption of the theory just explained. Briefly stated, the first and most important point is that a liquid free from ferment organisms or their germs does not undergo fermentation. In proof of this point, liquids were placed in flasks or tubes, the necks of which were tightly plugged with cotton wool. The liquids were then boiled for some time; the heat destroyed any organisms that might have been present in the liquids or the wool. As the flasks cooled, the contained steam condensed; and air forced its way through the cotton wool, which acted as a filter and stopped off any germs that might have been floating in the air. Hay and beef infusions, must, wort, urine, and other liquids, on being treated in this manner, may be kept for any length of time without undergoing fermentation or putrefaction. That the resistance to fermentation is due to the absence of fermenting organisms, and not to the liquids having been so changed by boiling as to be unfit for fermentation to proceed, is proved by adding a small quantity of yeast or other ferment to the sterile liquid, when fermentation sets in and proceeds vigorously. The chemical changes that are produced depend on the nature of the ferment that has been added. Yeast effects the decomposition of sugar into alcohol and carbon dioxide, other ferments cause putrefaction, and result in the typical bodies characteristic of that change. While these actions are progressing, the ferment is found to be developing and multiplying. Further, if the ferment used be pure, one species only of organism is found in the liquid. Within any possible limits of observation no transformation of one ferment into another occurs: each belongs to a distinct and separate race of organisms. This statement does not deny the possibility of the modification of species by means of a natural process of evolution. There is, on the contrary, strong evidence in favour of the gradual evolution of species in course of time.

262. Varieties of Fermentation.—Among the many changes included under this term, the following are of importance in the consideration of our present subject:—Alcoholic fermentation, resulting in the production of alcohol and carbon dioxide; lactic fermentation, in which sugar is converted into lactic acid; acetous fermentation, in which alcohol is transformed into acetic acid; viscous or ropy fermentation, resulting in the production of mannite and different viscous bodies; and putrefactive fermentation, in which butyric acid and a variety of offensive products are formed.

ALCOHOLIC FERMENTATION AND YEAST.

263. The nature of alcoholic fermentation has already been described. For the sake of exactness, Pasteur's definition of it is appended. "Alcoholic fermentation is that which sugar undergoes under the influence of the ferment which bears the name of yeast or barm." When the word "fermentation" is employed without any qualifying adjective, alcoholic fermentation is always understood.

264. Substances susceptible of Alcoholic Fermentation.—Pre-eminent among these are the glucoses, which are directly split up into alcohol and carbon dioxide. Most other sugars may also be fermented; but usually, as in the case of cane sugar, require first to be hydrolysed to glucose. As already explained, this change is effected, when yeast is added direct to cane sugar, by the enzyme, invertase; which latter functions independently of the cell itself, and therefore the inversion of the sugar is separate and distinct from fermentation proper. Both diastase and invertase are without action upon maltose; and, unlike cane sugar, maltose apparently undergoes no inversion before fermentation, all the evidence pointing to the direct and complete fermentability of this sugar.

Pure yeast is incapable of producing fermentation in either starch paste or dextrin; neither can albuminous bodies, whether of vegetable or animal origin, be fermented.

265. Fermentation viewed as a Chemical Change.—The conversion of glucose into alcohol and carbon dioxide may be represented very simply by the equation—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Carbon Dioxide.}}{2CO_2.}$$

In the case of the direct fermentation of maltose, the reaction is somewhat more complicated, as simultaneously with the production of alcohol and carbon dioxide, the yeast must induce the introduction of the elements of a molecule of water, thus—

$$\underset{\text{Maltose.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Alcohol.}}{4C_2H_5HO} + \underset{\text{Carbon Dioxide.}}{2CO_2.}$$

Taking the action on the glucose as the more simple of the two, the equation given above does not, however, represent the whole of the change, for 100 parts of glucose then would yield—

Alcohol,	51·11
Carbon Dioxide,	48·89
	100·00

Pasteur carefully collected the whole of the alcohol and carbon dioxide produced by fermentation of a definite weight of glucose, and found that he only obtained—

Alcohol,	48·51 per cent.
Carbon Dioxide,	46·40 ,,

100 − 94·91 = 5·09 parts of glucose not transformed into alcohol and carbon dioxide.

The following bodies occur as subsidiary products—glycerin, succinic acid; propyl, butyl, and amyl alcohols; acetic and butyric acids. Of these, the amount of glycerin and succinic acid produced have been found to be—

Glycerin,	3·00 per cent.
Succinic Acid,	1·13 ,,
	4·13

This, therefore, leaves but 0·96 per cent. for the various higher alcohols, and the acetic and butyric acids; and also for that portion of the sugar that goes to help to build up fresh yeast cells.

Monoyer proposes the following equation as showing the production of glycerin and succinic acid from glucose—

$$\underset{\text{Glucose.}}{4C_6H_{12}O_6} + \underset{\text{Water.}}{3H_2O} = \underset{\text{Succinic Acid.}}{H_2C_4H_4O_4} + \underset{\text{Glycerin.}}{6C_3H_5(HO)_3} + \underset{\text{Carbon Dioxide}}{2CO_2} + \underset{\text{Oxygen.}}{O.}$$

No free oxygen is, however, detected in fermentation; any that may be produced during the decomposition is probably used up by the yeast cells for purposes of respiration.

Pasteur claims that the glycerin and succinic acid, as well as the alcohol and carbon dioxide, are normal products of alcoholic fermentation; and further, that these bodies are produced from the sugar, and not from the ferment. He also shows that a portion of the sugar goes to help to build up the yeast globules. The quantities of glycerin and succinic acid produced are not constant, but vary with the conditions under which fermentation proceeds; when the action is slow the proportion of glycerin and succinic acid to alcohol is higher than with brisk and active fermentation.

Brefeld, however, argues that glycerin and succinic acid are not products of alcoholic fermentation proper, but rather are pathological products arising out of the death of the yeast cells. The same view is advanced in a more modernly expressed opinion that these bodies are due to the destructive metabolism[1] of the cells.

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[1] For an explanation of metabolism refer to Chapter XIII., par 385.

A small proportion of the carbohydrate, amounting to about 1 per cent., is assimilated by the yeast and employed in its constructive metabolism, being transformed into cellulose and fats.

266. Chemical Composition of Yeast.—When yeast has been washed carefully so as to free it as far as possible from foreign matters, and then dried, it is found to have, according to Schlossberger, the following composition—

	Surface Yeast.	Sedimentary Yeast.
Carbon, ...	48·7	46·4
Hydrogen, ...	6·4	6·2
Nitrogen, ...	11·8	9·5
Oxygen, ...	30·7	34·5
Ash (mineral matter), ...	2·4	3·4
	100·0	100·0

In addition to the above a number of other analyses might be quoted, showing that yeast is a body of somewhat variable composition; meanwhile attention is directed to the fact that yeast collected from the bottom of the fermenting liquid contains less nitrogen and carbon than does surface yeast.

Various attempts have been made to separate yeast into its proximate principles, and estimate these: as a result it may be stated that yeast contains one or more bodies of the proteid type. There are in addition, also present, cellulose and fatty matters. Payen gives the following as the result of an analysis of moisture-free yeast:—

Nitrogenous matter, ...	62·73
Cellulose (envelopes), ...	22·37
Fatty matters, ...	2·10
Mineral "	3·80

Naegeli states that the proximate constituents of a sample of yeast examined by him were as follows. The yeast was a sedimentary one, containing 8 per cent. of nitrogen:—

Cellulose, gum, and cell membrane, ...	37 per cent.
Proteids, ...	45 "
Peptones, ...	2 "
Fat, ...	5 "
Extractives (leucine, cholesterin, dextrin, glycerin, succinic acid), ...	4 "
Ash, ...	7 "

A sample of distiller's compressed yeast recently examined by the author gave the following results on analysis:—

Proteids, ...	12·67
Fat, ...	0·80
Mineral matter, ...	2·05
Water, ...	73·80
Cellulose, &c. (by difference), ...	10·68
	100·00

The mineral matter of yeast is of great importance, and has been made the subject of careful analysis by Mitscherlich and others. The following table gives the composition of the ash of surface and sedimentary yeasts by Mitscherlich, and of the surface yeast of pale ale by Bull—

	Surface Y.	Sedimentary Y.	Surface Y. of Pale Ale.
	Mitscherlich.		
Phosphoric acid, P_2O_5, ...	53·9	59·4	54·7
Potash, K_2O, ...	39·8	28·3	35·2
Soda, Na_2O, ...	—	—	0·5
Magnesia, MgO, ...	6·0	8·1	4·1
Lime, CaO, ...	1·0	4·3	4·5
Silica, SiO_2, ...	traces	—	—
Iron Oxide, Fe_2O_3, ...	—	—	0·6
Sulphuric acid, SO_3, ...	—	—	—
Hydrochloric acid, HCl, ...	—	—	0·1

Yeast ash is therefore composed principally of phosphoric acid and potash : attention is directed to the similarity in composition between the ash of yeast and that of wheat. The above acids and bases probably exist in combination as the following salts :—

	Surf. Y.	Sed. Y.
Potassium phosphates, ...	81·6	67·8
Magnesium phosphate, $Mg_3(PO_4)_2$,	16·8	22·6
Calcium phosphate, $Ca_3(PO_4)_2$, ...	2·3	9·7

The potassium phosphate must be looked on as a mixture of the dihydric phosphate, KH_2PO_4, and the monohydric phosphate, K_2HPO_4. The former of these phosphates contains 94 by weight of K_2O to 142 of P_2O_5; the latter contains 188 of K_2O to 142 of P_2O_5. The weight of K_2O in the surface yeast ash is between that required to produce either of these two potassium phosphates. The composition of the potassium phosphate of the sedimentary yeast ash nearly agrees with the formula, KH_2PO_4.

267. Yeast as an Organism.—Viewed as an organism, yeast may be said to be a plant of an exceedingly elementary structure ; it is in fact one of the simplest plants known. In very minute forms of life it is difficult to distinguish animals and vegetables from each other, for with almost any definition that may be selected, one or two species wander over the border line. One of the most marked differences between the higher plants and animals is, that the former are able to derive their sustenance from inorganic compounds, their carbon from carbon dioxide, and their nitrogen from ammonia. Animals, on the contrary, can make no use of carbon or nitrogen for the purpose of building up their tissues, unless these bodies are presented to them in the form of organic compounds. Hence, in the economy of nature, it will be found that while plants live and develop, as before stated, by the assimilation of the elements of carbon dioxide and ammonia, animals subsist either on vegetable substances, or on the bodies of other animals. Yeast is unable to assimilate carbon from inorganic sources, but being able to derive its nitrogenous nutriment from inorganic bodies, is placed in the vegetable kingdom. The chemical changes produced during the growth of the higher plants result in the building up of complex compounds from very simple ones: in the animal, complex bodies are required as nourishment, and are broken down into simpler bodies. The complexity here referred to is that which may be measured by the number of atoms in the molecule of the body; thus, water is a very simple compound, while starch has a most complex molecular structure. The chemical operations of plant-life may be summed up as consisting of synthesis; those of animal existence as analysis. In order to effect the synthesis of plant compounds from the substances at the disposal of vegetables, force is required; this they usually obtain in the form of heat from the sun. The act of growth of a plant means, therefore, a continual absorption of heat. On the other hand, animals, in taking complex bodies and breaking them down into simpler ones, liberate heat; consequently, one result of animal life is that heat is continuously being evolved. Yeast, in this particular, partakes both of the nature of an animal as well as a plant. Its nitrogen may be obtained from inorganic sources, but is more usually derived from suitable proteid matter, such as peptones. On the other hand, the carbon of yeast is taken from sugar with the breaking down of that body into simpler compounds, and the consequent liberation of heat; therefore during fermentation the temperature of the liquid rises considerably. From a chemical standpoint, yeast combines in itself the vegetable functions of synthesis with the animal functions of analysis.

268. Botanic Position of Yeast.—This organism belongs to the family of Fungi.

Fungi.—The fungi are those plants which are destitute of chlorophyll (the ordinary green colouring matter of grass, &c.). They reproduce by buds and spores.

Spores.—Spores are a variety of cell, and in all fungi the spores are similar in essential points to the yeast cell; notwithstanding that they may vary considerably in appearance and details of structure.

Hyphæ.—The spore, on being sown in a suitable medium for its growth, throws out a long delicate stem of tubular structure, termed a "hypha." A group of these hyphæ constitute the fungus.

Mycelium.—One of the best typical examples of a fungus is the common green mould found on old boots, bread, jam, &c. This has received the name *Penicillium glaucum.* On examining a specimen of such mould from the top of a pot of jam for instance, its base is found to consist of an interlaced growth of hyphæ, forming a more or less compact web or skin on the jam. This layer of intermingled hyphæ is termed the "mycelium." From its upper surface a number of hyphæ project into the air, each bearing a quantity of very fine green powder, these are termed "ærial hyphæ." On the lower surface again, other hyphæ grow down root-like into the liquid, which supports the mould; these are the "submerged hyphæ."

Conidia.—Some of the ærial hyphæ terminate in short branches, each of which is divided into a series of rounded spores which are only loosely attached to the hyphæ, and so may easily be shaken off; these spores are termed "conidia." Each separate conidium, if sown in a suitable liquid, develops a young fungus, which in its turn rapidly multiplies.

Sporangia.—Some of the fungi, as for instance that known as *Mucor mucedo*, have their hyphæ terminated in rounded heads; each of these is called a "sporangium."

269. Varieties of Yeast.—The yeast fungi constitute the genus *Saccharomyces*; they are so named because they mostly live in saccharine solutions, converting the sugar present into alcohol. The *saccharomyces* have no mycelium, and in common with the other fungi reproduce by buds and spores. The genus *saccharomyces* comprises several species, a detailed description of which will subsequently be given.

270. Nature of Yeast Cells.—The yeast organism consists of cells, mostly round, or slightly oval, from 8 to 9 μ in diameter; the cells may occur either singly or grouped together as colonies. It is impossible to obtain any real knowledge of the physical structure of yeast without a careful and systematic personal examination by the microscope: it has been thought well, therefore, to arrange the following description in such a form as to constitute a guide to actual yeast examination.

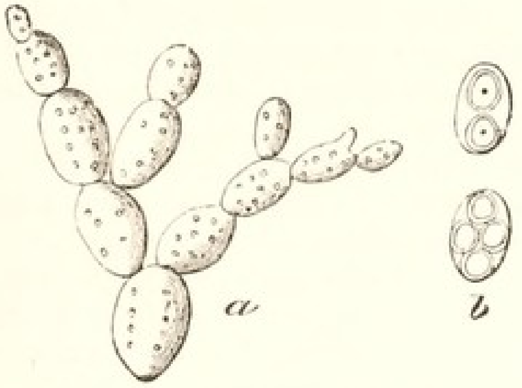

FIGURE 8.—*Saccharomyces Cerevisiæ.*

a, a bud-colony; *b*, two spore-forming cells (after Lürssen).

1. Take either a little brewers' yeast, or bakers' compressed distillers' yeast, and mix with some water until a milky fluid is produced. By means of a pointed glass rod, take a small drop of this fluid and place it on a clean microscopic slide, and gently cover with a cover-glass. Arrange the microscope in a vertical position, and proceed to examine the yeast by means of a fairly high power ($\frac{1}{8}$ objective). Notice that the yeast consists of cells, of which measure a few by means of the eye-piece micrometer, and observe that their dimensions agree with those just given. Each cell consists of a distinct wall or envelope, containing, within, a mass of more or less gelatinous matter devoid of organic structure. The interior substance is named "protoplasm;" this term being applied to that ultimate form of organic matter of which the cells of animals and plants are composed. The protoplasm of the yeast cell is not homogeneous, but is always more or less distinctly granular. Run in magenta solution under the cover-class. (This is readily done by placing a drop of the solution in contact with one side of the cover-glass, and placing a strip of blotting paper on the other.) Notice that

the sac or envelope remains uncoloured, while the protoplasm stains comparatively deeply; the vacuoles are unstained. One or more circular spots can usually be seen in yeast cells as obtained from a brewery; these are caused by the gelatinous matter moving toward the sides of the cell, and leaving a comparatively empty space, containing only watery cell-sap; hence these spots are termed vacuoles. A specimen of yeast is shown in Figure 8.

2. Remove the slide from the microscope, and burst a few of the cells by placing a few folds of blotting paper on the cover-glass, and then pressing sharply with the end of a pencil or rounded glass rod. Again examine under the microscope, note the empty sacs and the extruded protoplasm, which does not readily mix with the water.

If practicable, try this experiment with yeast of various ages; very old yeast cells break more easily, and the protoplasm is more fluid, and takes the colour more readily. By using the magenta stain in a dilute form, old and dead cells may be differentiated from those which are healthy and vigorous—the latter remain unstained, or take up the stain very slightly, while dead cells readily and quickly acquire a magenta hue.

3. Take six clean cover-glasses and coat one side of each with a thin layer of yeast, by painting on the mixture of yeast and water by means of a camel's hair brush, and set aside until thoroughly dry. The yeast adheres firmly to the glass, showing that the outside of the cell-walls is mucilaginous in character.

4. Add a drop of solution of iodine in potassium iodide to one of these covers, let it stand five minutes, and then wash slightly in water, and mount the cover-glass, yeast side downward, on a glass slide. The cell-wall stains slightly, and the protoplasm becomes dark brown; but no blue colour is produced; starch therefore is absent. As the cell envelope is continuous, containing no apertures, the iodine solution must have passed through its substance.

5. Similarly treat another cover preparation with iodine, and then, without washing, add one or two drops of 70 per cent. sulphuric acid. The cell-contents acquire a deeper brown stain, and the cell-walls become brownish yellow, but do not show any blue colouration.

The cellulose of the walls of the cells of most higher plants acquire a blue colour with this treatment, showing the presence of a cellulose allied to that of starch, but the cellulose of yeast, and of fungi generally, is devoid of this property.

6. Treat the yeast on another cover-glass with solution of potash. The protoplasm is dissolved, leaving nothing to be seen but empty cell-walls.

7. Treat another cover-glass preparation with a solution of osmic acid. Note that small, sharply defined, dark coloured bodies are seen. Jörgensen regards these as cell-nuclei of the same nature as those generally observed in the majority of plants without this treatment.

8. Break down a little yeast with water, and focus under the microscope, so as to observe distinctly the small bright granules of fat within the protoplasm of the cells. Put a piece of blotting paper on one side of the cover-glass, and run in at the other a few drops of ether from a fine pipette—the fat granules dissolve and disappear.

271. Life History.—On examining under a microscope a sample of skimmed yeast, as obtained from the brewer, it is found to consist either of single cells, or cells joined together in pairs. Such yeast having usually remained quiescent for some time, the cells rarely occur in large groups, because, with standing, they tend to separate from each other. The granulations in the protoplasm, and also the vacuoles, should be visible. On placing a very small quantity of this yeast in a suitable liquid for its growth, as malt wort, at a temperature of about 30° C. (86° F.), the cells, which at first were somewhat shrunken and filled throughout with granular matter, increase in size from absorption of the liquid in which they are placed. At the same time the granulations becomes less distinct, and the whole cell assumes a more transparent and distended appearance.

To observe this effect, mount a few cells on a microscopic slide with warm malt wort, and keep under observation with the microscope. After a time the round yeast cells become slightly elongated through the formation of a small protuberance at one end ; this grows more marked, until shortly a neck is formed by a contraction of the cell wall. But still, careful examination shows that there is a distinct opening through this neck, the contents of the smaller portion being continuous with those of the cell. As the growth continues, the strangulation at the neck proceeds until the cell wall completely shuts off the protuberance, which then constitutes a new or daughter cell, attached to the parent. This operation is known as "budding." The one parent cell is capable of giving off several buds in succession ; but after a time its reproductive energy is exhausted, and the cell breaks up. These daughter cells in their turn give rise to other cells, and so the multiplication of yeast globules proceeds with remarkable rapidity.

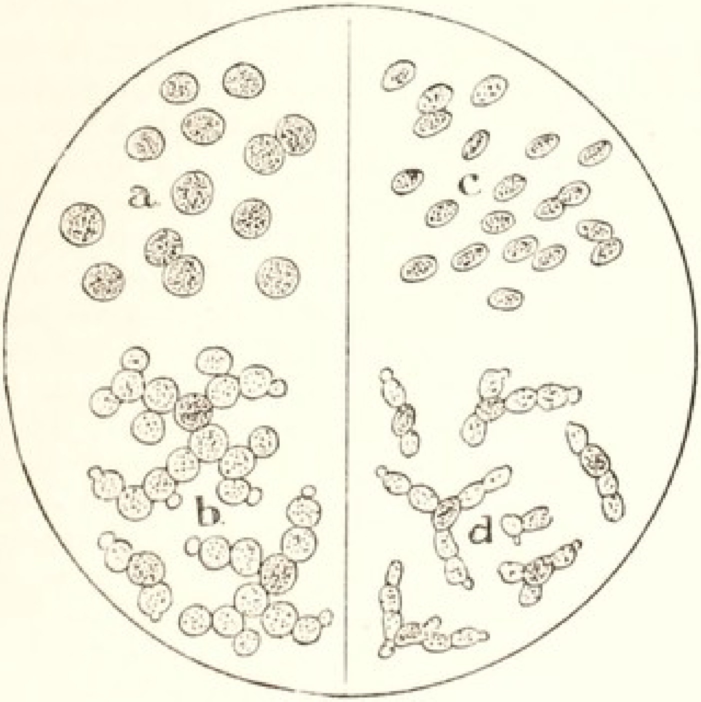

FIGURE 9.—*Saccharomyces Cerevisiæ.*

a, High Yeast, at rest ; *b*, High Yeast, actively budding ; *c*, Low Yeast, at rest ; *d*, Low Yeast, actively budding.

Pasteur states that on one occasion he watched two cells for two hours; during that time they had multiplied by budding into eight, including the original pair of cells. At this stage, buds of every size may be seen attached to the parent cells; some are so small as to be scarcely visible, while others are nearly as large as the parents.

With the progress of this growth and development, sugar is being decomposed, the liquid becomes alcoholic, and its specific gravity diminishes. The brewer terms this change "attenuation," or a becoming thinner. Another reason for the use of this name is that the liquid becomes less viscous, from the conversion of the sirupy solution of maltose into the highly mobile liquid, alcohol. Simultaneously with the production of alcohol, carbon dioxide gas is evolved; this rapidly rises to the surface, and carries up with it the yeast cells, which float on the top of the fermenting wort. Yeast now skimmed off is found to consist of colonies of some scores of cells linked together; the majority of these are clear and almost transparent. Usually in the middle of each such group, the old or parent cell can be recognised by its darker contour and comparatively exhausted appearance. As the quantity of sugar in the liquid becomes less, the fermentation slackens, and finally ceases. If the cells then be again examined under the microscope, they will be found to have a firmer outline, and their contents will be more granular. In what may be termed old age of the yeast cell, the walls become abnormally thick, and the granulations very dense. The yeast, on being removed from the fermenting tun, is usually set aside in store vats; on standing, it gradually assumes the appearance described on that of the yeast used for "pitching" or starting the fermentation. The quantity of yeast thus obtained is considerably in excess of that first added to the malt wort.

In the moist state, yeast decomposes quickly; hence if the store be kept for any length of time, the cells rapidly alter in character. The walls become soft, thin, and weak, and the interior protoplasm changes from its normal granular gelatinous condition to a watery consistency. After a time, if viewed with a high power, a distinct "Brownian" movement is seen of particles suspended in the contents of the cell. The particles may very possibly consist of minute fragments of cellulose from the envelopes. After a time the walls also break down and all traces of the yeast organism disappear. The normal bodies produced by the decomposition of nitrogenous and proteid bodies may now be detected in the liquid: putrefaction rapidly follows, with the production of a most offensive odour. Such is in broad outlines the life history of a yeast cell, when sown under normal conditions in malt wort.

Distillers' yeast putrefies much more readily than does that of the beer brewer: the hops used in the latter act as an antiseptic, and the yeast putrefies much less readily. Evidence of this is afforded in the method employed for the preparation of invertase from brewers' yeast.

High yeast produces a beer having a special and characteristic flavour, which distinguishes it at once from beer brewed with low yeast.

272. Influence of Temperature on Yeast Growth.—The temperature most favourable to the growth of yeast is from 25° C. to 35° C. (77° and 95° F.) Between these points yeast flourishes and grows well; at temperatures lower than 25° growth proceeds, but not so rapidly. At a temperature of about 9° C. (49·6° F.), the action of yeast is arrested; the vitality, however, of the cell is only suspended, not destroyed, for with a higher temperature it again acquires the power of inducing fermentation. Actual freezing does not destroy yeast, provided the cells do not get mechanically ruptured or injured. Above 35° C., the effect of heat is to weaken the action of yeast, until at a temperature of about 60° C. (140° F.), being that at which proteid principles begin to coagulate, the yeast is destroyed. This applies to moist yeast. When dry, the cells are able to stand higher temperatures than when suffused with water; thus, dried yeast has been heated to 100° C. without destroying its vitality.

Although a temperature of from 25° to 35° C. conduces to the rapid growth of yeast, yet there are other circumstances which render it advisable to conduct actual brewing operations at a much lower temperature. In English breweries, a pitching temperature of about from 18° to 19° C. (65° F.) is commonly employed: during the fermentation the heat rises to from 21° to 22° C. (72° F.).

Faulkner states that a tun of pale ale, containing 200 barrels of 36 gallons, on being pitched with 600 lbs. of yeast at 14·5° C. (58·1° F.) had sufficiently attenuated in 46 hours, during which time the temperature had risen to 22·2° C. (72° F.).

273. Substances Requisite for the Nutriment of Yeast.—It has several times been stated that sugar is required by yeast during its growth: as yeast cells likewise contain nitrogenous matter, and also certain inorganic constituents, it is evident that nitrogen in some form, and also the requisite mineral salts, must be supplied to the growing yeast. Summing these up, yeast requires for its growth, sugar, nitrogenous compounds, and appropriate inorganic matter.

274. Saccharine Matters.—These occupy the first and paramount position, as being absolutely necessary for the production of alcoholic fermentation. Pure yeast sown in a pure sugar solution causes it to ferment; but without the sugar neither alcohol is produced, nor carbon dioxide evolved. Malt wort, grape juice or "must," and dough, all ferment on the addition of yeast, because they all contain sugar. **"It is necessary indeed that sugar be present; for, if we abstracted by some means or other from the must or dough all the sugar contained in it [1][and also all substances capable, by the addition of yeast to flour, of being converted into sugar], without touching the other constituents, the addition of yeast would produce no gas. Everything would remain quiet until the moment when signs of a more or less advanced putrefaction showed themselves." (Pasteur).** It should be mentioned that yeast is also capable of inducing definite chemical changes in a few other bodies: among these is malic acid, which is broken up into succinic and acetic acids, carbon dioxide, and water. It is also stated that yeast decomposes glycerin into propionic and acetic acids; this

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[1] The clause in brackets, [ ], is inserted by the author.

change has been denied by Roos and Brown. As neither malic acid nor glycerin (in the free state) occur as constituents of flour, their fermentation lies altogether outside the scope of the present work.

Maltose and the glucoses, or sugars of the $C_6H_{12}O_6$ group, are the only sugars capable of direct fermentation; of these, dextrose is more readily decomposed by yeast than is lævulose. The two being together in the same solution, it is stated that the lævulose remains unacted on until the disappearance of the whole of the dextrose. Certain other sugars are capable of indirect fermentation by yeast; among these are cane sugar, which first, however, requires to be hydrolysed to glucose by the action of the invertase or soluble diastasic body secreted by the yeast cell. As already explained, this preliminary diastasis can be effected by yeast water, that is, water with which yeast has been shaken up, and then filtered in order to remove the whole of the yeast cells; such yeast water is, of course, totally incapable of setting up alcoholic fermentation.

Yeast causes certain effects, of which it is difficult to say whether they are absolutely correlatives of vital acts, as on organism, or merely results of diastasis. For practical purposes, it matters little to which of these two classes of chemical action any specific change produced by yeast belongs; in such cases it is the action of yeast, as a whole, that is of importance.

Sugar of milk is incapable of fermentation by yeast. Yeast alone is also unable to ferment either starch paste or dextrin: these bodies require some more powerful agent for their diastasis, such as malt extract. As mentioned in Chapter VIII., yeast, indirectly through its action on the proteids of barley or wheaten flour, transforms starch paste into dextrin and maltose, after which the yeast induces fermentation. Consequently, the two, yeast and proteids, in conjunction, are capable of effecting changes which neither can separately produce.

It almost goes without saying that water is necessary for the development of yeast, so requisite is it that saccharine solutions containing over 35 per cent. of sugar are incapable of fermentation. Such a solution, by outward osmose through the cell wall, deprives the yeast of its normal proportion of water as a constituent.

275. Nitrogenous Nutriment.—Yeast is capable of utilising, during its growth, the nitrogen of ammoniacal salts (but not that of the acid radical of nitrates); thus, a solution of pure sugar, mixed with either ammonium tartrate or nitrate, and certain non-nitrogenous inorganic salts, permits a healthy development of yeast. With the multiplication of the yeast cells, the amount of proteid matters present increases; therefore, by the action of yeast, the ammonium compounds are transformed into proteid bodies. Although yeast thus acts on ammonium salts, organic nitrogenous compounds form a more suitable nutriment; among such substances, the soluble proteids of yeast itself are especially seized on by yeast. Consequently, always supposing the presence of the inorganic salts required by yeast, yeast water and sugar form an admirable medium for its growth and development; so, too do natural saccharine juices, as "must," the juice of apples, pears, &c. In addition to these, malt infusion must be mentioned.

Albumin, whether from the white of egg or vegetable albumin, is entirely unfit for the nourishment of yeast. This fact is stated with force by Pasteur, whose opinion is confirmed by that of Mayer, who ascribes the inactivity of albumin, casein, and other similar bodies, to their highly colloid nature. The solution molecules of soluble proteids of malt have such an appreciable volume, that filtration of the solution through a thin porous earthenware diaphragm under slight pressure is sufficient to prevent these bodies from passing through into the filtrate (Brown and Heron). It may then be readily understood that yeast cell walls are impermeable to proteid bodies. The compounds produced by digestion of albumin and its congeners, the peptones, are much more diffusible, and are eminently suited for affording the requisite nitrogenous nutriment to yeast. Pepsin itself forms an admirable yeast food. Schützenberger considers it probable that must, malt wort, and yeast water owe their power of nourishing the cells of yeast, not to the proteid bodies, but to certain of their constituents that are analogous to the peptones, and which have the property by osmose of passing through the cell walls.

276. Mineral Matters necessary for the Growth of Yeast.—For his experiments on yeast, Pasteur used yeast ash as the source of his mineral matter. It is obvious that this substance may be replaced by an artificial mixture of the salts contained therein. A reference to Mitscherlich's analyses of yeast ash shows that the principal ingredient is potassium phosphate; together with this, there is magnesium phosphate and small quantities of phosphate of calcium. Pasteur finds, when an unweighable quantity of yeast is sown in a solution of pure sugar and ammonium tartrate, that development of cells and fermentation do not take place; the addition of yeast ash enables both to occur. Mayer endeavoured further to ascertain what salts are, in particular, necessary among those present in the ash. Potassium phosphate is absolutely indispensable; neither sodium nor calcium phosphates are competent to replace it. Magnesia is also of great value, if not indispensable, to the development of yeast; this base may be supplied either as sulphate or phosphate. Lime seems not to be absolutely necessary to yeast growth.

277. Insufficiency of either Sugar or Nitrogenous Matter only for the nutriment of Yeast.—Yeast is incapable of healthy development in solutions of sugar alone. A limited growth occurs when the quantity of yeast added is considerable, because, by a species of cannibalism, the healthier and stronger cells survive and develop to some extent by feeding on the nitrogenous and mineral matters obtained from the others. Necessarily, such growth must soon stop. Yeast was stated by Pasteur to multiply in a nitrogenous liquid, such as yeast water, "even when there was not a trace of sugar present, provided always that atmospheric oxygen is present in large quantities." Yeast finds air to be under these conditions an absolute necessity. Without it no development proceeds, nor is there any but the slightest trace of alcohol found; carbon dioxide gas is evolved, being formed by direct carbonisation of oxygen derived from the air. But, for this change, it must be remembered that air is a necessity. Assuming the correctness of Pasteur's views as to the growth of yeast by the assimilation of atmospheric oxygen, and expiration of carbon dioxide, it is necessary to remember that the conversion of oxygen into carbon dioxide gas results in no change of volume; this is clearly seen by reference to the molecular equation—

$$\underset{\text{Carbon.}}{C} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Under ordinary conditions of fermentation, albumin does not evolve alcohol or carbon dioxide gas. Neither does pepsin when similarly treated, although this body is well adapted as a nitrogenous food for yeast. Albumin is also unacted on when its solution is first of all mixed with a 2½ per cent. solution of sodium chloride.

278. Behaviour of Free Oxygen on Yeast.—As stated in the preceding paragraph, Pasteur regarded atmospheric oxygen as capable of acting as a substitute for sugar in the nutriment of yeast, and accordingly he examined very carefully the general behaviour of free oxygen and yeast to each other. In consequence, he developed the following theory of fermentation, which until comparatively recently has been generally accepted.

Pasteur states, as a result of experiment, that yeast grows better in shallow than in deep vessels. As a result of some determinations made, in which one sample of yeast and a saccharine solution were kept in an air-free flask, and another in a shallow vessel, by which it was freely exposed to the atmosphere, he finds that the proportion of yeast produced to the sugar consumed was much greater in the latter than in the former instance. By dint of most careful experiment he further finds, while a fermentable liquid may be made to ferment out of contact with air, yet in order that it shall do so it is essential that young and vigorous yeast cells shall be employed. With older yeast the fermentation proceeds more slowly, and with the production of malshaped cells, while a yeast still older is absolutely incapable of reproduction in a liquid containing no free oxygen. This is not due to the yeast being dead, for on ærating the liquid, either with atmospheric air or oxygen, fermentation proceeds apace. Pasteur therefore concluded that under favourable circumstances yeast functions as a fungus; that is, it lives by direct absorption of oxygen from the air, and the return of carbon dioxide gas. He consequently assumed the following relationship between its life in free oxygen and its life when submerged in a sugar solution—Let some yeast be sown in a sample of malt wort, containing as much oxygen as it can possibly dissolve; the yeast starts active growth, and rapidly removes all the free oxygen from the liquid, *after* which it commences to attack the sugar. During this time, yeast will be living not as a ferment but as a fungus, namely, by direct absorption of oxygen. Could each yeast cell be supplied with all the oxygen it requires in the free form, it is probable that it would not exert the slightest fermentative action; it would, at the same time, grow and reproduce active healthy cells with great rapidity. As soon as the whole of the air is exhausted, the yeast attacks the sugar, and obtains its oxygen by the decomposition of that compound, and ordinary fermentation proceeds. Consequently, yeast must be viewed as being capable of two distinct modes of existence, in free oxygen as a fungus; when submerged in a saccharine solution, as a ferment. Of the two the fungus life is the easiest; that is, yeast can perform its vital functions more readily when it obtains its oxygen in the free state than when it has for that purpose to effect the decomposition of large quantities of sugar. If yeast be grown continuously in saccharine solutions, under conditions which result in the rigid exclusion of air, fermentation becomes more and more sluggish: the conditions of life are in fact more severe than the yeast can stand, the struggle for existence is too acute, and its vitality succumbs. But if a sample of fermenting wort be taken at a time when, although the sugar is far from exhausted, the fermentation has become sluggish, and then thoroughly ærated by some means which shall bring it into full contact with air, a remarkable change ensues. At first the fermentation slackens, but the rate of growth of yeast increases; this is due to its living as a fungus on the dissolved free oxygen. During this time it exerts little action as a ferment, but grows and accumulates vital energy. After a while, the fermentation proceeds much more vigorously than before the æration; this is a necessary result of the renewed energy and vitality of the yeast cells.

That oxygen is capable of acting in some way as a stimulant to fermentation was known to brewers long before the announcement of this theory by Pasteur, as they had found that by "rousing" (stirring) tuns of wort that were fermenting sluggishly, the fermentation was invigorated. The agitation following from this rousing ærated the wort.

To borrow his own words, Pasteur summed up his theory of fermentation in the following terms:—"Fermentation by yeast is the direct consequence of the processes of nutrition, assimilation, and life, when these are carried on without the agency of free oxygen. . . . Fermentation by means of yeast appears, therefore, to be essentially connected with the property possessed by this minute cellular plant of performing its respiratory functions, somehow or other, with oxygen existing combined in sugar. Its fermentative power varies considerably between two limits, fixed by the greatest and least possible access to free oxygen which the plant has in the process of nutrition. If we supply it with a sufficient quantity of free oxygen for the necessities of life, nutrition, and respiratory combustions, in other words, if we cause it to live after the manner of a mould, properly so called, it ceases to be a ferment; that is, the ratio between the weight of the plant developed and that of the sugar decomposed, which forms its principal food, is similar in amount to that in the case of fungi. On the other hand, if we deprive the yeast of air entirely, or cause it to develop in a saccharine medium deprived of free oxygen, it will multiply just as if air were present, although with less activity, and under these circumstances its fermentative character will be most marked; under these circumstances, moreover, we shall find the greatest disproportion, all other conditions being the same, between the weight of yeast formed and the weight of sugar decomposed. Lastly, if free oxygen occur in varying quantities, the ferment power of the yeast may pass through all the degrees comprehended between the two extreme limits of which we have spoken." According to this view, fermentation is a starvation phenomenon, brought about by the want of free oxygen during the life of yeast cells in a fermentable liquid.

279. Brown on Influence of Oxygen on Fermentation.—In 1892, Adrian J. Brown contributed an important paper on this subject to the Journal of the Chemical Society, which paper necessitates a re-consideration of the theory of fermentation. In his experiments, Brown employed the method of *counting* the yeast cells in his various solutions, by means of the hæmatimeter, instead of *weighing* the yeast, as had been done by Pasteur in his various researches. This method of working has the advantage that the results are capable of being referred to the amount of effect being produced by the action of an unit cell.

Brown's first conclusions were that "when any fermentable nutritive solution, such as malt wort, or a solution of dextrose in yeast water, is inoculated with a high fermentation yeast, and kept at a temperature favourable to yeast growth, the cells reproduce themselves rapidly for a time, and then their reproduction ceases, and that the fermentation of the solution may still be carried on by the continued life of the cells already formed." Further, he found that with the same liquid, under the same conditions, the cells increase to about the same maximum, no matter how the number of cells introduced to start the fermentation may vary. In support of this view, the following experiment is quoted —Two flasks, A and B, were taken, and in each 150 c.c. of the *same* malt wort was placed, and then a different amount of the same yeast added to each. The contents of the flasks were thoroughly agitated, and the cells counted by the hæmatimeter. (The standard volume of the instrument employed was $\frac{1}{4000}$ of a cubic millimetre, called hereafter "Standard Volume.") The flasks A and B contained respectively 0·93 and 7·44 cells per standard volume. The flasks were kept at 25° C. until fermentation had completely ceased, when the cells were again counted. In flask A the number of cells per standard volume had increased from 0·93 to 25·24; whereas in flask B the increase was from 7·44 to 27·08. The rate of increase differed widely, but the ultimate number of cells produced was approximately the same. From these and a number of other similar experiments, the conclusion is drawn that in such fermentations the number of yeast cells increases to some fixed maximum, irrespective of the number originally added to induce fermentation.

The next point was to experiment by adding more cells than this maximum number, two similar flasks of malt wort were respectively seeded with 6·0 and 70·8 cells of yeast per standard volume. Fermentation was allowed to proceed, and, at its close, in No. 1 flask the cells had increased from 6·0 to 24·9, while in No. 2 they had decreased from 70·8 to 68·2 cells. In this experiment 24·9 cells may be regarded as the maximum number that the wort used would grow, consequently with No. 2 flask there is no increase. Brown regards the actual diminution as due to the death and disintegration of some of the cells. In the second flask as well as the first, fermentation proceeded with great rapidity. Other experiments made yielded the same results; therefore, if a nutritive liquid be seeded with a considerably larger number of yeast cells than the maximum number it is capable of producing by reproduction, fermentation proceeds, and a method is afforded of studying fermentation without multiplication of yeast cells. Having, throughout the experiment, the yeast a constant quantity evidently eliminates many disturbing factors present when the quantity of yeast is variable.

Brown in the first place applied this method to the investigation of the action of oxygen on yeast. A malt wort of 1065 sp. gr. was taken, and yeast added to the extent of 85 cells per standard volume. 120 c.c. of this solution were poured into a flask, A, so as to nearly fill it; its mouth was then stopped in such a manner as to permit the escape of carbon dioxide gas, but to prevent air gaining access to the solution. 120 c.c. of the same solution were also placed in another flask, B, of about 1500 c.c. capacity, so that it simply formed a thin layer on the bottom; this flask was so arranged as to permit a current of air being drawn through the liquid. Both flasks were thus similar, except that from the one air was excluded, while the contents of the other were subjected to abundant æration. The fermentation was conducted at 19°, and, after the end of three hours, arrested by the addition of salicylic acid. The liquids were distilled, and the amount of alcohol produced estimated from the specific gravity of the distillate. In A, flask, without æration, 3·35 grams of alcohol had been formed; while in B, through which a continuous current of air had been drawn, the alcohol amounted to 3·56 grams. The number of yeast cells remained unaltered at the close of the experiment, but slight attempts at abortive budding were observable, particularly in the ærated flask. Another experiment was tried, in which the fermentable medium was a solution of dextrose in yeast-water, which was seeded with 90 cells per standard volume. At the end of three hours, fermentation was arrested, and the residual sugar in the solutions determined polarimetrically. In A (unærated) 1·96 grams of dextrose had been fermented; while in B (ærated) the quantity of fermented dextrose was 2·32 grams. In neither case was there any sign of budding or enlargement of the cells.

In order to meet the objection that the mechanical effect of æration might stimulate the action of the cells in the B flasks, the following pairs of experiments were made in which the A flasks were subjected to the action of currents of carbon dioxide and hydrogen respectively, and at about the same rates as the air through the B flasks. The following were the results:—

"A" flask, with carbon dioxide passed, 3·99 grams of dextrose fermented.
Companion B flask, with air passed, 4·28 ,, ,,
"A" flask, with hydrogen passed, 2·26 ,, ,,
Companion B flask, with air passed, 2·45 ,, ,,

In every case the most work is done in the presence of oxygen.

In all the preceding experiments, as the consequence of the employment of large quantities of yeast, fermentation proceeded very rapidly; in order to watch the results under slower conditions, experiments were made with fermentation at a low temperature, 7° C. (44·6° F.), and were continued for 24 hours. Through A flask hydrogen had been passed, and 4·882 grams of dextrose had been fermented; while in B flask, through which air had been passed, the quantity was 5·289 grams. During the 24 hours 190 litres of air had been passed through B flask. In none of the preceding experiments was there any multiplication of yeast.

These results are in striking contradiction to the views of Pasteur, who affirms that in the presence of excess of oxygen fermentation practically ceases. **Brown, on the contrary, finds uniformly that in the presence of oxygen fermentation is more vigorous than in its absence.**

As Pasteur's results were obtained by weighing yeast, Brown in one experiment weighed as well as counted his yeast. At the commencement there were in each flask 87·6 cells per standard volume, and in 100 c.c. 1·903 grams of filtered, washed, and dried yeast. Fermentation resulted in the destruction of 6·20 grams of dextrose in the hydrogen flask, and 7·38 grams in the air flask. No increase in the number of cells had occurred, but the weights of yeast, treated as before, were respectively from hydrogen flask 2·130 grams, and air flask 2·060 grams. In both cases there is a slight increase in weight, due probably to assimilation by each individual cell, but in both cases at the finish of the fermentation we have almost exactly *the same weight of yeast*, as well as the same number of cells. Hence equal amounts of yeast, whether determined by weighing or counting, ferment rather more sugar when supplied with air than when deprived of it.

Another important experiment proceeded on different lines. The object was to determine the rate of multiplication of cells, and, at the same time, the rapidity of fermentation. Six similar flasks of dextrose in yeast-water were taken, and each seeded with 0·65 yeast cells per standard volume. All were allowed to ferment under similar conditions. At intervals, one of the flasks was taken and the number of yeast cells found, and the quantity of alcohol produced determined, with the following results:—

	A.	B.	C.	D.	E.	F.
Time of commencement of experiment, and subsequent determinations in separate flasks.	Number of cells found in each experiment.	Mean number of cells present during each interval of time.	Total grams of alcohol found in each experiment in 100 c.c. of the liquid.	Grams of alcohol found in each interval of time in 100 c.c. of the liquid.	Proportion of grams of alcohol per 100 c.c. to a single cell, in each interval of time.	Interval of time in each experiment in hours.
Jan. 9, 11 P.M.	0·65	...	...	...	...	...
,, 10, 11 A.M.	4·87	2·76	0·654	0·654	0·237	12
,, 10, 11 P.M.	12·03	8·45	1·933	1·279	0·151	12
,, 11, 11 A.M.	15·38	13·70	2 975	1·042	0·076	12
,, 12, 11 A.M.	15·88	15·63	4·237	1·262	0·080	24
,, 13, 11 A.M.	15·80	15·80	6·187	1·950	0·123	24

It will be noticed that the number of cells increases rapidly in the earlier stages of fermentation, and that also the proportion of alcohol produced by each single cell is greatest during the first twelve hours. This is contrary to general views that fermentation is slower during the more rapid multiplication stage of the development of yeast, an effect which was supposed to be a result of oxygen in the liquid, which, while aiding the reproduction of the cells, at the same time limited their fermentative power. Brown's experiments contradict this theory.

In a further paper communicated to the Chemical Society in 1894, A. J. Brown devotes himself to a critical examination of Pasteur's theory; of which criticism the following is a brief outline:—Pasteur, as previously explained, compared the fermentative power of yeast cells under varying conditions of æration, and arrived at the conclusion that when æration is perfect, fermentative power ceases, and when æration is reduced, fermentative power increases. The type of experiment used for this purpose was that of determining, under varying conditions of æration, the proportion of the weight of the yeast formed to the weight of sugar fermented. This ratio of yeast to sugar is, Pasteur considers, an expression of fermentative power. If, as Pasteur argued, the amount of yeast formed during fermentation were in direct proportion to the sugar fermented, the ratio of yeast to sugar would remain constant, however much or little sugar were available. Brown contends that his experiments show conclusively that such is not the case, there being no direct proportion between weight of yeast formed and sugar fermented. In order to show that the total fermentative power of yeast has not been measured in Pasteur's experiments, a fermentation was carried on under ærobic conditions until the sugar originally present was decomposed. Afterwards, using the principle of overcrowding as a means of preventing reproduction, the crowded cells were fed with more sugar. Feeding was carried on at intervals until three times the original weight of sugar had been thus fermented, but no increase in the weight of yeast had occurred. In Brown's opinion, Pasteur's apparent deficiency in fermentative power was due to the employment of a limited amount of sugar in the experiment. Brown objects to Pasteur's ærobic experiments in shallow dishes, because they were allowed to continue but a limited time, and therefore a *time* factor is introduced: further, cane-sugar was used as the fermentable material, and consequently the results were complicated by the hydrolytic functions of the yeast having to precede fermentation. Pasteur's measure of fermentative power in the experiments referred to is an expression of the action of the inversion and fermentative functions in a limited *time*. Brown concludes by submitting, in place of Pasteur's theory that fermentation is "life without air," the hypothesis that "yeast cells can use oxygen in the manner of ordinary ærobic fungi, and probably require it for the full completion of their life-history; but the exhibition of their fermentative functions is independent of their environment with regard to free oxygen." Nothing in the results of any of Pasteur's experiments are contradictory to such an hypothesis.

280. Mal-Nutrition of Yeast.—When yeast is deprived of a normal proportion of each of the necessary constituents for its healthy life, the vitality of the cells is thereby lessened. One result of this is that the cells tend to assume abnormal forms. Thus, when grown without access of free oxygen, yeast cells elongate, and at times are observed to be several times as long as broad (sausage-shaped). The same peculiarity of outline may be noticed in yeast that has been grown in sweetened water. The reason may be that, with a deficient supply of nutriment, each cell stretches itself out, as it were, in order to expose as great a surface as possible to the medium. It is well known that the area of surface of a sphere is less in proportion to its cubical contents than is that of a cylinder or of any other solid body. By offering a greater surface to the liquid in which it is growing, the yeast cell presumably is enabled to absorb a greater amount of nutriment. In breweries where sugar is largely used as a substitute for malt the yeast suffers from the low percentage of nitrogenous matters contained in the wort: the result is that such yeast has little vitality and is soon exhausted.

Large quantities of mineral salts also affect the shape of the yeast cell; thus, the yeast of Burton ale is oval (egg-shaped) in outline: the Burton water is extremely hard, containing calcium sulphate in large quantities.

Badly nourished yeast, on examination, is usually found to have abnormally thin and fragile cell walls, these being broken by the slightest pressure; the contents of the cells are also thin and watery, instead of full of healthy granulations of gelatinous protoplasm.

281. Sporular Reproduction of Yeast.—In addition to the budding process already described, yeast also reproduces, when deprived of all nourishment, by the formation of spores within the cell. To observe this effect, prepare first a block of plaster of Paris by taking some of the powder, rapidly making it into a thin paste, and then pouring same into a cardboard mould. Let it set, and then strip away the cardboard. Smear on the thin surface of the plaster a little pressed yeast which has been previously washed in distilled water. Place the block with yeast face upwards in a shallow dish, and pour in water until its surface is just a little below that of the yeast. Cover it over with a glass shade to keep out dust, &c., and stand in a warm place (about 20—25° C.). Each day remove a little and examine under the microscope; after a few days some of the cells will show denser masses of protoplasm aggregated around from two to four points. These gradually grow, and at last occupy the whole of the interior of the cell. They become coated with cell envelopes, and then constitute ascospores. The walls of the ascus or mother-cell after a time disappear, and the liberated spores perform the functions of yeast, inducing fermentation, and reproducing by the ordinary mode of budding. Among the conditions necessary for spore formation are young and vigorous cells, comparative absence of nutriment, and a fairly warm temperature. The speed of spore formation is greatly influenced by the latter condition; within certain limits increase of temperature quickens the formation of spores. This is also termed multiplication by *endogenous* division. Cells containing ascospores are shown in Figure 10, which represents the first stages of development of the spores of *S. Cerevisiæ* I., after Hansen: *a*, *b*, *c*, *d*, *e* contain rudiments of spores, with the walls not yet distinct; *f*, *g*, *h*, *i* are completely developed spores with distinct walls.

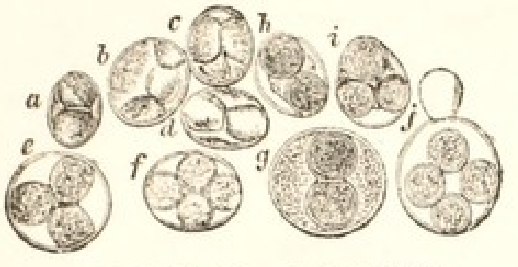


FIGURE 10.—ASCOSPORES.

282. Substances inimical to Alcoholic Fermentation.—Dumas has carefully investigated the action of foreign substances on alcoholic fermentation; Schützenberger quotes largely from his results; the following data obtained by Dumas are taken from the English translation of Schützenberger's work. In the first place, a series may be given of those bodies which retard, and when in sufficient quantity absolutely arrest, fermentation. These include the mineral acids and alkalies (phosphoric acid excepted), soluble silver, iron, copper, and lead salts; free chlorine, bromine and iodine, alkaline sulphites, and bisulphites of the alkaline earths, manganese peroxide; essences of mustard, lemon, and turpentine; tannin, carbolic acid (phenol), creasote, salicylic acid; sugar in excess, alcohol when its strength is over 20 per cent.; and hydrocyanic and oxalic acids, even in small quantities. Phosphoric and arsenious acids are inactive. Sulphur has no effect on fermentation, but the carbon dioxide gas evolved contains from one to two per cent. of sulphuretted hydrogen.

As may be gathered from the statement of the chemical changes produced by yeast, that substance gives always a more or less acid reaction. Dumas states that this acidity requires, for its neutralisation, alkali, equivalent to 0·003 grams of normal sulphuric acid per gram of yeast. In his experiments he added various acids to yeast in proportions of from one to a hundred times the normal acid of the yeast. In this manner were determined the retarding or other action of the various acids on fermentation. Similar experiments were made with bases, and also salts; with the latter, saturated solutions were first made; the yeast was allowed to soak in these for three days, and then its fermenting power tested by its action on pure sugar. Dumas divided the salts into four groups. First, those under whose influence the fermentation of the sugar is entire, and more or less rapid; second, those which permit partial but more or less retarded fermentation; third, those which permit the sugar to be more or less changed, but without fermentation; fourth, those that prevent both change and fermentation. Alum is placed in the first of these classes, borax in the second, and sodium chloride (salt) in the third. Strychnine has no effect on the properties of yeast. For a detailed account of Dumas' results the student is referred to Schützenberger's work.

283. Isolation of Yeast and other Organisms.—As a preliminary to the study of varieties of yeast, it is absolutely necessary to just have some means of separating and growing each variety in a state of absolute purity. Pasteur did an enormous amount of work in this direction ; but the crucial point in all such investigations as these is the purity or otherwise of the yeast used to commence the experiment ; in all Pasteur's researches he used an apparatus which afforded most excellent means for the prevention of the incursion of foreign germs during his growth ; but he does not give us an absolutely certain method of obtaining a perfectly pure yeast to start with. In flasks of special construction, well known as "Pasteur's Flasks" (Figure 11), Pasteur introduces wort, then sterilises the same by boiling it, and afterwards sows therein a small quantity of the yeast he wishes to cultivate in the pure state. The Pasteur's Flasks have a long narrow neck, which, as shown in the illustration, is bent twice on itself, the end being stopped with a plug of cotton wool. In addition, there is a side tubulure, stopped with india rubber tubing and a glass plug. The wort is introduced through the side tube, and when boiled the steam escapes through the bent tube. On cooling, the air which enters is sterilised by filtration through the cotton wool. The yeast is sown during a momentary removal of the glass plug. On the completion of this fermentation, a little of the new growth of yeast is taken and transferred with all due precautions to a second Pasteur's Flask of sterilised wort, and there again fermented. The yeast was grown in this way again and again, until the experimenter was of opinion that the preponderating growth of the yeast would have crowded out of existence any foreign germs. To further aid in accomplishing this object, Pasteur also introduced in his growth-flasks some substances inimical to the organisms he wished to exclude, or else worked at a temperature specially favourable to the particular organism whose growth he desired to favour. The yeast obtained in this manner he terms pure yeast ; undoubtedly this may be possible, and in many experiments was probably the case ; but it is nevertheless only a possibility we have to deal with, for the germs of foreign organisms may not be really dead, but only present in smaller quantity and in a weaker condition. More recent investigators have described methods by which it is possible to cultivate and develop the growth of yeast from one single isolated cell ; in this manner giving the surest guarantee of the actual purity of the yeast produced.

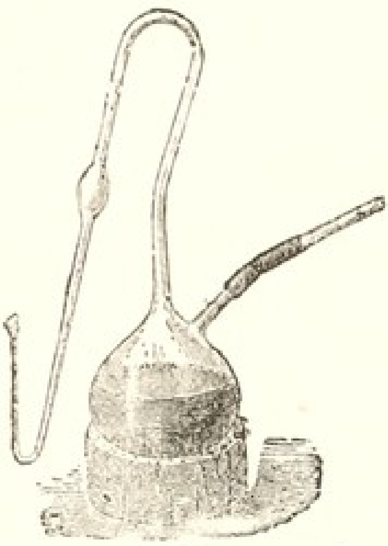


FIG. 11. "PASTEUR'S FLASK."

A first step in this direction is the adoption of what is known as "Nægeli's Dilution Method," which is based on diluting down the liquid under examination until a single drop will, on the average, contain but one organism. This may be accomplished in the case of yeast by taking a drop of the mixture of yeast and water, diluting it down considerably with water previously sterilised by boiling, until the number of cells present in a drop can be counted under the microscope. If these are estimated, for instance, to be about one hundred, then this liquid is further diluted to a hundred times its volume. Every precaution must be taken to sterilise all vessels and liquids used in the operation. Each drop of this ultimate dilution of yeast should contain one cell only. Ten drops are then placed in 20 c.c. of sterilised water, and thoroughly agitated. One c.c. is then placed in each of 20 separate flasks containing culture fluid, which may, for example, be sterilised wort. The probability is that ten out of the twenty flasks will contain but one organism only, the others remaining unimpregnated. But here again it is only a balance of probabilities, and no certain inferences may be drawn. Hansen proceeded a step further by showing that, if the inoculated flasks are vigorously shaken, and then allowed to stand, the yeast cells will sink to the bottom and attach themselves to the sides of the flask. If more than one cell be present, the probabilities are that they will lie on the bottom some distance apart. After some days the flask is raised carefully, and each yeast cell will be the centre of a small white speck visible to the naked eye, and consisting of a colony of yeast. If only one such speck be found, the flask contains a pure culture from one cell only. Subsequent cultivation may proceed on the lines laid down by Pasteur.

Koch, in his experiments on *Bacteria* (certain minute organisms to be hereafter described), used specially prepared gelatin as a cultivating medium. The material was mixed with water until it acquired such a consistency as to set, when cold, into a jelly, which became fluid at a temperature of 35° C. For a cultivation experiment some of the gelatin is melted, a few of the *bacteria* are taken out on the point of a needle and added to the gelatin. They are then diffused by shaking up the mixture, which is next poured out upon a flat surface properly protected. After some hours, a separate and pure culture is obtained from each single *bacterium* present. On taking a minute particle from one of these little culture spots, and again sowing it in gelatin, a single species of *bacterium* was obtained. It was by experiments based on this principle, but carried out with most special precautions, that Koch isolated and exhaustively studied the "*Comma Bacillus*" of cholera, so inseparably associated with his name.

Hansen modified this method for yeast culture, using, instead of Koch's nutrient gelatin (which consisted usually of meat broth and gelatin), a mixture of hopped wort and gelatin. In a bright hopped wort of about 1058 gravity is dissolved from 5—10 per cent. of gelatin, the quantity being regulated so as to cause the mixture to "set" at 30—35° C., being solid below, and liquid above those temperatures. This mixture must, of course, be thoroughly sterilised. Some of the yeast which it is desired to cultivate is first diluted down by the Nægeli method until of a convenient degree of dilution. This must be ascertained by experience: a drop of this solution is next taken by means of a sterilised piece of platinum wire, and transferred, wire and all, to a flask containing some of the treated gelatin preparation. This is agitated, so as to to secure thorough mixture, but at the same time the production of froth must be avoided. A drop of this gelatin is taken out and examined microscopically to determine whether a sufficient number of yeast cells are present. Should they be too crowded, the contents of the flask are diluted with more gelatin; if too few are present, some more must be taken from the yeast-containing flask by means of another piece of platinum wire. To cultivate the yeast, a modification of Koch's glass-plate, known as Böttcher's moist chamber, is employed.

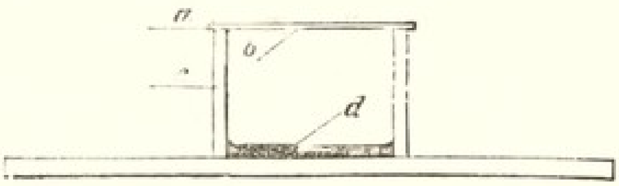


FIGURE 12.—BÖTTCHER'S MOIST CHAMBER.

a, Thin Cover-glass; *b*, Layer of Nutritive Material; *c*, Glass Ring; *d*, Layer of Sterilised Water.

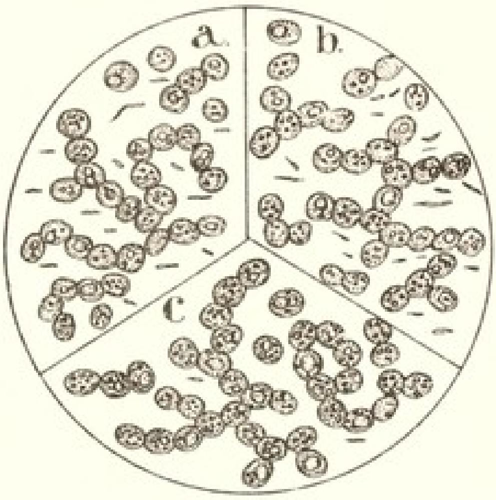
The chamber consists of a microscope slide, on which is cemented the glass ring, *c*, the upper surface of which is ground flat. In use, a small quantity of the gelatin and yeast, as prepared above, is placed on the under side of the cover-glass. The upper edge of the glass ring is smeared with vaseline, and a few drops of water placed in the bottom of the chamber. The cover-glass and gelatin is placed on the ring and gently pressed down, when the vaseline makes a tight joint between it and the chamber. Each yeast cell embedded in the gelatin can now be subjected to microscopic examination, and any particular one kept under observation. To do this, any of the devices in common use as finders for any particular part of a microscopic object may be employed, but a very convenient one is Klönne and Müller's marker, which consists of an appliance that can be screwed concentrically into the screw of the microscope which carries the objective. The desired cell is brought into the centre of the field: the objective is removed and the marker substituted for it. By means of the focussing screw it is lowered gently on to the cover, on which it marks a small ring encircling the cell required to be kept under observation. The cell is allowed to develop until a visible colony is formed. By means of a sterilised piece of platinum wire it is now picked off, and used to seed a prepared culture solution in a Pasteur's or other flask. This operation of transference may be conducted in a dust free room in the open air, but preferably in a small cupboard kept for the purpose, the walls of which have been moistened with glycerin, so as to maintain the interior as a germ-free space. The apparatus, and the hands of the operator, are introduced through a door just sufficiently large to provide for their admission. Large cultures are made, as before, by successive transferences to larger flasks.

Hansen's experiments on the effect on brewing, of specific varieties of yeast, were made with cultures obtained in this manner from single cells.

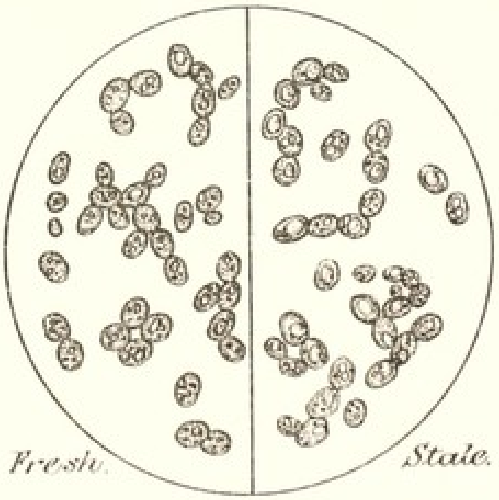
284. Classification of Yeasts.—In classifying yeasts as a genus of the fungi, they have received the following definition, based upon that of Rees.

CLASSIFICATION OF THE GENUS SACCHAROMYCES.

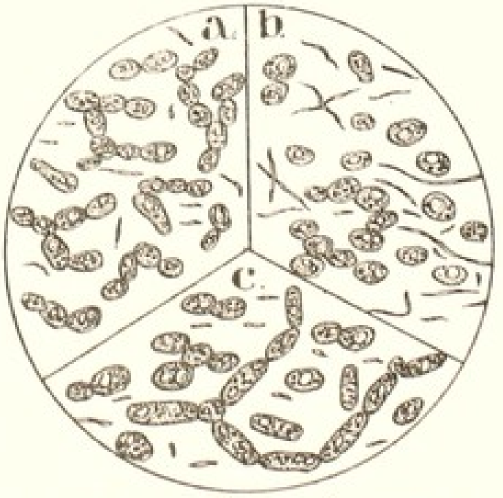
Budding Fungi, mostly without a mycelium, the individual species of which occur with cells of different form and size. Under certain treat-



Brewers' Yeast.



Compressed Distillers' Yeast.



Bakers' "Patent" Yeast.

VARIOUS COMMERCIAL YEASTS.

Saccharomyces Cerevisiæ.

Magnified about 400 Diameters.

A.E. Fuller.

ment, and sometimes also without any previous treatment, cell-nuclei are seen. Under certain conditions the cells develop *endogenous spores;* the germinating spores of most species grow to budding cells; in exceptional cases a promycelium is first formed. Number of spores 1 to 10, most frequently 1 to 4. Under favourable conditions the cells secrete a gelatinous network, in which they lie embedded.

The greater number of the species induce fermentation.

The following is a list of the more important species:—

Saccharomyces Cerevisiæ,	...	High Yeast. Low Yeast.
,, *Minor,* ...	...	Ferment of Leaven.
,, *Ellipsoideus,*	...	Ferment of Wine.
,, *Pastorianus.*		

285. Saccharomyces Cerevisiæ, or Ordinary Yeast.—At least two distinct varieties of ordinary yeast are known, to which the names of "High" and "Low" yeast have been given. The former of these is the common yeast of English ale fermentation; the other, that of the well-known "lager" beer of continental production. *Saccharomyces minor,* a species of yeast found in leaven, is also possibly a sub-variety of *S. cerevisiæ,* so, too, is the distillers' yeast imported so largely in this country from France, Holland, and Germany, and sold as compressed yeast.

286. High Yeast.—This variety is so called because of its ascending to the top of the fermenting liquid during fermentation. It consists of cells mostly round or slightly oval, from 8 to 9 μ in diameter, and answering generally to the description of yeast given in paragraphs 270 and 271. Illustrations of Brewers' High Yeast, Distillers' Yeast, and Bakers' Patent Yeasts are given in Plate II., to which reference is also made in Chapter XII.

287. Low Yeast.—Sedimentary yeast, or the "low" variety of *saccharomyces cerevisiæ,* is that used in the manufacture of lager beer. In general properties it much resembles the high yeast which has already been studied. In form the cells are somewhat smaller, and also rather more oval than those of normal high yeast; but differ very little in shape from high yeast when grown, as at Burton, in very hard waters. Figure 8, paragragh 221, gives illustrations of low yeast.

288. Distinctions between High and Low Yeast.—Whereas high yeast rises to the surface of the liquid during fermentation, "low" yeast always falls to the bottom, and forms a sediment there; hence the name "sedimentary" yeast. Brewing with low yeast is performed at much lower temperatures than with high; thus, whereas with the latter pitching temperatures of 20° or 21° C. (68° or 70° F.) are employed, the lager beer brewer starts his fermentation at as low as 8° C. (47° F.), or even 6° C. (43° F.) Working with this low temperature, fermentation proceeds much less rapidly than with high yeast; growth and reproduction proceed more slowly, and the budding gives rise to less extensive colonies of cells. As Pasteur aptly describes it, low yeast when growing has a much less ramified appearance. (See Figure 9.) It is doubtful whether the term "low," as applied to this yeast, has been given from the lowness of the temperature employed for fermentation, or because the yeast always drops to the bottom of the fermenting vat; both are characteristics of this variety. This yeast is further distinguished by its producing an inferior variety of beer to the celebrated product by high fermentation of English and Scotch breweries.

It may be well to mention that the low yeast of lager beer is *not* that which is being imported from the continent, and sold so largely for bread-making purposes. As a matter of fact, low yeast is very badly suited for the fermentation of bread; its action is extremely slow, and results in the production of a heavy, sodden, and frequently sour, loaf.

289. Convertibility of High and Low Yeasts.—This has been for many years a much-discussed problem both by brewers and scientists, and is typical of the discussions which arise on the general question of the immutability or otherwise of the different yeast species and varieties. Students who appreach this subject with a previous knowledge of the laws of the origin of species as a result of evolution, as enunciated and demonstrated by Darwin, will be prepared to expect from the general evidence of biology that not only high and low yeasts, but also all forms and species of *saccharomyces*, have had one common origin, their diversities having been produced by differences in environment extending over numberless generations. When discussing, however, whether or not low and high yeast are convertible, and really therefore of the same species, it is understood that the question refers to convertibility during small amounts of time, not such lengthy periods as are requisite for an actual evolution of distinct species. Pasteur, at an earlier period of his researches, considered the two yeasts to be convertible, but as the result of later investigations, affirmed the two yeasts to be distinct. This belief is founded on experiments in which high yeast was grown repeatedly at the lowest possible temperature, and low yeast at the temperature employed for high fermentation. Supposing the yeasts to be pure at the commencement of such an experiment, he asserts that no transformation of the one variety into the other is effected. In this opinion he differs from many brewers, who state that under such conditions the one yeast is converted into the other. Pasteur gives the following explanation of the observed change: if the high yeast had in it a few cells of low yeast as impurity, on being sown and caused to reproduce at a low temperature, the low yeast cells present would thrive well, while the high yeast would languish. The minute quantity of low yeast cells, finding the conditions favourable to their growth, develop; and the others, through the conditions being unfavourable, are after a time outnumbered and disappear. The change of low into high yeast is explained as being just the converse of that now described. The latest authoritative dictum on this subject is that of Jörgensen, who, in 1893, asserts that, "in spite of many assertions to the contrary, it has not hitherto been possible to bring about an actual conversion of top-yeast into bottom-yeast, or *vice versa*. The investigations of Hansen and Kühle show that it is certainly possible for a bottom fermentation yeast to produce transitory top-fermentation phenomena; these, however, quickly disappear with the progressive development of the yeast."

290. Distillers' Yeast.—The yeasts employed by distillers for the purpose of fermenting their worts differ in some most important characteristics from ordinary brewers' yeast. They are, in the first place, grown in un-hopped worts, as against the hopped worts of the brewer. In appearance they resemble low yeast more closely than the normal brewers' high yeast, averaging slightly smaller in size, and forming less extensive colonies. The yeast is less mucilaginous than that of the brewer, and so does not form so sticky a mass. The distillers' yeasts are invariably high yeasts, but are sharply separated from the brewers' yeast by their capacity for inducing a vigorous fermentation in dilute mixtures of flour and water. If equal weights of brewers' and distillers' yeast be sown in a solution of sugar in water, and fermented under the same conditions, the brewers' yeast will usually cause a slightly more rapid evolution of gas; but if, instead, a mixture of flour and water be used, the distillers' yeast will cause many times more gas to be evolved than does that from the brewer. This difference does not seem to be owing to the absence of sugar, for if to the flour and water sugar be added in the same proportion as in the pure sugar solution, there is still little or no more fermentation caused by the brewers' yeast. The probable reason is the physical difference caused in the flour mixture by the presence of the inert constituents of the flour.

Jörgensen states that distillery yeasts exhibit marked differences in their sedimentary forms, and in ascospore formation, to brewers' yeasts. Microscopic examination of compressed yeast, according to Bêlohoubek, indicates, in the following manner, alterations in the appearance of the cells. As decomposition sets in, the protoplasm becomes darker in colour and more liquid; the vacuoles become larger, and the sharp outline between them and the plasma gradually disappears: the plasma shrinks from the cell-wall, and finally collects in irregular masses in the cell-fluid. At times cells appear in pressed yeast, which suddenly develop a number of small vacuoles; these abnormal vacuolar cells speedily perish.

291. Saccharomyces Minor.—This is a form of yeast described by Engel as being obtained by him from leaven (a name given to old dough). To obtain the ferment he washes a piece of leaven in the same way as described in a previous chapter for the separation of the gluten of flour from its starch. The yeast cells pass through, and may be detected by microscopic examination of the liquid after the larger starch cells have settled to the bottom. The cells of *Saccharomyces minor* are globular, occurring either isolated or in pairs or groups of three. They are about 6 mkms. in diameter and have an indistinct vacuole. In Pasteur's fluid they reproduce but slowly, and form new cells of the same dimensions as were the original. They easily reproduce by sporulation, the spores being about 3 mkms. in diameter, and are united in twos or threes. They, on the whole, closely resemble the yeast of beer. Although Engel treats saccharomyces minor as a distinct variety, the balance of evidence is in favour of its identity with *S. cerevisiæ*. Grove considers it to be but a form of that ferment. The lesser size and activity may be attributed to its having continually reproduced itself in an unfavourable medium, such as dough; hence its stunted appearance and slow growth, as compared with the more favourably environed yeast of beer.

Engel views this form of yeast as being the active ferment in the fermentation of bread. In this, of course, he is referring to continental black bread, in the fermentation of which leaven is employed, this being made by kneading together flour, bran, and water, and allowing the mass to undergo spontaneous fermentation.

White bread fermented with either brewers' or distillers' yeast belongs to a totally different category.

Saccharomyces minor and other yeast varieties are illustrated in Plate III. The numbers following the multiplying sign give the magnification in diameters.

292. Saccharomyces Ellipsoideus.—This is the ordinary ferment of vinous fermentation, that is, that by which "must," or the expressed juice of the grape, is converted into wine. The cells of this variety of yeast are oval, and about 6 mkms. long; they reproduce both by budding and spores. When grown in malt wort, they produce a beer of a decided vinous flavour, which is sometimes made and sold as "barley wine."

293. Saccharomyces Pastorianus.—The cells of this variety of yeast vary considerably in size; they are cylindrical in shape, with oval ends, and appear when seen in colonies somewhat like strings of sausages. Budding occurs at the joints, where groups of smaller daughter cells may be observed; these are first either round or slightly oval. The elongated cells are from 18 to 22 mkms. long, and about 4 mkms. in diameter; the daughter cells are about 5 to 6 mkms. in length.

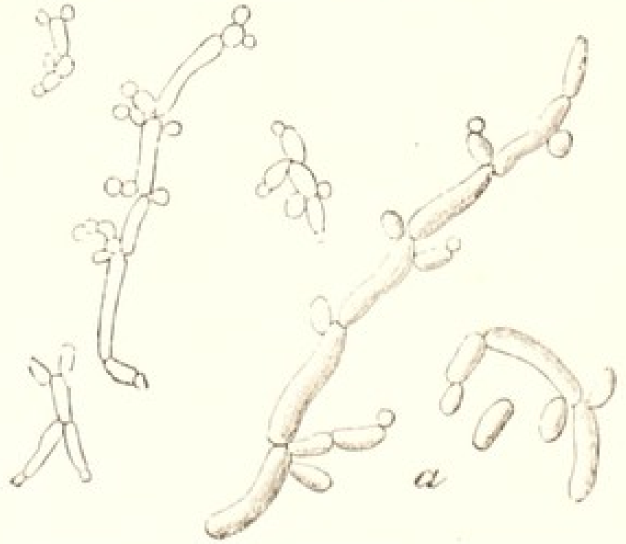
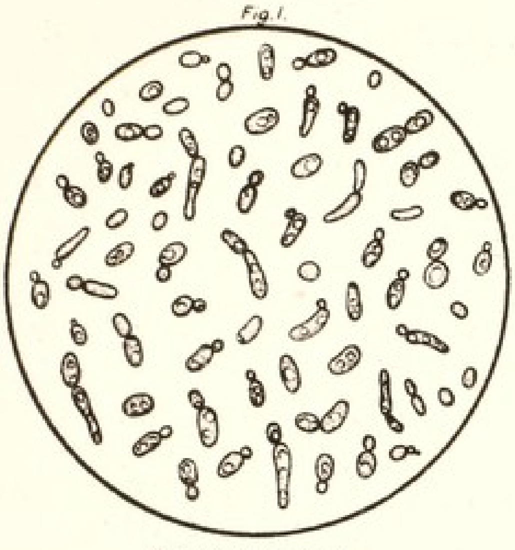


FIGURE 13.—*Saccharomyces Pastorianus.*
a, The same more highly magnified (after Pasteur).

S. Pastorianus occurs in the after-fermentation of wine and beer, and also in bakers' "patent" yeasts. As it is found in English beers which

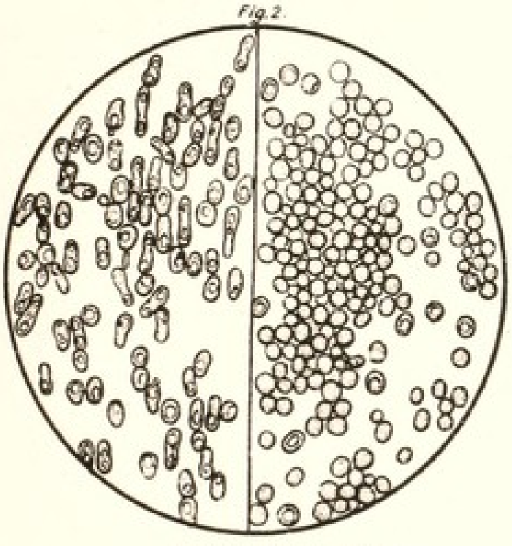
PLATE III.

Fig. 1.



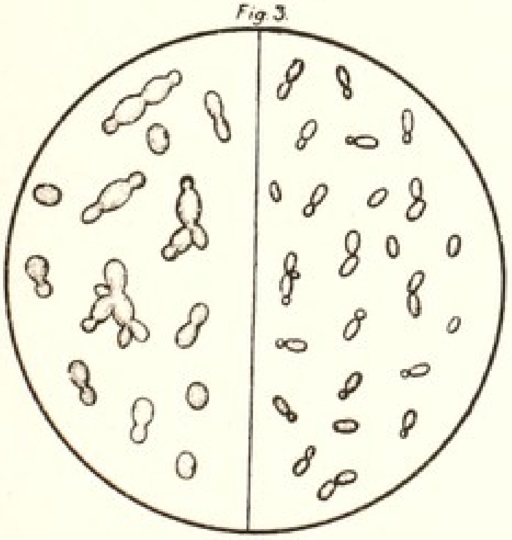
S. Pastorianus. x 350.

Fig. 2.



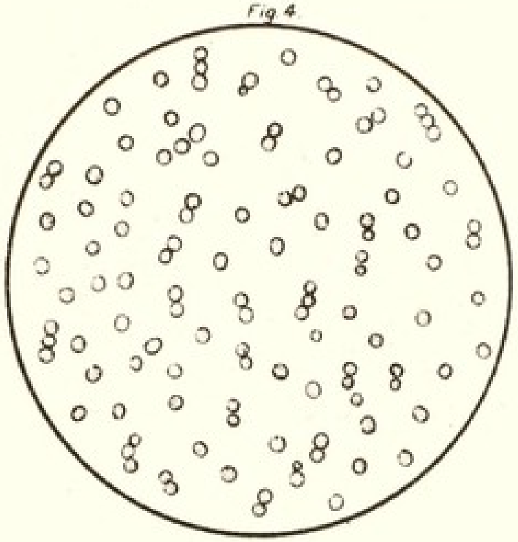
Caseous Yeasts. x 350.
L.H. Nº 1 R.H. Nº 2.

Fig. 3.



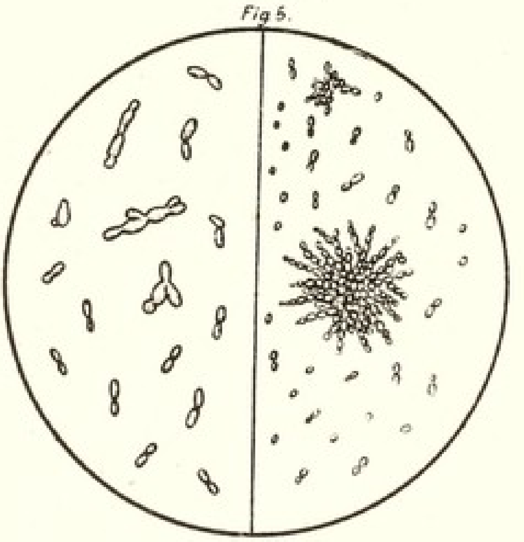
S. Ellipsoideus. x 300.
L.H. After Reess. R.H. M. & L.

Fig. 4.



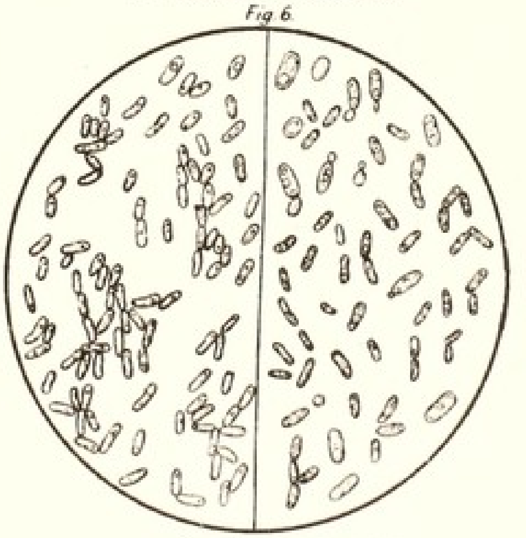
S. Minor. x 350.

Fig. 5.



S. Exiguus. x 300.
L.H. After Reess. R.H. M. & L.

Fig. 6.



Mycoderma Vini x 300.
L.H. Aerobian form. R.H. Submerged form.

(after Matthews & Lott)

VARIOUS "FOREIGN" YEASTS.

have been keep for some time in store, cells of it are probably more or less present in all commercial English yeasts. Being a less active variety than *S. cerevisiæ*, it remains dormant while the first or principal fermentation proceeds; but when the most of the sugar has disappeared, the *S. pastorianus*, being able to live and develop in a less nutritious medium, grows and reproduces. Brown and Morris point out that the amyloïns cannot be either fermented or hydrolysed by ordinary yeast; but that *S. pastorianus* is capable of hydrolysing maltodextrin for itself, thus giving rise to an apparent direct fermentation of that body. This will explain how this latter ferment thrives and reproduces in a medium so deficient of sugar as not to permit the growth of *Saccharomyces cerevisiæ*.

294. Saccharomyces Mycoderma, or Mycoderma Vini.—Closely allied to the *saccharomyces* already described under the name of yeast is this species, which belongs to the fungus family proper. *Saccharomyces mycoderma* requires for its growth and development free oxygen, and belongs to Pasteur's division of "ærobian" plants. Although the fungi proper luxuriate rapidly when growing with free access to air, yet they are speedily destroyed by enforced submergence below the surface of a liquid. *Saccharomyces mycoderma* occurs on the surface of wine, beer, and bakers' yeasts, on their being exposed for some days to the air, forming after a time a thick wrinkled skin or mycelium; in which state it is said to be "mothery." The mycoderma is known as that of wine (vini), or of beer (cerevisiæ), according to the liquid on which it appears. Viewed under the microscope, the mycelium is found to consist of extending branches of elongated cells closely felted or intertwined together. See illustration on Plate III., and Figure 14 of *Mycoderma Cerevisiæ*. The individual cells are either oval or cylindrical, with rounded ends. They are about 6-7 mkms. long, and 2-3 mkms. in diameter. The *mycoderma vini* reproduces either by budding or by spores. The spore forming cells attain a length of as much as 20 mkms. Home made or fermented ginger-beer readily permits the growth of this particular mould; the so-called ginger-beer plant being largely composed of *Saccharomyces mycoderma*. Particularly in summer time, the growth of this fungus proceeds with extreme celerity, the mycelium first formed being thrown into folds by its rapid development; at the same time considerable heat is produced. Microscopic examination shows that *Mycoderma vini* is very like yeast in appearance; for a long time it was supposed that the two were identical, and that the mouldiness of beer was produced by the yeast cells ascending to the surface, and there developing as a fungoid growth. The two organisms are, however, distinct species, and have not been transformed

FIG. 14.—*Mycoderma Cerevisiæ.*
From Copenhagen Breweries.

one into the other. *Mycoderma vini* during its growth seizes oxygen with great avidity, entirely preventing, during the period of its actual life, the development of other organisms also requiring oxygen, but endowed with less vital energy. Pasteur states that on submerging this mould during its actual growth into malt wort, or other saccharine liquid, it for a short time causes fermentation, with the production of small quantities of alcohol; but this action soon ceases with the early death of the fungus. In addition to this limited fermentative action, *mycoderma vini* acts on wines and beers as a somewhat powerful oxidising agent; it conveys the oxygen of the air to the alcohol of the liquid, causing its complete slow combustion into carbon dioxide and water, and consequently rapidly lessening the alcoholic strength of the medium. Although wines and beers become sour simultaneously with the development of *mycoderma vini*, the souring is not due to this organism, but to another distinct growth.

The limited alcoholic fermentation produced by *mycoderma vini* leads to its being classed among the *saccharomyces*.

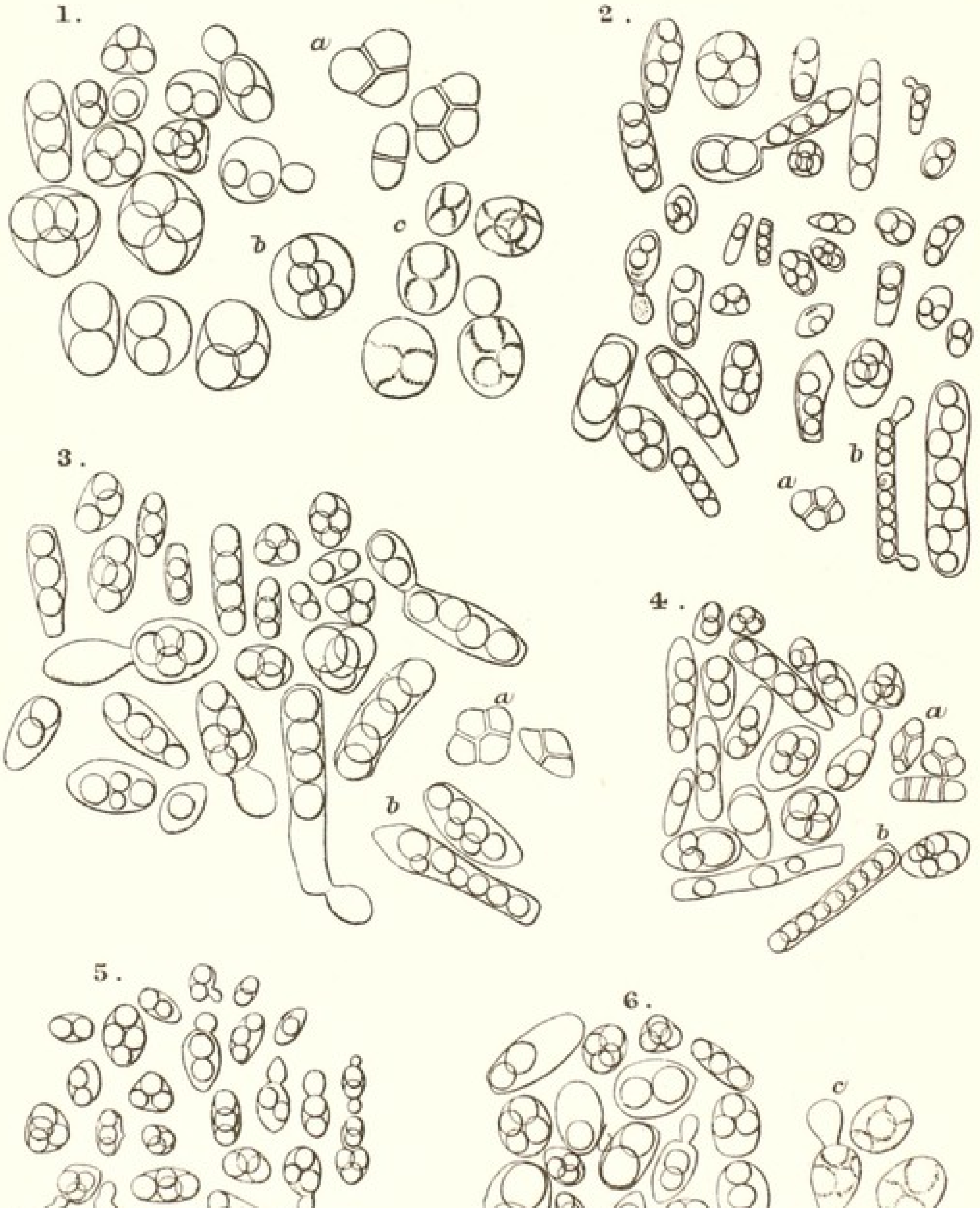
295. Hansen on Analysis of Yeasts.—It is principally due to the researches of Hansen that we are able to classify yeasts into species and races with such accuracy as is now possible. The results of his work have had such important effects on the brewing industry, and indirectly on that of bread-making, that the present work would not be complete without some reference to these latest classical investigations.

Hansen's fundamental idea was that the shape, relative size, and appearance of yeast cells, taken by themselves, were not sufficient to characterise a species, since the same species under different external conditions could assume very different forms. Further, although, for example, a microscopic field of pure *S. cerevisiæ* could be distinguished by its appearance from pure *S. pastorianus*, yet in a mixture of the two it is not possible to distinguish individual cells of the one from those of the other. *S. cerevisiæ* forms at times sausage-shaped cells, while *S. pastorianus* occurs to a certain extent as round or oval cells. Some other method, then, than microscopic examination is necessary for their differentiation.

296. Formation of Ascospores.—By investigation of the conditions under which different races of yeast formed ascospores, Hansen was enabled to arrive at a mode of analysis of yeasts. A description of the mode of procedure by which ascospores are obtained has already been given, but Hansen ascertained with more exactitude the precise conditions necessary, and thus sums up his conclusions:—The cells must be kept moist and have a plentiful supply of air; further, to form spores they must be young and vigorous. For most species a temperature of 25° C. is the *most* favourable; for all species this temperature favours their development.

Hansen found the process of spore-formation to vary in different species. *S.S. cerevisiæ, pastorianus, and ellipsoideus* germinate into spores in essentially the same way. *S. ludwigii* and *S. anomalus* have each a separate and distinct mode of spore growth.

PLATE IV.



Formation of Ascospores.

1. *Sacch. cerevisiæ I.*
2. *Sacch. Pastorianus I.*
3. *Sacch. Pastorianus II.*
4. *Sacch. Pastorianus III.*
5. *Sacch. ellipsoideus I*
6. *Sacch. ellipsoideus II.*

(after Hansen × 1000.)

While all species form spores at 25°, Hansen set himself to determine whether with different species there was any difference in their behaviour under varying conditions of temperature. In making observations, he registered the time when the cells first showed distinct indications of spore formation. The limits of temperature for all species are between from 0·5 to 3° C. and 37·5° C. At the highest temperature all species develop first indications in about 30 hours, and show very little difference in time at 25° C.; but with lower temperatures very evident differences occurred. Hansen also found that there were differences in anatomical structure of spores that could be utilised for analytic purposes. In the so-called cultivated yeasts, *S. cerevisiæ*, employed for brewing, the spores have a distinct membrane, with non-homogeneous granular contents and a definite vacuole. In the case of the so-called wild yeasts, the spore wall is frequently indistinct, the cell contents homogeneous, and the vacuole absent.

Hansen investigated very closely the following six species of yeast, particulars of which are furnished.

Illustrations of the formation of ascospores are given in Plate IV.

Saccharomyces cerevisiæ I., English top-fermentation yeast. Ferments dextrose and maltose very vigorously. Spores strongly refractive to light, walls very distinct; size, 2·5—6 μ.

S. pastorianus I., Bottom-fermentation yeast; frequently occurs in the air of fermenting rooms; imparts to beer a disagreeable bitter taste and unpleasant odour; can also produce turbidity and interfere with clarification in fermenting vat. Size of spores, 1·5—5 μ.

S. pastorianus II., Feeble top-fermentation yeast; found in air of breweries; apparently does not cause diseases in beer. Size of spores, 2—5 μ.

S. pastorianus III., Top-fermentation yeast, one of the species which produce *yeast-turbidity* in beer; but in certain cases clarify opalescent worts. Size of spores, 2—5 μ.

S. ellipsoideus I., Bottom-fermentation yeast; occurs on *ripe grapes.* Size of spores, 2—4 μ.

S. ellipsoideus II., Usually bottom-fermentation yeast; causes *yeast turbidity*, more dangerous than *S. pastorianus III.*; also imparts a sweetish, *disagreeable*, *aromatic* taste to beer, and a *bitter*, *astringent after-taste.* Size of spores, 2—5 μ.

It will be noticed that Hansen sub-divides both *S. pastorianus* and *ellipsoideus.* He also sub-divides other species into different races or varieties. The leading points of connection between temperature and spore formation are given in the following table:—

TEMPERATURE AND SPORE-FORMATION OF YEASTS.

	Sacch. Cerev. I.	Sacch. Past. I.	Sacch. Past II.	Sacch. Past. III.	Sacch. Ellip. I.	Sacch. Ellip. II.
Highest limit of development. Temperature of	37·5°	31·5°	29°	29°	32·5°	35°
Most rapid development. Temperature of	30°	27·5°	25°	25°	25°	29°
Most rapid development. Time, in hours, of appearance of first indication of spores,	20	24	25	28	21	22
Time, in hours, of appearance of first indications at 15° C.,	110	50	48	48	45	62
Lowest limit of development. Temperature of	9°	0·5°	0·5°	4°	4°	4°

It will be seen that considerable differences exist between the various yeasts in the particulars given. In addition, Hansen has also investigated the conditions of film formation and other properties which aid in the task of yeast-differentiation.

297. Detection of "Wild" Yeasts.—In utilising spore formation, cultures are made at temperatures of 25° and 15° respectively, the latter being examined after three days—72 hours. All the wild yeasts will have commenced to show indications, while the cultivated yeast will be free from them. When used practically for technical purposes, this method is capable of detecting with certainty an admixture of 0·5 per cent. of a wild yeast in an otherwise pure culture. For this and other tests applied to yeast by Hansen's methods, it is essential that the preliminary trials of the yeast be uniform, so as to make the tests comparative.

298. Varieties of Cultivated Yeast.—Not only have distinctions been drawn between cultivated and wild yeasts by the methods just described, but also well-marked and distinct varieties of cultivated yeast have been grown. Each of these possesses distinct characteristics, and is valued for certain kinds of beer. Thus, Jörgensen, *for practical purposes,* classifies different races of yeast prepared by pure culture methods in his laboratory into the following groups:—

A.—BOTTOM-FERMENTATION SPECIES.

1. Species which clarify very quickly and give a feeble fermentation in the fermenting vessel; the beer holds a strong head. The beer, if

kept long, is liable to yeast-turbidity. Such yeasts are only suitable for draught-beer.

2. Species which clarify fairly quickly and do not give a vigorous fermentation; the beer holds a strong head; high foam; yeast settles to a firm layer in the fermenting vessel. Beer, not particularly stable as regards yeast-turbidity. Yeasts are suitable for draught-beer, and partly for lager beer.

3. Species which clarify slowly and attenuate more strongly; the beer has a good taste and odour; the yeast deposit is less firm in the fermenting vessel. Beer is very stable against yeast-turbidity. These yeasts are suitable for lager beer, and especially for export beers which are not pasteurised or treated with antiseptics.

B.—TOP-FERMENTATION SPECIES.

1. Species which attenuate slightly and clarify quickly. The beer has a sweet taste.

2. Species which attenuate strongly and clarify quickly. Taste of beer more pronounced.

3. Species which attenuate strongly, clarify slowly, and *give a normal after-fermentation*. The beer is stable against yeast-turbidity.

Hansen has isolated two yeast races from ordinary yeast, both of which are employed in the Carlsberg breweries; these are known as Carlsberg No. I. and Carlsberg No. II. Each has distinct properties of its own; thus, No. I. gives a beer well adapted for bottling, containing less carbon dioxide than No. II., and possessing a lower degree of attenuation; well adapted for home use. No. II. is principally cultivated for export, giving a good draught-beer containing more carbon dioxide.

Passing for a moment the work of different investigators in review, Pasteur freed yeasts from weeds or foreign vegetable growths of the bacteria group. Hansen first eliminated wild yeasts as a fruit grower might eliminate crab-apples and other wild fruits from his orchard. Lastly, he has devoted his attention to the growth of distinct breeds of cultivated yeast, each specialised for a particular type of beer.

In a less prominent degree much the same is being done for the bakers. Yeasts are selected for their vigour and capacity for fermentation, and these are cultivated to the exclusion of types incapable of yielding such excellent results.

EXPERIMENTAL WORK.

299. Substances produced by Alcoholic Fermentation.—Prepare some ten or twelve ounces of malt wort, by mashing ground malt in five times its weight in water; and take its density by a hydrometer. To the wort add a small quantity of either brewer's or compressed yeast, place it in a flask arranged with a cork and leading tube, and set it in a warm place (30—35° C.). Attach the leading tube to a flask containing lime-water, so that any gas evolved by the yeast has to bubble through the liquid. Notice that after a time fermentation sets in, and that the yeast rises to the top; gas bubbles through the lime-water and turns it milky, thus showing that carbon dioxide is being evolved. When the liquid becomes quiescent through the cessation of fermentation, again take its density with the hydrometer, notice that it is less than before; return the liquid to the flask, and connect to a Liebig's condenser and distil; notice that the first drops of the distillate have the appearance of tears, as described in paragraph 91, Chapter III. Cease distilling when about one-tenth of the liquid has distilled over; notice that the distillate has an alcoholic or spirituous odour. Test it for alcohol by the iodoform reaction.

300. Microscopic Study.—Preceed with this on the lines of paragraph 270.

Mount a trace of the yeast in a little warm malt wort, and examine carefully: notice alteration in appearance of the yeast cells as they set up fermentation: keep the microscope with slide in focus for some time in a warm place, and observe from time to time the changes as they proceed. Watch specially for the development of budding, and as soon as any signs are detected watch the cell at short intervals until the bud has become completely detached from the parent cell.

Sow a little yeast in a beaker in a small quantity of wort; take out a little and examine under the microscope a few hours later: examine again on each successive day until some three or four days have elapsed since the fermentation has ceased. Note during the height of the fermentation the colonies of cells, sketch some of these: observe the clear outlines and transparent protoplasm of the new cells as compared with the shrunken appearance of the parent cells. As time proceeds, notice the gradual alteration in appearance of the yeast, until at last the new cells are similar in appearance to those originally sown.

Study sporular reproduction as directed in paragraph 281.

CHAPTER X.

BACTERIAL AND PUTREFACTIVE FERMENTATIONS.

MOULDS.

301. Schizomycetes.—Grove defines the *Schizomycetes* or "splitting fungi" (*Spaltpilze*) as being unicellular plants, which multiply by repeated subdivision, and also frequently reproduce themselves by spores, which are formed endogenously. They live, either isolated or combined in various ways, in fluids and in living or dead organisms, in which they produce decompositions and fermentations, but never alcoholic fermentation.

Among these organisms are included *bacteria*, *bacilli*, *vibrios*, &c., but comparatively few of these have an immediate bearing on the present subject, and so the great majority need not here be described.

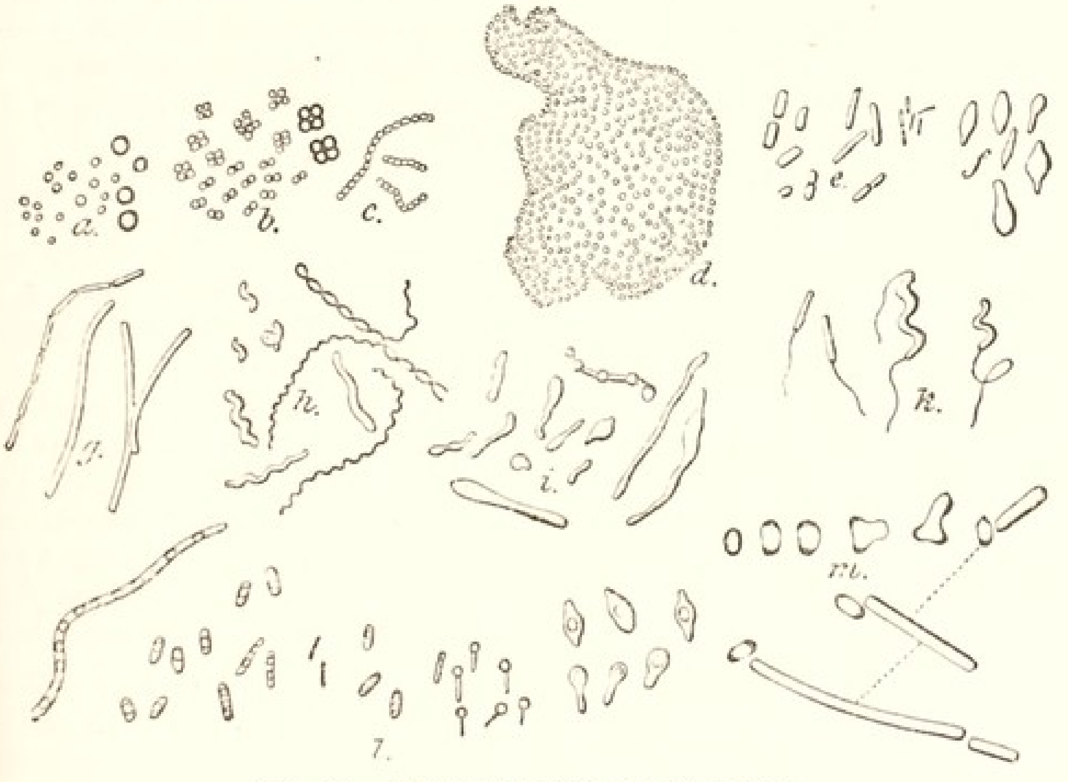


FIG. 15.—GROWTH-FORMS OF BACTERIA.

a, Cocci ; *b*, Diplococci and Sarcina ; *c*, Streptococci ; *d*, Zooglœa ; *e*, Bacteria and Bacilli ; *f*, Clostridium ; *g*, Pseudo-filament, Leptothrix, Cladothrix ; *h*, Vibrio, Spirillum, Spirochæte, and Spirulina ; *i*, Involution-forms ; *k*, Bacilli and Spirilla, with cilia or flagella ; *l*, Spore-forming Bacteria ; *m*, Germination of the Spore.

The difficulty of classifying the *Schizomycetes* increases with a more minute acquaintance with these organisms, as investigation shows that one and the same organism occurs in varying forms under different conditions. Some of the various growth-forms are illustrated in Figure 15. If, on the other hand, grouped according to the chemical changes they produce, then in many instances more than one organism is found capable of inducing the same chemical reaction. For the purposes of the present work, it will be more convenient to accept provisionally a classification according to chemical effects produced.

The *Schizomycetes* possess the property of surrounding themselves with a gelatinous substance, in which large colonies of them may be seen imbedded. They are then said to be in the "Zooglœa" stage.

302. Bacteria.—These organisms consist of small cells, commonly cylindrical in shape; they increase by transverse divisions of cells, and reproduce by sporulation. *Bacteria* have a spontaneous power of movement.

ORGANISMS OF PUTREFACTION.

303. Bacterium Termo.—This is essentially the ferment of putrefaction. It is present in air, and also in waters contaminated with sewage. Hay, meat, or flour infusions, malt wort and other liquids, on being exposed to the atmosphere, become turbid, and are then found on microscopic examination to be densely crowded with *bacteria.* The cells are oval in shape and about 1·5 to 2 mkms. in length: they are constricted in the middle, giving them a sort of hour-glass appearance; at each end is an extremely fine filament, termed a "*flagellum*," and sometimes a "*cilium*." This is probably the organ by which the *bacterium* exerts its motile or moving power. For illustrations of this and other Forms of Bacteria see Plate V.

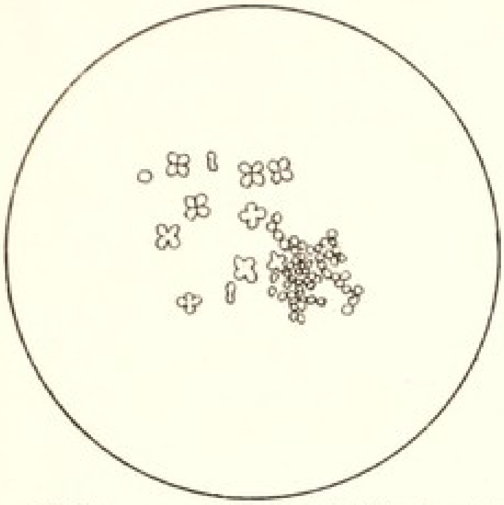
This definite movement of the *bacterium* must not be confounded with the simple oscillatory movement of small particles of matter when suspended in a fluid. This latter may be observed by rubbing up a little gamboge in water, and microscopically examining a drop of the liquid: the small solid particles are seen to be in a continual state of motion. This latter is termed the "Brownian" movement.

The spores of the *bacteria*, in common with most other of those of the *schizomycetes*, are extremely tenacious of life. They may be dried up and exist in a dormant state for an indefinite time without losing their vitality; for immediately on being again moistened and placed in a suitable medium, they commence an active existence and cause putrefaction. The dry spores are not destroyed by even boiling them for so long as a quarter of an hour; they are also not affected by weak acids.

304. Bacilli.—The word *bacillus* literally means a stick or rod, and is applied to the organisms of this genus because of their rod-like shape. The cells are long and cylindrical and occur attached to each other, thus forming rod-like filaments of considerable length. There is little or no constriction at the joints, which with low microscopic powers are scarcely observable. They increase by splitting transversely, and reproduce by spores. *Bacteria* and *bacilli* are closely allied genera, some species of the one closely resembling species of the other. In the very long cells of *bacteria* the transverse divisions may be detected, while in the equally long cells of *bacilli* no traces of division can be seen. *Bacilli* are some-

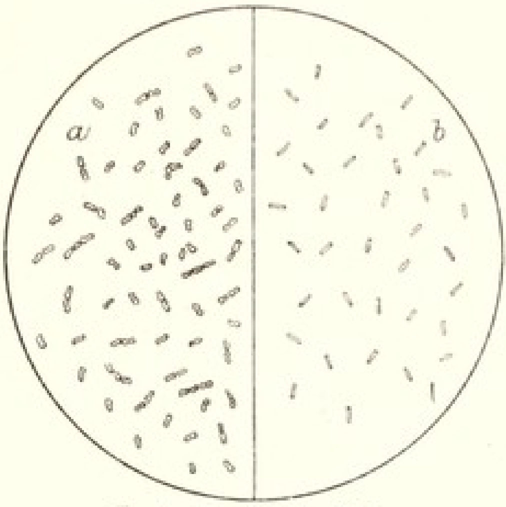
PLATE V.

Fig: 1.



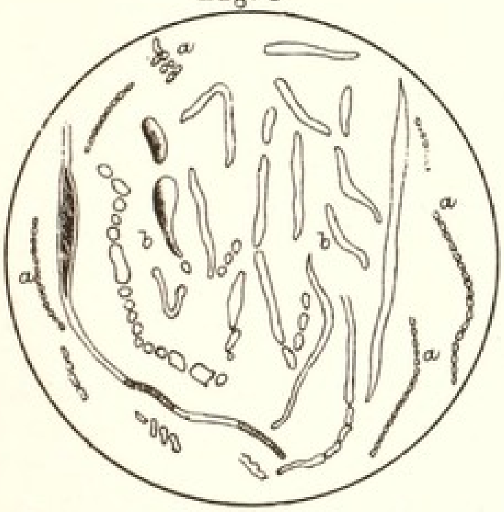
Pediococcus acidi lactici (Lindner) ×1100.

Fig: 2.



Bacterium lactis. ×350
a. Pasteur. b. Matthews & Lott.

Fig: 3

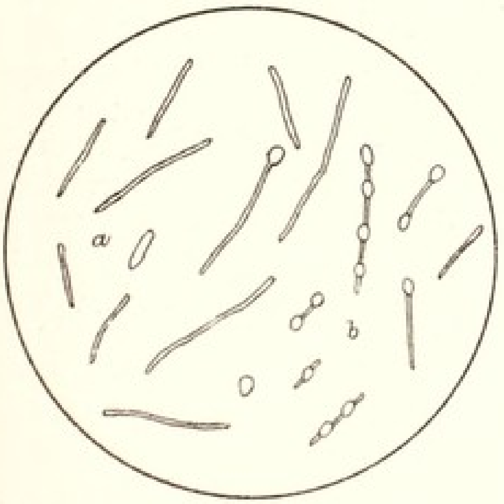


Bacterium aceti. (Hansen) × 400 (about).

Fig: 4.

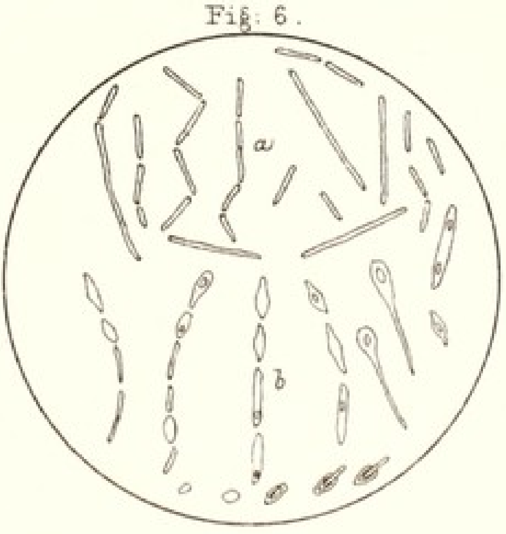
Bacterium Termo. (a & b, Cohn. c, Dallinger). ×650 & ×4000.

Fig: 5.



Bacillus subtilis (Cohn). × 650.

Fig: 6.



Clostridium butyricum (Prazmowski) × 650 (about).

VARIOUS DISEASE FERMENTS.

times motile, but after a time pass into a condition of rest, or zooglœa stage. The long threads of *bacilli* often assume a zig-zag or bent form; and unless subjected to very careful examination, appear to be continuous. Pasteur's filaments of turned beer "consist of *bacilli*."

305. Bacillus Subtilis.—This organism is alzo termed "*Vibrio subtilis*," and is largely present in air. Owing to its being the predominant organism produced when an aqueous infusion of hay is exposed to the air, it is frequently referred to as the bacillus of hay. The cells are cylindrical, and grow to about 6 mkms. in length, and are provided with a flagellum at either end. They usually occur adherent to each other, forming long filaments, as shown in Plate V.

The term "*vibrio*," applied to certain forms of *schizomycetes*, is derived from their appearing to have a wriggling or undulatory motion; this effect is illusory, being actually caused by their rotating on their long axis.

An enlarged illustration of *B. subtilis* is given in the following figure, 16.

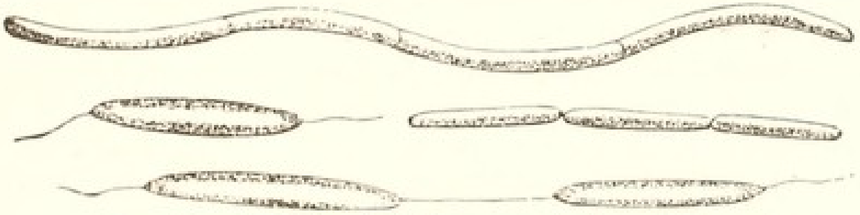


FIG. 16.—*Bacillus Subtilis* × 4000 (after Dallinger).

They increase by transverse division, and reproduce by spores. As the spore formation of *B. subtilis* has been most carefully observed, a description of its mode of reproduction will be of service as a type of that of the *schizomycetes* generally. In spore formation the protoplasmic contents of the cell accumulate at the one end, causing an enlargement there; the rest of the cell after a time drops off and dies; the mature spore may then live for even years without losing its vitality; and being of extreme minuteness, these spores permeate the atmosphere, and are ever ready to germinate on finding a suitable medium. In the act of germination the spore splits its membrane open, and a new rod grows and projects through the opening. The dry spores are extremely tenacious of life, and withstand boiling for an hour in water without losing their vitality. Some three or four consecutive boilings in a flask plugged with cotton wool, with a few hours' interval between, are necessary to ensure sterilisation from this organism.

Various writers impute different specific fermentative actions to B. subtilis, but it is doubtful whether the production of any particular chemical compound should be associated with it. It is essentially the organism of putrefaction, and effects the decomposition both of nitrogenous and carbonaceous bodies with the evolution of mal-odorous gases. Both it and *B. termo* are stated to possess the power of peptonising proteids, this operation being a preliminary to their further conversion into leucin, tyrosin, and allied bodies.

306. Diastasic Action of Bacteria.—This latter action is a consequence of the property possessed by the *bacteria* of attacking proteid bodies and converting them into peptones Wortmann has devoted considerable attention to the investigation of the problem whether or not *bacteria* have any action on starch: whether or not, by the secretion of a starch-transforming substance similar to diastase, or in any other but not clearly defined way, they are capable of transforming starch into soluble and diffusible compounds. In order if possible to obtain a solution of this problem, Wortmann experimented in the following manner:—

To about 20 or 25 c.c. of water a mixture of inorganic salts (sodium chloride, magnesium sulphate, potassium nitrate, and acid ammonium phosphate, in equal proportions) was added to the extent of 1 per cent. The same quantity of solid wheat-starch was next added, and the liquid then inoculated with one or two drops of a strongly bacterial solution; shaken, corked, and allowed to remain in a room at a temperature of 18° to 22° C. (*Bacterium termo* was the predominating organism in the inoculating fluids employed.) In from five to seven days, the first signs of commencing corrosion of the starch granules had become visible, the larger grains being first attacked, and much later, when these had almost completely disappeared, those of lesser size.

In a second series of experiments, soluble starch was substituted for the solid form, the progress of the reaction being watched by the aid of iodine. Samples taken from time to time exhibited at first the blue colour, then violet or dark red, passing to wine red, and finally, when the starch had disappeared, underwent no change.

Wheat-starch grains are found to be by far the most readily attacked by *bacteria* when compared with other varieties, in several experiments having even completely disappeared before other sorts of starch were attacked. Of a number of starches, that of potatoes alone entirely resisted attack. When wheat-starch in the solid state was mixed with starch solution or with starch paste, the solution became entirely (and the paste in greater part) changed before any action occurred on the solid granules.

With regard to this unequal power of resistance shown by different kinds of starch, Wortmann concludes from his further observations that the difference of rapidity with which a given kind is attacked and dissolved by a ferment is inversely proportional to its density, provided always that the granules in question are entire and uninjured by cracks or fissures. In the same way are explained the differences in point of time in which granules of the same kind are sometimes observed to undergo change accordingly as they are intact or otherwise.

The cause of potato-starch, or of bean-starch, and even under certain conditions, wheaten starch, resisting attack, in spite of the abundant presence of *bacteria*, is apparently to be sought for in the fact that other more easily accessible sources of carbon nutriment were also present, certain proteid constituents of the potato slices, or of the beans employed affording this more readily than the starch granules, just as in the experiments above cited, with wheaten starch solution and solid wheaten starch, the former was preferentially attacked; only after all, or at least the chief portion, of the proteids present had been used up, was the starch in these cases attacked.

Another point was also established in the course of these experiments—that if air is excluded, no appearance of corrosion or solution of the starch granules are manifested.

That the starch in the process became changed in part to glucose was easily ascertained by testing with Fehling's solution, and a detailed series of experiments, made with a view to eliminating if possible the ferment itself, yielded evidence showing that *bacteria* possess the remarkable property of producing a starch-transforming ferment, only when no source of carbon other than starch is at their disposal, and this ferment is incapable of changing albumin into peptone, just as in the case of diastase. The results of Wortmann's researches may be briefly recapitulated—

1. *Bacteria* are capable of acting on starch, whether in the solid state, as paste, or in solution, in a manner analogous to diastase.
2. As in the case of diastase, different kinds of starch are attacked by *bacteria* with different degrees of rapidity.
3. The action of *bacteria* on starch is manifested only in the absence of other sources of carbon nutriment, and when access of air is not prevented.
4. The action of *bacteria* on starch is effected by a substance secreted by them, and which, like diastase, is soluble in water, but precipitable by alcohol.
5. This substance acts precisely as diastase in changing starch into a sugar capable of reducing cupric oxide, but is not possessed of peptonising properties.

These results of Wortmann's are quoted at some length because of their bearing on the action of *bacteria* in dough. One most important point is, that the diastasic action of *bacteria*, or their secretions, only occurs in the absence of proteid matter, which is the substance most specially suited for the development of these organisms; consequently, with the exception of the transformation of sugar more or less into lactic acid, the carbohydrates are unattacked by the *schizomycetes* during normal dough fermentation. The *bacteria* cause more or less change in proteids, but exert no diastasic action. These proteid changes are, by the way, unaccompanied by any appreciable evolution of gas.

It will be noticed that Wortmann expressly states that the *bacteria* have no peptonising action; while it is also as expressly stated that they readily attack the proteids. He does not state what substances he finds produced by this action. The opinion is, nevertheless, very generally held that peptones are produced during changes which occur during the fermentation of dough, and it has been supposed that the *bacteria* were the active agents. Thus, Peters describes a bacillus which he found among the organisms of leaven which possesses a peptonising power.

307. Putrefactive Fermentation.—Putrefaction is that change by which most organic bodies containing nitrogen in a proteid form are first resolved into substances having a most putrid odour, and ultimately into inorganic products of oxidation. *Bacterium termo* and *B. subtilis* have already been mentioned as the principal organisms of putrefaction. Pasteur divides the act of putrefaction into two distinct stages, which it will be well here to describe. On exposing a putrescible liquid to the air, there forms on the surface a film composed of *bacteria*, &c.; these completely exclude any oxygen from the liquid, by themselves rapidly absorbing that gas. Beneath, other more active organisms, which Pasteur groups together under the name of "*vibrios*," act as ferments on the proteid matters of the liquid, and decompose them into simpler products; these simpler products are in their turn oxidised still further by the surface *bacteria*. Pasteur practically defines putrefaction, or putrid fermentation, as fermentation without oxygen.

308. Action of Oxygen on Bacterial and Putrefactive Ferments.—Pasteur draws a hard and fast line between certain *bacteria* which he affirms live in oxygen, and absolutely require it, and others to which oxygen acts as a poison; to which latter class he states that the *vibrios* belong. This name is used by him seemingly to refer to those micro-organisms which are in active motion. Of the *bacteria* of the first type, he mentions that if a drop full of these organisms be placed on a glass slide, and examined with a microscope, there is soon a cessation of motion in the centre of the drop, while those *bacteria* nearest the edges of the cover glass remain in active movement in consequence of the supply of air. On the other hand, if a drop of liquid containing the *vibrios* of putrefactive fermentation be studied in a similar way, motion at once ceases at the edge of the cover glass; and, gradually, from the circumference to the centre, the penetration of atmospheric oxygen arrests the vitality of the *vibrios*. Pasteur thus divides the *bacteria* into an *ærobian* and an *anærobian* variety; the former require oxygen, the latter find it a poison, and live and thrive best in its total absence. In proof of this view he describes experiments of a most careful character made by him.

309. Conditions Inimical to Putrefaction.—First and foremost among these is the keeping out of the germs of putrefactive ferments from the substance. Meat and proteid bodies, generally, have come to be ordinarily viewed as very changeable substances, whereas in the absence of germ life they are very stable bodies. Putrefaction is the concomitant, not of death but of life. If animal fluids are drawn off into sterilised vessels without access of air, they keep for an indefinite length of time. Or the germs may be destroyed by heat, when putrescible substances also remain unchanged. This latter is the basis of Appert's methods for the preservation of animal substances. These methods consist of exposing the substances to a sufficiently high temperature in hermetically sealed vessels; or they may be heated in vessels so arranged that air may escape, but that any re-entering shall be freed from bacterial germs either by passing through a red-hot tube, or by being filtered through a thick layer of cotton-wool.

Tinned meats, milk, &c., are preserved on this principle of Appert's.

Putrefaction may be arrested by intense cold, although even freezing *bacteria* does not destroy their power of inducing putrefaction when again warmed. As a consequence of this action of cold, meat when thoroughly frozen may be preserved almost indefinitely. The absence of water is another preventative of putrefaction. Vegetables and meat, if thoroughly desiccated, show, on keeping, no signs of putrefying. In the same way, yeast, although in the moist state one of the most putrescible substances known, may, by being carefully dried, be kept for months, not merely without putrefying, but also without destroying the life of the cell.

310. Products of Putrefaction.—These are exceedingly numerous and complex, among them may be found volatile fatty acids, butyric, and other of the series; ammonia, and some of the compound or substitution ammonias; ethylamine, trimethylamine, propylamine, &c.; carbon dioxide, sulphuretted hydrogen, hydrogen, and nitrogen.

LACTIC AND OTHER FERMENTATIONS.

311. Lactic Fermentation.—This is primarily the fermentation by means of which milk becomes sour. The chemical change is a very simple one. Milk contains the variety of sugar known as lactose or sugar of milk, $C_{12}H_{22}O_{11}$. By hydrolysis, this splits up into two molecules of a glucose called lactose, galactose, or lacto-glucose, $C_6H_{12}O_6$. When subjected to the influence of the lactic ferment, lacto-glucose is decomposed according to the following equation:—

$$\underset{\text{Lacto Glucose.}}{C_6H_{12}O_6} \quad = \quad \underset{\text{Lactic Acid.}}{2\ HC_3H_5O_3.}$$

Ordinary glucose, and also cane-sugar and maltose, are susceptible of the same transformation. From numerous recent researches, there is evidence of a number of organisms which possess the power of producing lactic acid by the conversion of glucose. One or more of these is always found present in greater or less quantity in commercial yeasts, also on the surface of malt; in the latter case it may be detected by washing a few of the grains in water, and then examining the liquid under the microscope. Its shape, according to Lister, when developed in milk, is shown in the accompanying illustration. When viewed with a lower power in a field of yeast, the lactic ferment appears as small elongated cells somewhat constricted in the middle, generally detached, but occurring sometimes in twos and threes; their length is about half that of an ordinary yeast cell. When single they exhibit the Brownian movement.

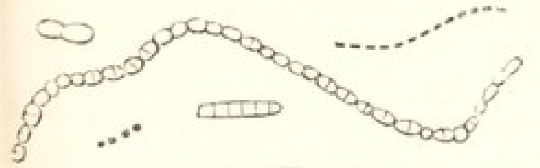


FIG. 17.—*Bacterium Lactis* × 1140 (after Lister).

Lactic fermentation proceeds most favourably at a temperature of about 35° C., and is retarded and practically arrested at a temperature which still permits the growth and development of the yeast organism, and consequent alcoholic fermentation. For this reason brewers always take care to ferment their worts at a low temperature, thus preventing the lactic ferment, which is always more or less present, from any rapid development. The other bacterial and allied ferments are also affected in a similar manner by temperature. Dilute solutions of carbolic and salicylic acids (and also hydrofluoric acid) greatly retard lactic fermentation, while in such very weak solutions they have but little action on the yeast organism; hence yeast is sometimes purified by being repeatedly grown in worts, to which small quantities of these acids have been added. The most favourable medium for lactic fermentation is a saccharine solution rather more dilute than that used for cultivating yeast, and containing proteids in an incipient stage of decomposition. The analogy between this fermentation and the alcoholic is close, because the two may proceed side by side in the same liquid. The presence of acid is inimical to lactic fermentation; hence the fermentation arrests itself after a time by the development of lactic acid; provided this is neutralised from time to time by the addition of carbonate of lime or magnesia, the fermentation proceeds until the whole of the sugar has disappeared. In a slightly acid liquid, as for instance the juice of the grape, alcoholic fermentation proceeds almost alone; but with wort, which is much more nearly neutral (if made with good malt), lactic fermentation sets in with readiness, and consequently has to be specially guarded against. Some varieties of the lactic acid ferment require air for their growth and development, while others are anærobic in their character.

In addition to its specific action on glucose, converting it into lactic acid, the lactic ferment has other functions of importance in commercial operations: thus, the presence of lactic ferment germs on malt result in the formation of a little lactic acid during the mashing; in distillers' mashes this is found to be somewhat valuable, and is encouraged, as it apparently helps to effect a more complete saccharification of the malt, and consequently increases the yield of alcohol. It also peptonises the proteids, bringing them into a condition more adapted for the nutrition of yeast. Distillers, therefore, frequently allow their malts to develop considerable acidity before using them, and give new mash tuns a coating of sour milk before bringing them into use. In bread-making, by the Scotch system, the presence of the lactic ferment is deemed to make better bread: either the ferment, or the lactic acid produced, softens and renders the gluten of the flour more elastic.

Hansen's methods have recently been applied to the preparation of pure cultivations of lactic ferments, with the view of securing a more satisfactory acidification of cream preparatory to its being made into butter. Two distinct species have been isolated, which give particularly favourable results in butter-making; one of these is stated by Storch to give a pure and mild slightly sour taste, imparting at the same time a very pure aroma to the cream and butter made therefrom. There are other lactic acid-forming bacteria, which, on the contrary, produce diseases in milk; thus, one species causes the milk to become viscous at the same time as it undergoes lactic fermentation. Further, certain bacteria induce a tallow-like flavour in butter. Not only may we have a fermentation producing lactic acid as distinct from other acids, but also there are differentiations in the character of the secondary products formed at the same time as the lactic acid, and which secondary products affect most vitally the success or otherwise of the particular process from its manufacturing standpoint. It is more than possible that these variations in the nature of lactic fermentation itself may have a direct bearing on the success of bread-making operations.

Even at the risk of tautology, it must again be stated that lactic fermentation cannot proceed without the intervention of one of the organisms known as lactic ferments, and that the yeast organism *per se* never produces the least trace of lactic acid.

312. Butyric Fermentation.—At the close of the lactic fermentation of milk, the lactic acid or lactic salts, as the case may be, seem to be acted on by ferment organisms and converted into butyric acid with the evolution of carbon dioxide and hydrogen—

$$\underset{\text{Lactic Acid}}{2HC_3H_5O_3} = \underset{\text{Butyric Acid.}}{HC_4H_7O_2} + \underset{\text{Carbon Dioxide.}}{2CO_2} + \underset{\text{Hydrogen.}}{2H_2}.$$

Several species of *bacteria* are capable of inducing butyric acid fermentation. The most carefully examined among these is *Clostridium butyricum*, known also as *Vibrio butyricus*, which occurs in the form of short or long rods, and is in shape and general appearance very similar to *B. subtilis*, differing, however, from that organism in that it contains starch. In breweries and pressed yeast factories, butyric fermentation is often caused by organisms of altogether different type to *C. butyricum*. This particular organism is anærobic in character, but others of the species producing butyric acid are distinctly tolerant of oxygen. The general conditions of butyric fermentation are similar to those of lactic fermentation. A temperature of about 40° C. (104° F.) is specially suitable; the presence of acids is to be avoided; or where butyric fermentation is not wished, its prevention is more or less attained by working at a lower temperature and with a slightly acid liquid. However, with the fully developed organism, a slight acidity is unable to prevent butyric fermentation. Although butyric fermentation is usually preceded by lactic fermentation, the butyric ferment is also capable of acting directly on sugar itself, and also on starch, dextrin, and even cellulose.

Tannin has a markedly prejudicial effect on the growth and development of bacterial life, hence the addition of this substance, or any compound containing it, to a fermenting liquid, exercises great preventive action on the development of lactic and butyric fermentation. Hops contain tannin as one of their constituents, and also the bitter principles of the hop cause a hopped wort to be much less liable to lactic fermentation than one unhopped. For a similar reason, bakers add hops to their patent yeast worts.

313. Acetic Fermentation.—Certain organisms effect the change of wine and beer into vinegar. The reaction is one of oxidation of the alcohol present: in the first place, aldehyde is formed, and then this body is oxidised into acetic acid, according to the following equations:—

$$\underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Aldehyde.}}{2C_2H_4O} + \underset{\text{Water.}}{2H_2O}.$$

$$\underset{\text{Aldehyde.}}{2C_2H_4O} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Acetic Acid.}}{2HC_2H_3O_2}.$$

Pasteur described under the name of *Mycoderma aceti* an organism through whose agency alcohol is oxidised into acetic acid. Hansen has detected two distinct species under this name, distinguished by the one staining yellow, and the other blue, with iodine solution. Both possess the same chemical properties, and in order to develop vigorously require a plentiful supply of oxygen. They are, in fact, strictly ærobic. A temperature of about 33° C. is the most favourable to the production of acetic fermentation. *Bacterium aceti* also converts propyl alcohol into propionic acid, but is without action on either butyl alcohol or the amyl alcohol of fermentation.

Bacterium aceti forms a mycelium on the surface of liquids, possessing a certain amount of tenacity: viewed under the microscope, this mycelium is seen to consist of chains of cells, as shown in Plate V.

In the substance known as "mother of vinegar" or the vinegar plant, long supposed to be identical with *B. aceti*, A. J. Brown discovered a separate organism, which, in addition to producing acetic acid, is also marked by the property of causing the formation of cellulose; to this he has given the name of *Bacterium xylinum*.

Peters has discovered in extremely old and sour leaven an acetic acid bacterium, distinct from those just described. The individuals are about 1·6 μ long, and 0·8 μ broad, truncated at one end, and tapering at the other. Interest attaches to the isolation of this specific organism, inasmuch as a small proportion of the acidity of bread is due to acetic acid.

A temperature below 18° C. is almost inhibitory to the action of the acetic acid ferment, while most antiseptics, and especially sulphur dioxide, are exceedingly inimical to acetous fermentation.

314. Viscous Fermentation.—Viscous fermentation is that variety which causes "ropy beer." Pasteur supposed this to be due to an organism consisting of globular cells of from 1·2 to 1·4 μ in diameter, adhering together in long chains. Moritz and Morris, who have devoted particular attention to this subject, disagree with Pasteur's views, and ascribe ropiness principally to a ferment known as *Pediococcus cerevisiæ*. This organism occurs either in pairs of cells or tetrads (*i.e.*, four cells arranged in the corners of a square), diameter of each cell being 0·9—1·5 μ. These organisms are similar in appearance to those marked *b*, Figure 15. Beer, after having undergone this fermentation, runs from the tap in a thick stream; and in very bad cases, a little, when placed between the fingers, pulls out into strings.

A somewhat similar condition sometimes holds in bread, which then is termed ropy bread; it is possibly due to the same cause.

315. Disease Ferments.—The ferments of lactic, viscous, and other than alcoholic fermentation, are frequently called "disease ferments," from their producing unhealthy or diseased fermentations in beer.

316. Spontaneous Fermentation.—In this country, alcoholic fermentation is usually started by the addition of more or less yeast from a previous brewing; it was formerly the custom to allow the fermentation to start of itself. This is said still to be practised in some parts of Belgium in the manufacture of a variety of beer, known as "Faro" beer. In manufacturing such beers, the vats of wort are allowed to remain exposed to the air, and fermentation is excited by any germs of yeast that may find their way therein. It is possible that under such circumstances a wort may only be impregnated by yeast germs, in which case pure alcoholic fermentation alone will be set up. It is far more likely, however, that germs of lactic ferment and other organisms will also get into the wort; consequently the beer will be hard or sour, and also likely to speedily become unsound. On the other hand, grape juice is always allowed to ferment spontaneously, but then this liquid is always distinctly acid, through the presence of potassium bitartrate; and acidity retards or prevents bacterial fermentation.

Bakers' barms or patent yeasts are at times allowed to ferment spontaneously; they are then found to contain a large proportion of foreign organisms, principally the lactic ferment. Except where very special precautions are adopted, they are liable to be uncertain in their action, and often produce sour bread.

But in all cases of so-called "spontaneous" fermentation it must be remembered that the fermentation is due to the presence in the wort of yeast cells or spores that either have been introduced along with the malt and hops without being destroyed, or else have found their way into the wort from some external source, such as germs floating in the air. It is also frequently possible that a sufficient quantity of yeast remains about the fermenting vessel from the last brewing to again start fermentation.

MOULDS AND FUNGOID GROWTHS.

317. The nature of these has been already referred to in Chapter IX., and the mould of beer, *Mycoderma cerevisiæ*, described and its properties explained. The moulds are all of them members of the fungus family. A few other varieties, because of their having more or less connection with the subject of this work, require description.

318. Penicillium Glaucum.—This is the ordinary green mould of bread, jam, &c. The base of this consists of a mycelium bearing both submerged and aerial hyphæ. The upper ends of the aerial hyphæ terminate in a string of conidia or spores, which break off on the slightest touch; these constitute the green powder which gives this mould its characteristic appearance. One of these spores, on being sown in an appropriate medium, as hay infusion or Pasteur's fluid, germinates and produces a young *penicillium*. The conidia retain their vitality for a long time, and from their extreme minuteness are readily carried about by the air; hence substances that offer a suitable medium for the growth and development of moulds, become impregnated on being exposed to the atmosphere.

Under favourable circumstances *penicillium* developes with extreme rapidity; some few years since the barrack bread at Paris was attacked by this fungus, a few hours was sufficient for its development, and the mould was in active growth almost before the bread was cold. It is stated that the spores of this species are capable of withstanding the heat of boiling water, so that the act of baking an infested flour would not necessarily destroy the spores.

319. Aspergillus Glaucus.—This is another mould very similar to *penicillium* in appearance and colour, but having at the ends of its hyphæ small globose bodies containing the spores; these bodies being termed sporangia.

320. Mucor Mucedo.—This mould develops well on the surface of fresh horse dung; this substance, if kept warm, will be found after two or three days covered with white filaments, these being the hyphæ, and termining in rounded heads or sporangia. In form *M. mucedo* somewhat resembles *A. glaucus*, but is distinguished from it by having a whitish aspect, *A. glaucus* being of a greenish colour.

321. Micrococcus Prodigiosus.—This organism consists of round or oval cells, from 0·1 to 1 mkm. diameter. These are at first colourless, but gradually assume a blood-red tint: they grow on wheat-bread, starch paste, &c. *M. prodigiosus* is the cause of the appearance known as blood-rain occasionally seen on bread: at times the growths proceed so far as to produce dripping blood-red patches on the bread.

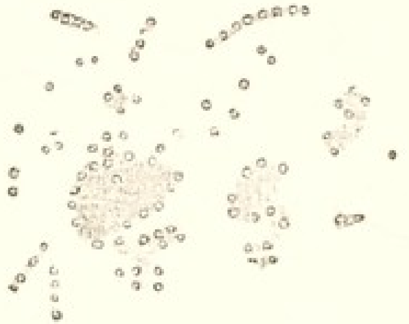


FIG. 18.—*Micrococcus Prodigiosus*, Cohn × 1200 (from nature).

322. Red Spots in Bread.—A phenomenon sometimes confused with the effect of *M. prodigiosus*, but nevertheless quite distinct therefrom, is that of intensely red-coloured spots in freshly baked bread. These are so bright as to lead to the suspicion that concentrated tincture of cochineal or other powerful dye had by accident got on to the dough and been baked with it. Fortunately for the baker, the occurrence of these spots is rare, and consequently there are few opportunities of minutely investigating them. So far as the author's experience goes, the spots occur most frequently in bread made from flour of the very highest class, such as Hungarian patents: he has also seen them in bread containing a large admixture of Oregon flours. The spots in bread do not increase in size as the bread grows old, nor are they apparently associated with any change in its constituents: there are no signs, in fact, of the colouration being due to the presence of any living and multiplying organism. It is exceedingly difficult to obtain specimens of the colour spots in unbaked dough, and only on one occasion has such a specimen come into the hands of the author. In that case a small patch of dough was sent him while absent from home, and was only examined by him on his return after two days. The dough had then got a slight dry skin on, but there were no signs of any growth or spreading in the dough; so far, therefore, as any conclusion may be drawn from this, it is against the source of colour being any organism developing in the dough. Careful microscopic examination of coloured portions of the bread show in the fainter spots that while the starch is uncoloured, there is a red dyeing of the gluten. In the larger and darker spots there may be sometimes seen by the naked eye a nucleus, which is so dark in colour as to be almost black. On breaking down a little of this nucleus with water, and examining microscopically, the author has invariably found fragments of the outer integument of the grain. Among these have been detected portions of the outside layer of bran, showing its characteristic markings, and also hairs of the beard of the wheat, all of which are intensely coloured. In one sample, only cursorily examined some years ago, a number of filaments somewhat similar to cotton wool were observed, but not identified; these, too, were coloured a very deep red. No signs of fungus spores or other special organisms were observable, but spores might possibly be crushed in the breaking down with water. The lack of material for purposes of further examination has prevented the author from carrying these investigations beyond this point, and such tests as are here recorded were made some two years ago. The most probable cause of the colour is its deposit on the outside of the grain after its removal from the husk and prior to its being milled. It is suggested as its possible source either some insect of the cochineal species, or an intensely coloured microscopic vegetable growth, such as a mould. These minute particles of outer bran carrying the colour on the surface are sufficiently fine to pass through the dressing silks, and so get into the flour. They would be so small as to be perfectly invisible in any ordinary examination by the naked eye. On being wetted the colour spreads and stains the surrounding gluten, hence the colour in the dough, which remains also and is seen most distinctly in the baked bread.

323. Musty and Mouldy Bread.—Mouldiness may be very often noticed in bread which has been kept for a few days: at times a loaf of one day's production will remain quite sound, while another will rapidly become mouldy. The "Analyst" of October, 1885, contains an article by Percy Smith, giving an account of some experiments made by him on musty bread. The bread when new had no disagreeable taste, but on the second day had become uneatable. Smith made a series of experiments, among which were the following:—

(a) Musty bread, one day old, soaked in water, enclosed between watch glasses.

(b) Flour from which the bread was made, similarly treated.

In six days *a* had begun to turn yellow, emitted a disagreeable odour, and began to assume a moist cheesy consistency and appearance. This portion was found to be swarming with *bacteria*. On *b*, *mucor mucedo* grew in abundance; the flour ultimately dried up without further change.

(c) Sweet bread similarly treated.

Aspergillus glaucus appears, but no *mucor*, neither does the bread become cheesy nor evolve odour of musty bread. The following are Smith's conclusions based on these and other experiments.

"Ordinary bread turns mouldy owing to the growth of *A. glaucus*. Musty bread, on the other hand, yields both *A. glaucus* and *M. mucedo*, and then undergoes putrefactive decomposition, becoming the home of *vibriones* and *bacteria*. These organisms, of course, can have nothing to do with the mustiness; they only flourish because there is a suitable nidus for their growth. It is, however, curious that the musty bread should decay while the sweet bread should not, whilst the only *apparent* difference between them is in the growth of *M. mucedo*. The suspected flour produces an abundant crop of *mucor*, but does not decay. This is no doubt due to the fact that starch is not so suitable a nidus as is dextrin for *bacteria*. Perfectly pure flour failed to decompose when kept between watch glasses, but when placed in a damp cellar readily became musty, and produced a crop of *M. mucedo*." He further concludes that this fungus is the cause of the mustiness in the cases cited, although other species may possess similar properties. Smith is of opinion that of the musty bread and flour supplied to him the following is the history :—"The flour was stored in a damp place, causing fungoid growth; to avert decomposition, *the flour was then baked*." (This idea occurred through the flour having a dark colour, as though charred.) When the bread was baked, the assimilation of moisture regenerated the fungus, thus causing the bread to become musty, for which result it is not necessary for the plant to arrive at maturity; the disagreeable taste being developed as soon as flocci are visible under the microscope. *Mucor* has apparently a specific chemical action on bread that is not possessed by *Aspergillus glaucus*.

The baking of the flour seems rather a peculiar treatment, since any baking that would produce anything like charring in the flour would entirely destroy its gluten, and consequent doughing properties. It is more probable that the flour was simply of an exceedingly low grade.

Hebebrand has recently published the results of some investigations on mouldy bread. He infected some samples of rye bread from mouldy bread, the organisms being chiefly *Penicillium glaucum* and *Mucor mucedo*. These were kept for periods of seven and fourteen days, and similar samples at once dried for analysis. The results showed that the mould caused a considerable loss of substance, carbohydrate being converted into water and carbon dioxide. There was only a slight loss of proteids, but the loss of carbohydrates caused the percentage of proteids to appear much higher in the dry substance of the mouldy bread. The decomposed proteid was converted into amides. The following numbers show the percentage composition (1) of dried fresh bread, and (2) of the dried mouldy bread :—

	No. 1.	No 2.
Proteid, Insoluble, ...	9·75 per cent.	9·77 per cent.
,, Soluble, ...	1·92 ,,	5·15 ,,
Maltose, ...	1·54 ,,	0·50 ,,
Dextrin, ...	8·02 ,,	11·86 ,,
Starch, ...	76·75 ,,	63·52 ,,
Fat, ...	0·26 ,,	2·11 ,,
Ash, ...	1·44 ,,	2·41 ,,
Crude Fibre, ...	0·05 ,,	2·47 ,,

324. Diseases of Cereals.—Certain diseases to which the cereal plants are subject are due to parasitic fungoid growths. Among these are mildew, smut, bunt, and ergot. Their nature may briefly be considered at this stage of our work.

325. Mildew.—To the farmer this blight is unhappily too familiar; if a wheat field be examined in May or June, a greater or less number of the plants will appear as though some of the lower leaves had become rusty; at the same time the leaves are sickly and atrophied. As the disease develops, the number of rusty leaves increases; the "rust" itself will be found on examination to consist of the spores of a fungus, known as the *Puccinia graminis* or corn mildew. The mycelium penetrates the tissues of the leaves, occupying the intercellular spaces, and thus gradually destroys them, with the effect of seriously injuring and reducing the corn crop.

326. Smut.—This disease is also know as "dust brand," "chimney sweeper," and by other names all referring to the black appearances of ears of grain infested by it. When the grain is nearly ripe, there will be noticed here and there in a wheat field shrivelled looking ears, which look as though covered with soot. Smut is due to a fungus which has received the name of *Ustilago segetum.* The fungus develops within the seeds, destroying the contents of the grain, and replacing them by a mass of spores which appear as a fine brownish black powder. Smut is a very destructive parasite, and attacks barley, oats, and rye, and also, although to a somewhat lesser extent, wheat. Viewed microscopically, the spores of *U. segetum* are found to be spherical, and to have a diameter of about 8 mkms.; their appearance is shown in the following figure;

FIG. 19.—*a*, SMUT, *b*, BUNT × 400 diameters.

327. Bunt or Stinking Rust.—Unlike smut, bunt produces no external signs of its presence in a wheat field: there is no sooty appearance of the ear, nor any rust above the leaves. It is not until the wheat is threshed from the straw that the bunted grains are discovered in the sample. Externally, these grains are plumper than those which are sound; but on their being broken, the interior, instead of being white and flour-like, is found to be filled with a black powder, having a greasy feel when rubbed between the fingers, and a most fœtid and unpleasant odour. This dust consists of the spores of a fungus termed *Tilletea caries*, mixed with portions of its mycelium. The spores are much larger than those of smut, and, viewed under the microscope, appear as shown in Fig. 19: they are about 17 mkms. in diameter.

The presence of bunt is said not to affect the wholesomeness of flour; it is stated that bunted flour is at times made up into gingerbread; the other condiments used masking its colour and odour. With the extreme care manifested in modern systems of milling, it is improbable that bunt often finds its way into the flour.

328. Ergot.—This disease is almost exclusively confined to rye; like bunt and smut, ergot is due to a fungus which develops within the grain, filling its interior with a compact mass of mycelium and spores. and altering the starch cells by replacing the amylose with a peculiar oily matter. This fungus is termed *Oidium abortifaciens*. The ergotised grains are violet-brown or black in colour, moderately brittle; and when in quantity evolve a peculiar nauseous fishy odour, due to the presence of trimethylamine. Ergot possesses powerful medicinal effects, and when taken in anything over medicinal doses, acts as a violent poison. The presence of ergot in flour is therefore extremely dangerous.

Chemical tests for the detection of ergot and moulds will be given in the analytic section of this work.

EXPERIMENTAL WORK.

329. Prepare some malt wort; filter and allow the liquid to remain for some days in an open flask. In about 24 hours the liquid becomes turbid; examine a drop under the microscope with the highest power at disposal. *Bacteria* will be seen in abundance; notice that they have a distinct migratory movement. Examine a sample each day, and observe that the *bacteria* grow less active, and ultimately become motionless; they have then assumed the zooglœa stage. Carefully search the liquid for other organisms; *bacilli* should be detected, being recognised by their filamentous appearance. *Vibrios* should also be observed; they appear very like *bacilli*, except that they have bent joints. When actively moving they exhibit an undulatory movement, depending on their rotation on their long axis.

Examine microscopically some of the sediment of "turned" beer; large quantities of *bacilli* can usually be observed. These organisms are also commonly found in bakers' patent yeasts.

Place some fresh clear wort in a flask and plug the neck moderately tightly with cotton wool; boil the liquid for 5 minutes and allow to cool: notice that the contents of the flask remain clear. At the end of a week, remove the plug and examine a drop of the liquid under the microscope, *bacteria* and other organisms are absent. The wort is still sweet and free from putrefactive odour. Let the flask now stand freely open to the atmosphere: organic germs gain entrance, and putrefactive or other changes rapidly occur. On the next and succeeding days, examine microscopically.

Procure a small quantity of milk and allow it to become sour; examine microscopically for *bacterium lactis*. Also, wash a few grains of malt in a very little water, and examine the washings for this organism.

Prepare two samples of wort, strongly hop the one by adding hops in the proportion of one-tenth the malt used: boil the two samples, filter, and set aside under precisely the same conditions. Observe the relative rate of growth and development of bacterial life in the two.

CHAPTER XI.

TECHNICAL RESEARCHES ON FERMENTATION.

330.—In this chapter are contained the results of certain technical researches made by the author on matters having a more or less direct bearing on bread-fermentation. Some of these appeared in a previous work of the author's, while others are now published for the first time.

331. Strength of Yeast.—To the baker, the first consideration about yeast is its strength or gas-yielding power: there are other effects which it also produces, but its all-round activity may be fairly measured by the quantity of gas it evolves from a suitable saccharine medium. The term "strength" is therefore used in this sense; it follows that the strongest yeast will also raise bread better, because the rising of the dough is due to the gas evolved by the yeast from the saccharine constituents of the flour. Different modes have been adopted from time to time for the purpose of testing the strength of yeast. The essential principle of these has been to ferment a definite quantity of some saccharine fluid with a constant weight of yeast, at a constant temperature, and to then determine the volume of gas evolved in a given time. Meissl, of Vienna, used the following process, which, like most others of its kind, is based on the principle that the strength of the yeast can be judged from the amount of carbon dioxide it produces from a certain quantity of sugar, the other substances being in equal proportions.

In order to carry out the experiment, the following substances must be prepared by rubbing them together: 400 grams of refined cane sugar, 25 grams of phosphate of ammonium, and 25 grams of phosphate of potassium. A small vessel should be ready at hand of 70 to 80 c.c. capacity, and fitted with an india-rubber stopper containing two holes, in one of which should be placed a bent glass tube, the long end of which should nearly reach the bottom of the vessel, and the top end, during the fermentation, should be corked up. The second hole serves for the reception of a small chloride of calcium tube.

The testing of the yeast may then be commenced in the following manner: 4·5 grams of the above mixture should be stirred gently, and dissolved in 50 c.c. of distilled water. In this liquid one gram of the yeast on which the experiment is to be tried should be carefully stirred and mixed until no lumps are to be seen. The vessel with its contents must be weighed and then placed in water at a temperature of 30° C., and left to remain during six hours. At the end of this time it must be taken out and plunged immediately into cold water in order to cool it as quickly as possible. The stopper is then taken out of the bent glass tube, and the air allowed to enter during a minute or two, so as to drive out the carbon dioxide. The vessel and its contents must then be weighed. The loss of weight arises from the quantity of carbon dioxide which has been thrown off during the process. By this method, the carbon dioxide is estimated by weight : the chloride of calcium tube is affixed for the purpose of retaining any traces of aqueous vapour which otherwise would escape.

In many ways this apparatus and method were susceptible of improvement, at least when used for technical and commercial purposes. In the first place the actual weight of the flask with contents amounts to some 80 or 90 grams, while the weight of carbon dioxide evolved varied, in some experiments made by the author, from 0·291 to 1·237 grams. To accurately measure these differences of weight in an apparatus, itself weighing so much, a very delicate balance is requisite. This method is capable, in competent hands, of yielding accurate results ; but it is tedious, and does not give all the information that could be wished.

Another mode of procedure is to collect the gas in a jar over mercury in a pneumatic trough ; this undoubtedly gives the most accurate results, but is open to the objection that mercury is expensive, and the apparatus, from its great weight, heavy and cumbersome. The reader is already aware that water is capable of dissolving carbon dioxide gas to the extent of its own volume ; this, therefore, is an obstacle to the employment of water for its collection. The writer, nevertheless, made the experiment, and found that on collecting the gas evolved by the yeast during fermentation, in the ordinary manner in a graduated gas jar over water, most interesting results could be obtained. These were of course not absolutely correct, because a certain quantity of the gas was absorbed by the water ; still, duplicate experiments gave corresponding quantities of gas, while most important information was gained as to the general character of different yeasts when examined in this manner. Results obtained in this way may therefore be viewed as comparable with each other.

332. Yeast Testing Apparatus.—In the next place a series of experiments were made in which the gas was admitted to the graduated jar through the top, and so did not bubble through the water at all. When collected in this way the amount of absorption was small and very uniform. Two jars were two-thirds filled in this manner with washed carbon dioxide gas prepared from marble and hydrochloric acid. They were then allowed to stand, and the amount of absorption observed hourly. The rate of absorption, with the particular jars used, was as nearly as possible a cubic inch per hour. Subsequent trials with jars of one hundred cubic inch capacity gave an outside rate of absorption of two cubic inches per hour. A still better plan is to use instead of water an aqueous solution of calcium chloride, of a degree of concentration giving a specific gravity of 1·4. With this solution there is practically no absorption of carbon dioxide. As a result of numerous experiments, the writer now employs the form of apparatus figured on next page.

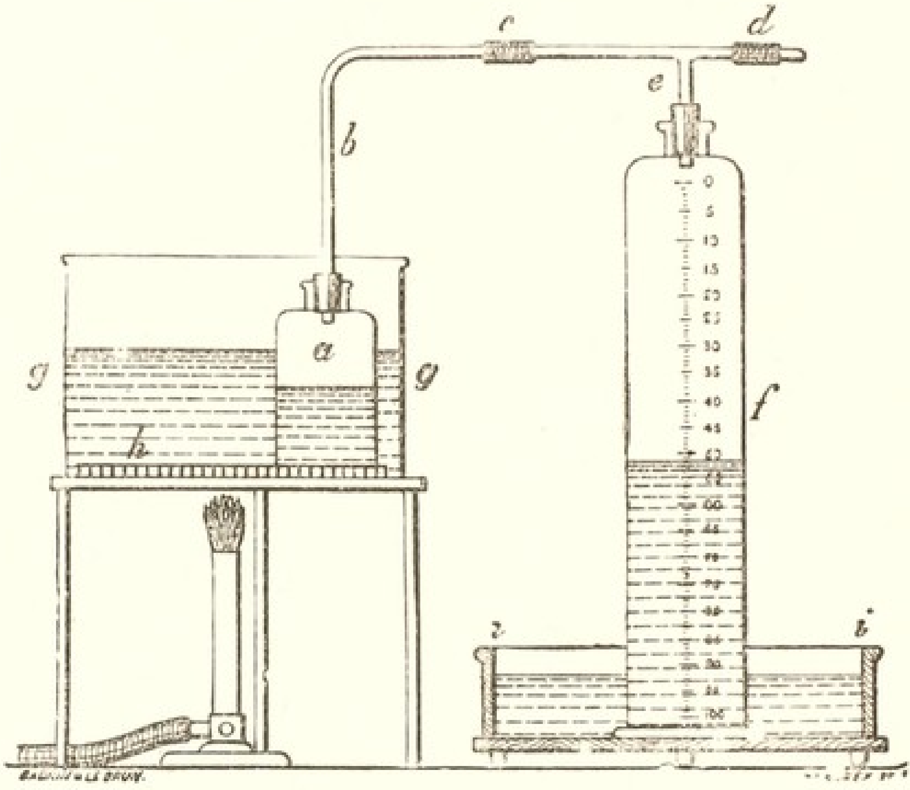


FIG. 2C.—YEAST TESTING APPARATUS.

The glass bottle, marked *a* in the figure, is of about 12 ounces capacity, and is fitted with india-rubber cork and leading tube, *b*. The sugar or other saccharine mixture to be fermented is raised to the desired temperature, and then placed in this bottle. The yeast is weighed out, and then also added; they are then thoroughly mixed by gentle agitation. By means of an india-rubber tubing joint at *c*, the generating bottle is connected to the leading tube, *e*, of the glass jar, *f*. This leading tube is provided at *d* with a branch tube, which may be opened or closed by means of a stopper of glass rod and piece of india-rubber tubing. The jar, *f*, is graduated, as shown, into cubic inches, commencing immediately below the shoulder with 0, and ending near the bottom with 100. More recently the author has employed jars graduated into cubic centimetres, and has had them made of two sizes, 500 c.c. and 1000 c.c. respectively. This constitutes the apparatus proper; in use the generating bottle, *a*, is placed in a water bath, *g g*. This bath is fixed on a tripod over a bunsen burner, and is provided with an iron grid, *h*, in order to prevent the generating bottle coming in absolute contact with the bottom of the bath. By means of an automatic regulator the bath is maintained at any desired temperature. The gas jar, *f*, stands in a pneumatic trough, *i i*.

As a rule, more than one test is made at a time, the water-bath should therefore be sufficiently large to take four or six bottles at once: two pneumatic troughs are then employed, and either two or three of the gas jars, *f*, arranged in each. While for strictly accurate experiments it is essential that the yeast bottles be kept as nearly as possible at a definite temperature, yet results of interest may be obtained without the employment of a water-bath. The whole apparatus should, under those circumstances, be placed in some situation where, as nearly as possible, a constant temperature is maintained.

At the start of the experiment the air is exhausted through *d*, which is again closed with the stopper. As the fermentation goes on the gas evolved is collected in *f*, and its volume read off, from the surface of the water, at the end of each half-hour or hour. Full and detailed particulars are given at the end of this chapter as to the exact mode of procedure in using this apparatus.

When the requisite allowance is made for the absorption of the gas by water, the corrected reading very nearly corresponds with the absolute amount of gas which has been evolved. It is far better, however, to use calcium chloride solution, and so prevent any absorption of the gas. There are slight variations due to alterations of barometric pressure and of temperature; these can, if wished, be calculated out and allowed for—that is not, however, for ordinary purposes necessary. Gases are usually measured at a standard pressure of 760 millimetres, or very nearly 30 inches of mercury, that is with the barometer standing at 30. A rise or fall of the barometer through half an inch only makes a difference of one-sixtieth on the total reading, and this may as a rule be neglected. In case the estimation is being made in either the laboratory or a bakehouse, the temperature is, as a rule, fairly constant. Supposing it be taken at 70° F., then it will be found that a difference of 5° either way only causes a variation in the volume of the gas of one hundredth the total amount. Barometric and thermometric variations may, therefore, for most practical purposes, be neglected. Further, whatever variations there may be either in temperature or pressure, all the tests made at the same time are made under precisely similar conditions.

In all the experiments quoted, except the later ones, the gas was collected over water. No corrections were, however, made for absorption, because it is evident that at the outset the carbon dioxide remains as a layer of gas within the bottle, simply displaying air over into *f*; during this time no absorption can take place. It should, however, be remembered that, when the gas remains stationary for any length of time, a quantity must have been evolved about equal to that being absorbed.

333. Degree of Accuracy of Method.—This is a matter of great importance, because unless fairly constant and accurate results are obtainable, little or no confidence can be placed in them, or any deductions based thereon. A number of duplicate experiments were therefore first made in order to test the accuracy of the estimations; the results are appended:—

No. 1. Brewers' Yeast, $\frac{1}{2}$ oz.; Sugar Mixture, $\frac{1}{2}$ oz.; Water, 6 oz. at 30° C.

No. 2. Duplicate of No. 1.

No. 3. French Compressed Yeast, $\frac{1}{4}$ oz.; Sugar Mixture, $\frac{1}{2}$ oz.; Water, 6 oz. at 30° C.

No. 4. Duplicate of No. 3.

TIME.	GAS EVOLVED IN CUBIC INCHES.								Temperature.
	No. 1.		No. 2.		No. 3.		No. 4.		
0	0·0		0·0		0·0		0·0		29·7
		0·7		0·5		3·1		2·5	
½ hour ...	0·7		0·5		3·1		2·5		30·0
		5·8		5·5		16·1		15·2	
1 ,, ...	6·5		6·0		19·2		17·7		30·0
		7·7		7·8		21·8		21·4	
1½ hours ...	14·2		13·8		41·0		39·1		29·8
		7·8		8·2		21·0		20·7	
2 ,, ...	22·0		22·0		62·0		59·8		28·9
		8·0		7·7		20·0		20·4	
2½ ,, ...	30·0		29·7		82·0		80·2		29·5
		11·0		11·3		21·5		21·0	
3 ,, ...	41·0		41·0		103·5		101·2		30·0
		6·0		5·7		22·3		23·2	
3½ ,, ...	47·0		46·7		125·8		124·4		30·25
		7·5		8·0		17·8		20·4	
4 ,, ...	54·5		53·7		143·6		144·8		30·25
						14·9		15·9	
4½ ,, ...	...		...		158·5		160·7		30·0
						9·5		9·3	
5 ,, ...	...		...		168·0		170·0		30·0
						7·0		5·0	
5½ ,, ...	...		...		175·0		175·0		30·0
						2·8		0·8	
6 ,, ...	...		..		177·8		175·8		29·9

The figures placed opposite the brackets represent the volume of gas given off in each successive half-hour. A thermometer was placed in the water-bath and the temperature observed at the time of each reading, and registered in the last column. The temperature in this experiment shows considerably greater variations than that in those made later. It will be noticed that both pairs of duplicates agree very closely throughout the entire fermentation.

It may here be mentioned that a half ounce of sugar yields, on the supposition that the whole is transformed inth carbon dioxide and alcohol, the following quantities :—

½ oz. of sugar = 14·2 grams, and yields 7·30 grams of CO_2 =
3·705 litres = 226 cubic inches at 0° C. =
242 ,, 20° C.
(One cubic inch = 16·4 c.c.)

It will be remembered that actually only about 95 per cent. of the sugar is thus converted into carbon dioxide and alcohol ; these quantities in strictness, therefore, require to be reduced about 5 per cent.

As in the experiments to be now described the same brand or kind of yeast was used on different days, it was necessary, as a preliminary, to ascertain the degree of constancy of strength of the same yeast. Determinations were made on one brand of compressed yeast with the following results :—

No. 1.—April 27th, 1885,
No. 2.—May 7th, 1885,
No. 3.—June 30th, 1885,
Yeast, ¼ oz.; Sugar Mixture, ½ oz.; Water, 6 oz. at 30° C.

TIME.	GAS EVOLVED IN CUBIC INCHES.					
	No. 1		No. 2.		No. 3.	
0	0·0		0·0		0·0	
		21·7		24·5		28·7
1 hour	21·7		24·5		28·7	
		41·3		36·4		31·9
2 hours	63·0		60·9		60·6	
		33·0		43·1		43·6
3 „	96·0		104·0		104·2	
		34·3		32·0		40·8
4 „	130·3		136·0		145·0	
		24·2		22·5		30·0
5 „	154·5		158·5		175·0	
		15·7		17·5		2·8
6 „	170·2		175·0		177·8	

Although these results do not agree with that closeness observable in the duplicates, yet it will be seen that the yeast is throughout fairly similar in behaviour; still, it must be remembered that in experiments made on different days the results are not always strictly comparable, because the yeast is sure to be not absolutely the same in each case.

334. Effect of Different Media on Yeast Growth.—That certain substances are eminently fitted for aiding the growth and development of yeast, while others are not so suited, has already been stated. In order to measure quantitatively the effect of sowing yeast in different solutions, the following determinations were made.

335. Comparison between Sugar, "Yeast Mixture," Pepsin, and Albumin.—The "yeast mixture" referred to is based on the fluid in which Pasteur cultivated yeast, and which is known as "Pasteur's Fluid." Pasteur employed a solution of sugar and ammonium tartrate to supply saccharine matter and nitrogen; to this he added some yeast ash as a source of mineral constituents. This fluid may be closely imitated by use of the following formula—

Potassium Phosphate	20	parts.
Calcium Phosphate	2	„
Magnesium Sulphate	2	„
Ammonium Tartrate	100	„
Purest Cane Sugar	1500	„
Water	8376	„
	10,000	parts.

As this solution keeps badly, the yeast mixture consists of Pasteur's Fluid, *minus* the water. The salts are first powdered and dried, and then mixed until thoroughly incorporated. This mixture has the great advantage that while dry it can be kept any length of time without change.

Date, 26th April, 1885.

No. 1. Pure sugar, ½ oz. (14·2 grams[1]); compressed yeast, ⅛ oz. (3·5 grams); water, 6 oz. (170 grams) at 30° C.

No. 2. Yeast mixture, ½ oz.; compressed yeast ⅛ oz.; water, 6 oz. at 30° C.

No. 3. Pure Sugar, ½ oz.; pepsin, 1·5 grams; compressed yeast, ⅛ oz.; water, 6 oz. at 30° C.

No. 4. Yeast mixture, ½ oz.; pepsin, 1·5 grams; compressed yeast, ⅛ oz.; water, 6 oz. at 30° C.

At the expiration of seven hours, the following quantities of gas had been evolved:—

No. 1,	... 51·3 cubic inches.	No. 3,	... 112·0 cubic inches.
No. 2,	... 132·0 ,,	No. 4,	... 181·5 ,,

Experiments were also made with pepsin and albumin by themselves, but neither of these gave practically any evolution of gas.

From these experiments the following conclusions are derived:—

Pure sugar undergoes a regular but somewhat slow fermentation.

Sugar mixed with about ten per cent. of pepsin ferments at first more slowly, but afterwards much more rapidly.

"Yeast mixture," consisting of sugar, ammonium tartrate, and inorganic salts, ferments from the commencement still more rapidly.

Yeast mixture, with about 10 per cent. of pepsin, undergoes still more rapid fermentation.

Nitrogenous bodies alone, as pepsin, albumin, in water, or 2½ per cent. salt solution, evolve practically no gas.

Pepsin and other nitrogenous bodies must therefore be considered, not as the substances from which yeast causes the evolution of gas, but as stimulating nitrogenous yeast foods.

336. Comparison between Filtered Flour Infusion. Wort, and Yeast Mixture Solution.—Pursuing the same line of investigation, experiments were next made for the purpose of examining and comparing flour infusion, wort, and yeast mixture, as fermentable substances. An infusion of flour was made by taking 400 grams of flour, and 1000 c.c. of water; these were shaken thoroughly in a flask,

---

[1] In these experiments an anomaly will be noticed in the systems of weights employed. In deference to the fact that many of the readers of this book will be much more familiar with the English than the metric weights and measures, the writer has, where practicable, used the former system; although were he to follow his own predilections, all quantities would throughout have been expressed in grams and cubic centimetres.

The relation between grams and fractions of an ounce may be understood by remembering once for all that

1 ounce or 16 drams = 28·35 grams.
½ ,, ,, 8 ,, = 14·2 ,,
¼ ,, ,, 4 ,, = 7·1 ,,
⅛ ,, ,, 2 ,, = 3·5 ,,

from time to time, for half an-hour, and then allowed to subside: the clear liquid was filtered, and its specific gravity taken; this amounted to 1007·2. Meantime, some malt wort had been prepared; this was divided into two portions, the one of which was boiled, the other allowed to remain at the mashing heat. These were next cooled, and each diluted down until the specific gravity coincided with that of the flour infusion. A solution of yeast mixture of the same density was also prepared. Fermentation was started in each of these with the results given in the following table:—

Date, 8th May, 1885.

No. 1. 40 per cent. filtered flour infusion, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

No. 2. Unboiled malt wort, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

No. 3. Boiled wort, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

No. 4. Yeast mixture and water, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

At the end of five hours, the following quantities of gas had been evolved:—

No. 1, ...	8·3 cubic inches.	No. 3, ...	18·2 cubic inches.
No, 2, ...	17·1 „	No. 4, ...	24·3 „

The flour infusion evolved gas but slowly, and toward the end of five hours, over which the experiment lasted, had fallen off considerably. The two malt infusions yielded carbon dioxide at about double the speed; that in the boiled wort being the higher. The greater quantity of gas in the latter instance is due to the fact that boiling coagulates some of the proteids of the wort, and so leaves a greater percentage of sugar in the liquid, when both are diluted to the same density, This is an interesting instance of the removal of proteids resulting in a more copious and rapid evolution of gas. The yeast mixture causes the carbon dioxide to be evolved with still greater rapidity. Summing up the results—

In solutions of the same density,
Flour infusion, on fermentation, yields gas somewhat slowly;
Unboiled wort, at about double the speed;
Boiled wort, slightly more rapidly than the unboiled; and
Yeast mixture solution, at about three times the rate of the flour infusion.

The soluble extract of flour is thereby shown to be capable of only a slow fermentation; this is due to its containing a comparatively low proportion of sugar, and much of that of a kind which requires to be inverted before it can be fermented.

337. Comparison between Flour and its various constituents fermented separately.—From the baker's boint of view, it is of very great importance that he should know which of the several constituents of flour it is that affords, during fermentation, the gas by which his dough is distended. The following experiments were made for the purpose of obtaining definite information on this subject—

No. 1 requires no further explanation. In No. 2, 34 grams of flour were mixed with 6 oz. (= 170 c.c.) of water, being equivalent to 20 per cent. of flour in the water. In No. 3, the flour was agitated several times with large quantities of water, and allowed to subside between each washing, the supernatant liquid being poured off, and only the insoluble residue retained. In this manner, the washed insoluble residue is obtained comparatively free from the other constituents. Of these three samples, No. 2 represents the whole of the flour, No. 1 the soluble, and No. 3 the insoluble portion. No. 4 consisted of 20 per cent. flour infusion, with gelatinised starch added; the whole being subjected to a temperature of 30° C. for 12 hours before fermentation: this method was adopted in order to determine what diastasic effect was produced by the flour infusion on the gelatinised starch, it being assumed that whatever starch was converted into sugar would, under the influence of the yeast, be decomposed with the evolution of carbon dioxide gas. No. 5 was a somewhat similiar experiment, made with gluten; some flour was doughed, and then the gluten washed as well as practicable in a stream of water. In order to get as large a surface as possible, this gluten was next rubbed in a mortar with clean sand; it was in this way cut up into a ragged mass. The gluten was mixed with water and kept at 30° C. for 12 hours, in order to permit any degrading action, that warm water is capable of exerting on gluten during that time, to assert itself. In Nos. 4 and 5, yeast was added at the end of 12 hours. No. 6. was a repetition of No. 4, except that the gelatinised starch and flour infusion were mixed immediately before fermentation. In No. 7 the starch was simply added to the flour infusion without previous gelatinisation. No. 8 consisted of wheat-starch and water only, to which yeast was added. The starch used for these experiments was specially prepared in the laboratory from the best Hungarian flour by washing the dough, enclosed in muslin, thus separating the gluten. The starch was allowed to settle, and the supernatant liquid poured off; the starch was then stirred up with some more water, and again allowed to subside. These washings were repeated daily for about a fortnight, at the end of which time the starch was air dried. On being tested with Fehling's solution the starch gave no trace of precipitate: its purity was therefore assured. This series of fermentation tests altogether extended over a period of three days.

Date, 11th May, 1885.

No. 1. 20 per cent. filtered infusion of flour, 6 oz. at 30° C., compressed yeast, $\frac{1}{4}$ oz.

No. 2. 34 grams flour; water, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

No. 3. Washed insoluble residue from 34 grams of flour: water, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

Date, 12th May, 1885.

No. 4. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams taken and gelatinised, cooled, then added to flour infusion. Mixture placed in bottle and maintained at 30° C. for 12 hours; then $\frac{1}{4}$ oz. compressed yeast added and fermentation commenced.

No. 5. Moist thoroughly washed gluten, 5 grams, triturated in mortar with sand in order to expose large surface: gluten with 6 oz. of water at 30° C. placed in bottle and maintained at 30° C. for 12 hours; then $\frac{1}{4}$ oz. compressed yeast added and fermentation commenced.

Date, 13th May, 1885.

No. 6. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams, gelatinised; compressed yeast, $\frac{1}{4}$ oz.

No. 7. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams, ungelatinised; compressed yeast, $\frac{1}{4}$ oz.

Date, 11th May, 1885.

No. 8. Wheat starch, 5 grams, gelatinised, water 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

At the expiration of six hours, the following quantities of gas had been evolved :—

No. 1, ...	2·5 cubic inches.	No. 5, ...	1·3 cubic inches.
No. 2, ...	17·5 ,,	No. 6, ...	33·7 ,,
No. 3, ...	3·0 ,,	No. 7, ...	8·2 ,,
No. 4, ...	37·5 ,,	No. 8, ...	0·9 ,,

No. 1, consisting of 20 per cent. flour infusion, gave off very little gas, the quantity amounting to only 2·5 cubic inches in six hours; this is very much less than that obtained in the previous series of experiments in which a 40 per cent. infusion was employed; the latter gave off 8·3 cubic inches in five hours. No. 2, containing the whole of the flour, gave off gas much more copiously, in six hours there being 17·5 cubic inches of gas evolved. After the second hour, the evolution fell off slowly but regularly.[1] The washed residue gave off just the same amount of gas as did the filtered infusion; in fact, at the end of the fifth hour, No. 3 gave the higher reading. It will be noticed that the whole of the flour gives off three times as much gas as do the filtered infusion and the washed residue together. The reason is that, when flour is shaken with water and then filtered, the substances which under the action of yeast evolve gas are not all removed in the filtrate: they are only separated from the insoluble residue with great difficulty, and several washings do not so thoroughly remove fermentable matter as to leave the residue completely unfermentable. That the fermentation in No. 3 is not due to the insoluble residue is proved by the result of experiment No. 5; for with well washed and kneaded gluten, but very little gas is evolved, the total amount in nine hours being only 1·5 cubic inches, and this although the gluten for twelve hours previous to fermentation was digested with water at 30° C. Much of the fermentable matter of flour belongs to what may be called the semi-soluble portion, that is, the part of the flour which is retained by an ordinary filter paper, but on kneading is readily separated by the mechanical action from the gluten. In Nos. 4 and 6 the quantities used are

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[1] In all these tests, readings were made either every hour or half-hour, but usually the result of one reading only is here given. When of special interest, however, the explanatory remarks contain also references to other readings.

the same, but the former of the two samples affords evidence of diastasis having been occasioned during the twelve hours for which the gelatinised starch was subjected to the action of the flour infusion. No. 6 at first proceeded somewhat the more rapidly, but evolved very little gas during the second hour; during the third hour, however, it recovered itself and proceeded regularly, until at the expiration of six hours the evolution of gas ceased, with a total of 33·7 inches. In No. 4 the fermentation proceeds rapidly and regularly, falling off towards the end, and finishing at five hours with 37·5 cubic inches. As a result of the previous diastasis, a larger quantity of gas is evolved, but in each instance the greater part of the starch remained behind, as if 5 grams of starch were completely changed into sugar, and then by fermentation into carbon dioxide and alcohol, the yield of gas would roughly be about 85 cubic inches at 20° C. The diastasic action of the flour infusion will have more or less effected the hydrolysis of the starch into dextrin and maltose; the latter will have undergone fermentation, while the former is unfermentable. Experiment No. 8 shows that the diastasis of the starch is effected by the flour infusion, and not by the yeast, for where pure gelatinised starch and yeast alone are employed, exceedingly little gas is evolved; during eight hours, but 1·2 cubic inches only having accumulated. This experiment was allowed to proceed overnight, and at the end of twenty-one hours, 7·0 cubic inches had been evolved. Another reading was taken at the end of the twenty-second hour, and showed that 0·8 cubic inches had been evolved during the hour. It would seem that the diastasic action of yeast on pure starch increases somewhat after some hours; but within a limit of eight hours, which covers the time that flour is in most instances subjected to fermentation, little or no action has occurred. The greater evolution of gas after twenty-one hours may possibly be due to sugar formed by the action of *bacteria* on the starch. Very striking in connection with this is the result obtained in experiment No. 7, for when the ungelatinised starch was mixed with flour infusion and subjected to fermentation, 8·5 cubic inches of gas were obtained in eight hours. The flour infusion must under these circumstances have succeeded in hydrolysing some of the starch; for although starch is washed most carefully, there will always be a certain number of cells whose walls are sufficiently thin to permit diastasis to occur; and as stated in a previous chapter, some investigators are of opinion that even unbroken wheat starch cells are comparatively readily attacked by hydrolysing agents. (Refer to Chapter VIII., paragraph 229). Summing up the results obtained in these experiments, it is found that—

Filtered flour infusion supports fermentation slowly.

The frequently washed residue of flour supports fermentation at about the same rate.

The entire flour, mixed with water, evolves about six times as much gas as either the filtered infusion or the washed residue from the same weight.

Kneaded and washed gluten evolves practically no gas.

Flour infusion and gelatinised starch together evolve gas in considerable quantity.

The quantity of gas is increased when the infusion and the gelatinised starch remain together some time before fermentation; which result is due to diastasis by the proteids of the infusion.

Ungelatinised starch, under the influence of yeast and flour infusion, evolves a moderately large quantity of gas.

Gelatinised starch alone undergoes little or no fermentation during a period of eight hours, but ferments slowly after standing some twenty hours.

338. Further Investigation of Fermentation of Flour Infusion.—In order to further determine the source of gas during the fermentation of flour infusion, the following experiments were made:—A forty per cent. filtered infusion of stone milled flour, from English wheat, was prepared by taking 600 grams of flour, and 1500 c.c. of distilled water: these were several times shaken together during half-an-hour, and then allowed to subside. The upper layer of liquid was next poured off and filtered through washed calico: this was subsequently again filtered in the ordinary manner through paper until perfectly clear. On testing with iodine no colour was produced, thus showing the absence of both starch and amyloïns. The specific gravity of the infusion was 1008·5, being somewhat higher than that of the forty per cent. infusion used in a previous experiment. A portion of the infusion was tested for sugar, before and after inversion, and also for proteids. Six ounces of the infusion were then fermented at 25° C., with a quarter ounce of Encore yeast. The experiment was continued for twenty-two hours, at the end of which time fermentation had entirely ceased. The clear liquid was then decanted off from the layer of yeast at the bottom, and tested for sugar and proteids as was done in the separate portion of the original infusion. To the yeast remaining in the bottle there was at once added a half-ounce of sugar and six ounces of water at 25° C., and the testing apparatus set up, and the quantity of gas evolved measured.

The sugar was estimated by Fehling's process in the following manner:—A weighed quantity of the flour infusion was raised to the boiling point, and maintained at that temperature for about five minutes, in order to coagulate proteids; the loss by evaporation was then made up by the addition of distilled water, and the solution filtered.

Quantities taken = 25 c.c. Fehling's Solution.
50 c.c. Water.
20 c.c. Forty per cent. Flour Infusion.

Weight of cuprous oxide, Cu_2O, yielded = 0·1531 grams. Assuming this precipitate to be due to maltose, then

0·1531 × 0·7758 = 0·1187 grams of maltose in 20 c.c. of the flour infusion = 1·48 per cent. of maltose in the flour.

In the next place, 50 c.c. of the flour infusion were taken, 5 c.c. of fuming hydrochloric acid added, and the solution inverted by being raised to 68° C. The acid was then neutralised by solid sodium carbonate, and the solution made up to 100 c.c. with water. This produced a twenty per cent. inverted solution.

Quantities taken = 25 c.c. Fehling's Solution.
50 c.c. Water.
20 c.c. Twenty per cent. inverted Flour Infusion.

Weight of cuprous oxide, Cu_2O, yielded = 0·1860 grams.

In 20 c.c. of a forty per cent. solution there would be double this quantity = 0·1860 × 2 = 0·3720 grams. From this must be deducted the amount of precipitate due to the maltose present.

0·3720 − 0·1531 = 0·2189 grams of Cu_2O due to a reducing sugar produced by inversion. Assuming this sugar to be cane-sugar, or at least to have the same reducing power, then

0·2189 × 0·4791 = 0·1048 grams of cane-sugar in 20 c.c. of the forty per cent. infusion = 1·31 per cent. of cane-sugar in the flour.

The total sugar in the flour would thus be 2·79 per cent.

After fermentation, the upper liquid from the yeast bottle was also tested for sugars, after filtration and coagulation of proteids as before. The uninverted solution gave no precipitate whatever with Fehling's solution. A portion was next inverted with acid in the manner already described; 20 c.c. of this solution gave a slight trace of precipitate with Fehling's solution, which was too little to weigh. So far, the practical result may be summed up in the statement that **filtered aqueous flour infusion contains two or more varieties of sugar; these during the act of fermentation entirely disappear.**

The infusion was tested for proteids by distillation with alkaline permanganate solution, with the following results, calculated to the percentage present in the flour—

In the infusion before fermentation—0·76 per cent.
,, ,, after ,, 0·78 ,,

Compared with analyses of other flours, these quantities are low; this is probably accounted for by a forty per cent. infusion being made, whereas a ten per cent. infusion is used in most analyses; the more dilute solution extracts the somewhat viscous proteids with greater readiness. The only deduction from these determinations is, that **the amount of proteids in a filtered flour infusion is practically unchanged by the act of fermentation, there being no disappearance whatever of these bodies.** The small *increase* observable is probably due to proteid matter being yielded to the solution by the yeast itself.

The following are the results of the fermentation experiments—

No. 1. Flour Infusion, 6 oz.; Encore Yeast, ¼ oz.; Temperature, 25° C.

No. 2. Yeast from previous experiment after cessation of fermentation: Sugar, ½ oz.; Water, 6 oz., at 25° C.

At the expiration of six hours, the following quantities of gas had been evolved:—

No. 1, ... 9·6 cubic inches. | No. 2, ... 73·5 cubic inches.

As six ounces of the forty per cent. flour infusion would contain the soluble matter of 68 grams of flour, it follows that there would be present, according to the analysis, 1·89 grams of sugar. This quantity, if entirely converted during fermentation into carbon dioxide and alcohol, would yield about 32 cubic inches of gas at 20° C. By the method adopted for testing, 15 cubic inches were registered at the end of twenty-two hours; to this would have to be added a correction for the amount lost by absorption by the water, in order to obtain a correct estimate. It is difficult, when the total quantity of gas evolved is small, to determine with accuracy the loss by absorption, because the gas in the apparatus consists of a mixture in which air is predominant, consequently the rate of absorption is less than with pure carbon dioxide gas. If it were desired to accurately estimate the quantity of gas, collection over mercury would have to be adopted. This is of little importance in the present experiment, because the total measured comes well within the amount of gas that the sugar would theoretically yield. In other words, there is no need to go outside the sugar to find a source from which the carbon dioxide is obtained, as the whole of the sugar disappears, and in the act of fermentation is capable of yielding more gas than that observed to be evolved. That the cessation of fermentation is not due to the exhaustion of the yeast is proved by experiment No. 2, in which the same yeast has more sugar added to it, when a vigorous fermentation was immediately set up. That the cessation of fermentation is due to the exhaustion of the sugar is proved by that compound being absent on analysis of the infusion after fermentation. Summing up the whole of the results—

Flour Infusion.

Before Fermentation.	*After Fermentation.*
Sugar, 1·89 grams in the six ounces of infusion.	Sugar, absent.
Proteids, 0·517 grams present.	Proteids, 0·530 grams present.
	When Fermentation had ceased, 15 cubic inches of gas had been evolved, and the yeast was still unexhausted, and capable of inducing fermentation in fresh sugar solution.

Reasoning on these results, together with those obtained in the series of experiments on flour and its various constituents taken separately, the only logical conclusion is that the fermentation of dough is essentially a saccharine fermentation.

It may be demurred that the circumstances are different in an aqueous infusion to those which hold in a tough elastic mass such as dough. But it is inconceivable that the fermentation actually immediately depends on the conversion of any but soluble constituents of the flour into gas; therefore, if those proteids, so soluble as to pass through filter paper, are not capable of yielding gas as a result of fermentation by yeast, it follows that the more insoluble proteid compounds likewise will not yield gas. The fact that washed gluten yields no gas affords corroborative proof of this point. (The small quantity actually obtained by experiment may be accounted for by the well-known difficulty of actually freeing gluten from all starchy and soluble matters). That the fermentation of the flour itself yields several times more gas than does the filtered infusion, lends no support to the theory that it is the proteid matter that is evolving gas, because it has been shown that pure ungelatinised starch causes a marked evolution of gas, being doubtless first converted into dextrin and maltose by diastasis. The fermentability of the washed residue is also accounted for by its containing starch. Supposing even that in dough, after fermentation had ceased, sugar as such existed and could be removed and detected by analytic methods, that of itself would be no proof of the evolution of gas being at the expense of the proteids, or peptones derived therefrom (for the argument equally applies to these latter bodies), because simultaneously with the fermentation produced by the yeast there is a production of sugar by diastasis of the starch. Fermentation of sugar in a stiff dough is rough work for yeast cells, and it may well be that after a few hours they are thoroughly exhausted, and disappear through disruption of their cell walls: the continuance of diastasis would still cause the slow production of more or less sugar. Further, the diastasis of the starch must throughout fermentation *precede* its subsequent conversion into carbon dioxide and alcohol; and so, if the reaction be stopped at any point, more or less sugar would as a rule be found. Again drawing a conclusion, **the fermentation of dough is in part due to the fermentation of the sugar present, in part to the diastasis of a portion of the starch of the flour and its subsequent fermentation: these sources are sufficient, and more than sufficient, for the production of all the gas evolved: these statements admit of experimental proof. There is no satisfactory evidence in favour of the gas evolved being in any sensible degree derived from the proteid constituents of dough.** It should be noticed that no assertion is made that no gas whatever is derived from the proteid constituents of flour; it is possible that in extreme cases gas is produced from proteid matters as a result of butyric and putrefactive fermentations; but in ordinary bread-making, as it holds in the United Kingdom, the amount of gas derived from this source is of no importance compared with that from sugar, and indirectly from starch. Whatever amount of gas there is that is thus obtained from proteids is the result, not of the action of yeast, but of *bacteria*. Further, the statement that proteid bodies do not themselves evolve gas during panary fermentation must not be construed into meaning that they do not affect the quantity evolved. In their capacity as nitrogenous yeast foods, they aid the yeast in its development, and consequently in its production of gas by decomposition of saccharine bodies.

339. Effect of Salt on the Fermentation of Flour.—Most bakers are familiar with the general statement that salt retards fermentation: in order to determine the amount of such retardation the following experiments were made. In the first, flour and water alone were fermented; the others consisted of flour mixed with salt solutions of various strengths. The appended table contains the results:—

Date, 27th May, 1885.

No. 1. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.

No. 2. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.; salt, 2·5 grams = 1·4 per cent. salt solution.

No. 3. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, $\frac{1}{4}$ oz.; salt, 5·0 grams = 2·9 per cent. salt solution.

No. 4. Flour, 34 grams; water, 6 oz. at 30° C.: compressed yeast, $\frac{1}{4}$ oz.; salt, 8·5 grams = 5·0 per cent. salt solution.

At the termination of six hours, the following quantities of gas had been evolved:—

No. 1,	...	18·2 cubic inches.	No. 3,	...	15·1 cubic inches.
No. 2,	...	15·2 ,,	No. 4,	...	13·3 ,,

In the first test, 19·2 cubic inches of gas were evolved in seven hours, while with 1·4 per cent. of salt present in the solution (No. 2) the gas was diminished to 15·8 cubic inches. Summing up the conclusions derived from this series of experiments—

The use of a 1·4 per cent. solution of salt instead of water produced a marked diminution in the evolution of gas.

Increasing the amount of salt to 2·9 per cent. made very little difference on the speed of fermentation.

With 5·0 per cent. of salt, gas was evolved still more slowly.

340. Effect on Fermentation of addition of various substances to Yeast Mixture.—Taking yeast mixture as being a substance well fitted to undergo fermentation, the following experiments were made in order to determine the effect of the addition of certain other substances which have an important bearing on the fermenting operations involved in bread-making. The appended table describes sufficiently the substances used in each test of the series; the quantity of yeast mixture was constant throughout.

Date, 19th May, 1885.

No. 1. Yeast mixture, $\frac{1}{2}$ oz.; compressed yeast, $\frac{1}{4}$ oz.; water, 6 oz. at 30° C.

Date, 12th May, 1885.

No. 2. Yeast mixture, $\frac{1}{2}$ oz.; compressed yeast, $\frac{1}{4}$ oz.; water, 6 oz. at 30° C.; pure wheat starch, 5 grams.

No. 3. Yeast mixture, $\frac{1}{2}$ oz.; compressed yeast. $\frac{1}{4}$ oz.; water, 6 oz. at 30° C.: wheat starch, 5 grams, gelatinised and allowed to cool.

Date, 14th May, 1885.

No. 4. Yeast mixture, $\frac{1}{2}$ oz.; compressed yeast, $\frac{1}{4}$ oz.; water, 6 oz. at 30° C.; raw flour, 5 grams.

Date, 13th May, 1885.

No. 5. Yeast mixture, $\frac{1}{2}$ oz.; compressed yeast, $\frac{1}{4}$ oz.; water, 6 oz. at 30° C.; flour, 5 grams, gelatinised with small quantity of water, and allowed to cool.

No. 6. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; potato, 5 grams, boiled.

Date, 18th May, 1885.

No. 7. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.: potato, 5 grams, in small pieces, boiled; clear filtered water employed for boiling them, made up to 6 oz. at 30° C., and used instead of ordinary water.

No. 8. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; salt, 5 grams = 2·9 per cent. salt solution.

Date, 19th May, 1885.

No. 9. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; salt, 2·5 grams = 1·4 per cent. salt solution.

No. 10. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; salt, 8·5 grams = 5 per cent. salt solution.

In six hours, the following quantities of gas had been evolved:—

No. 1,	... 174·5	cubic inches.	No. 6,	... 188·0	cubic inches.
No. 2,	... 173·7	,,	No. 7,	... 183·5	,,
No. 3,	... 167·8	,,	No. 8,	... 170·2	,,
No. 4,	... 173·5	,,	No. 9,	... 178·0	,,
No. 5,	... 205·2	,,	No. 10,	... 150·5	,,

The results of No. 2 are identical with those of No. 1, showing that the starch under these circumstances is unacted on. This experiment stands out in contrast to that in a previous series (paragraph 337) in which ungelatinised starch was added to flour infusion. There, a diastasic agent was present, and diastasis of the starch ensued; here, with yeast only, the starch remains throughout unaltered. In No. 3 the starch was gelatinised and allowed to cool; in this case there is a marked *diminution* in the evolution of gas: this is most likely due to the viscous nature of the liquid containing starch in solution, the effect being a mechanical one, resulting from a physical retardation of fermentation. During the latter part of the experiment, which altogether extended to ten hours, the production of gas exceeds that in No. 1, amounting to 183·5 against 174·5 cubic inches, and does not terminate until the end of the ten hours, whereas both Nos. 1 and 2 ceased within six hours. In No. 4 raw flour is substituted for ungelatinised starch: again a series of readings are obtained closely resembling Nos. 1 and 2, and showing that with yeast mixture as a basis, raw flour produces no appreciable action. But when the flour is gelatinised as in No. 5, the evolution of gas is more copious and more rapid, and at the end of eight hours a total of 209·4 cubic inches of gas is registered, with an increase during the last hour of 1·2 cubic inches. Gelatinised flour favours fermentation to a much greater extent than does gelatinised starch; the principal chemical difference between the two is that in the former there are present the proteids of the flour non-coagulable by heat. To No. 6 were added 5 grams of potato, boiled; the result is a considerable increase in the amount of gas evolved, which shows itself more particularly during the earlier period of fermentation: boiled potato therefore acts as a stimulant, and also furnishes saccharine matter as food for the yeast.

In experiment No. 7, it is remarkable, and contrary to the generally received ideas, to find that the clear filtered water in which potatoes were simply boiled exercises such marked influence on fermentation The increase in rapidity of production of gas is very nearly as great as when the whole of the potatoes are used. In No. 7, 9 more cubic inches of gas were evolved than in No. 1, the action terminating at the same time. It may be of interest to mention here that in some parts of Lancashire, where it is a prevalent custom for families to make their own bread, they adopt the plan of setting the sponge with water in which the potatoes have been boiled. Nos. 8, 9, and 10, were similar experiments to those of the preceding series (paragraph 339), except that the action of salt was tested on yeast mixture instead of on flour. No. 8 shows a slightly less quantity of gas evolved than does No. 1. No. 9, on the other hand, shows a decided increase in the quantity of gas over that evolved either in Nos. 1 or 8. In No. 10, however, where 5 per cent. of salt is employed, the gas falls off to 165·2 cubic inches in seven hours, although at the end of the time fermentation is still actively proceeding. Summarising the results of these experiments,

The addition to yeast mixture of—

Ungelatinised wheat-starch has no practical effect on fermentation.

Gelatinised wheat-starch at first retards the action, which afterward is slightly accelerated.

Raw flour produces very little action.

Gelatinised flour induces a much more rapid and copious evolution of gas.

Boiled potato produces a similar effect to gelatinised flour, but to a less extent.

The water used for boiling potatoes is almost as effective as the potatoes themselves.

Quantities of salt, up to 3 per cent. of water used, do not retard fermentation greatly: above that quantity salt considerably diminishes the evolution of gas.

341. Effect on the Fermentation of Sugar of the addition of Flour and Potatoes.—As yeast mixture contains within itself not only sugar, but also other ingredients which stimulate a rapid fermentation, it was thought advisable to repeat some of the preceding experiments with sugar only. Accordingly, the experiments recorded in the following table were performed.

Date, 21st May, 1885.

No. 1. Sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; raw flour, 5 grams.

No. 2. Sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; flour, 5 grams, gelatinised in small quantity of water and allowed to cool.

Date, 18th May, 1885.

No. 3. Sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; potato, 5 grams, boiled.

No. 4. Sugar, ½ oz.; compressed yeast, ¼ oz.; potato, 5 grams, in small pieces, boiled; clear filtered water employed for boiling them, made up to 6 oz. at 30° C., and used instead of ordinary water.

Quantities of gas evolved in six hours:—

No. 1,	... 84·3 cubic inches.	No. 3,	... 138·1 cubic inches.
No. 2,	... 135·0 ,,	No. 4,	... 133·6 ,,

In the first experiment, with raw flour, the quantity of gas evolved keeps very close to that evolved from the sugar solution and yeast only, until three hours have elapsed. After that time the speed of evolution of gas falls off sharply, until in nine hours the quantity of gas evolved is only just as much as the sugar alone had evolved in six hours. The actual diminution of speed of the evolution of gas, as a result of the presence of flour, is noticeable in several experiments. With gelatinised flour, on the other hand, the fermentation proceeds more rapidly, and to a greater extent than with sugar only. The speed of production of gas is less than in the corresponding experiment of the previous series with yeast mixture, but as the action continues longer before commencing to fall off, the actual amount of gas evolved is about the same. The result of No. 3 with boiled potato is almost similar to No. 2. No. 4, containing boiled potato water, ferments at almost exactly the same rate as did No. 2 with the whole of the potato. Summing up,

The addition to sugar of—

Raw flour retarded the fermentation in the latter part of the experiment.

Gelatinised flour, boiled potato, and boiled potato water, each stimulated and increased the amount of fermentation to about the same degree.

342. Effect of Temperature on Fermentation.—In order to measure quantitatively the effect of variations of temperature on the production of gas by fermentation, the following experiments were made:—Two different brands of compressed yeast were employed, one of which is designated yeast "A," the other yeast "B;" the same quantity of yeast was employed throughout the experiment. The series included tests by each yeast on sugar, yeast mixture, and flour, at the respective temperatures of 20°, 25°, 30°, and 35° C. = (68°, 77°, 86°, and 95° F.).

The following are the results of one set of tests:—

Date, 3rd July, 1885.—The complete series at 20° C. made this day.
,, 2nd July, 1885.— ,, ,, 25° C. ,,
,, 30th June, 1885.— ,, ,, 30° C. ,,
,, 29th June, 1885.— ,, ,, 35° C. ,,

No. 1. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 30° C.

No. 2. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 25° C.

No. 3. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 30° C.

No. 4. Yeast mixture, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 35° C.

Gas evolved at the end of six hours:—

No. 1, ...	83·8 cubic inches.	No. 3, ...	177·8 cubic inches.
No. 2, ...	113·3 ,,	No. 4, ...	175·0 ,,

(At the end of three hours, Nos. 3 and 4 had evolved 104·2 and 128·0 cubic inches respectively).

Considering first the series consisting of yeast A with yeast mixture, a temperature of 25° C. increases the total quantity of gas considerably over that evolved at 20° C.; a further increase to 30° more than doubles the average speed of evolution of gas. Beyond 30° the amount of gas evolved is not materially increased with the rise in temperature, thus at 35° C. there is very little more gas evolved that at 30° C. In the series where sugar is substituted for yeast mixture, the production of gas is less, but the same general relation exists between the various members of the series.

With flour, on the other hand, there is a more equal increase, as shown by the following table, still there is a greater increase between Nos. 2 and 3 than the others:—

No. 1. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 20° C.

No. 2. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 25° C.

No. 3. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 30° C.

No. 4. Flour, 34 grams; compressed yeast, A, ¼ oz.; water, 6 oz. at 35° C.

Gas evolved at the end of six hours:—

No. 1, ...	14·6 cubic inches.	No. 3, ...	24·4 cubic inches.
No. 2, ...	18·2 ,,	No. 4, ...	28·3 ,,

Another precisely similar series of experiments were made with B yeast, which, being the stronger yeast of the two, gave off in every case more yeast than did yeast A in the corresponding experiment. This difference was not so striking when yeast mixture was used, because its stimulating effect helped the weak yeast proportionally the more. But in sugar each yeast has to depend more fully on its own vitality in producing fermentation. Consequently the stronger yeast B causes the evolution of a proportionately higher quantity of gas than does the yeast A.

Summarising the results obtained—

In the three media employed, the rapidity of production of gas increases with the temperature; this increase is more marked between 25° and 30° than between 30° and 35° C.

343. Behaviour of Yeasts at High Temperatures.—In view of the fact that, in baking, some of the work of the yeast is done in the oven, it becomes of interest to ascertain how different yeasts behave as fermenting agents at high temperatures. For this purpose the following experiments were made :—

EXPERIMENT ON YEAST AT 77° F. (25° C.)

Quantities taken—yeast, ¼ oz. ; flour, 2·4 oz. ; water, 6 oz.
No. 1.—Compressed distillers' yeast.
,, 2.—Compressed brewers' yeast, ordinary.
,, 3.— ,, ,, ,, special.
,, 4.—Thin brewers' yeast.

GAS EVOLVED IN CUBIC INCHES.

TIME.	No. 1.	No. 2.	No. 3.	No. 4.
1 hour	4·0	2·0	7·0	...
2 hours	...	6·0	15·0	...
3 ,,	15·0	10·0	18·5	4·0
4 ,,	...	13·0	22·5	6·5
5 ,,	...	...	...	8·0
5½ ,,	21·0	...	...	...
7 ,,	22·0	...	...	...

Yeasts Nos. 1 and 4 were next tested in precisely the same manner, except that the temperature was raised to 122° F. (50° C.) The following were the results :—

GAS EVOLVED IN CUBIC INCHES.

TIME.	No. 1.	No. 4.
1 hour	13·0	1·0
2 hours	22·75	...
2½ ,,	23·15	...
3 ,,	Stop	1·5

Notice how completely No. 4 ceases work at this higher temperature ; while No. 1 for a time is even more energetic in action.

In the next place a series of tests were made at 131° F. (50° C.). The quantities taken were not precisely the same as in the previous tests, but are given in detail.

No. 1. Compressed distillers' yeast, ¼ oz. ; flour, 1·2 oz. ; water, 6 oz.
No. 1*a*. Yeast as No. 1 ; sugar, ¼ oz. ; water, 6 oz.
[No. 4. Thin brewers' yeast did not work with flour at 122° F.]
No. 4*a*. Thin brewers' yeast, ¼ oz. ; sugar, ¼ oz. ; water, 6 oz.
No. 5. Another sample compressed distillers' yeast, ¼ oz. ; flour, 1·2 oz. ; water, 6 oz.
No. 5*a*. Yeast as No. 5 ; sugar, ¼ oz. ; water, 6 oz.

GAS EVOLVED IN CUBIC INCHES.

TIME.	No. 1.	No. 1*a*.	No. 4*a*.	No. 5.	No. 5*a*.
15 minutes ...	1·0	1·25	...	2·0	2·0
30 ,, ...	4·0	5·0	...	2·75	3·0
1 hour	6·25	7·75	2·75	3·0	3·5
2 hours	6·5	8·75	4·0	3·5	5·5
3 ,, ...	7·0	10·0	5·75	...	...
4 ,, ...	Stop	10·75	Stop	4·0	7·5

Comparing the two samples of distillers' yeast; No. 1, it will be noticed, works more vigorously, both in flour and in sugar, than No. 5. The thin brewers' yeast, No. 4, works at this temperature in sugar; although inactive in flour and water, at a temperature lower by nine degrees. At a temperature of 140° Fahr., neither Nos. 1 nor 4 evolved any gas in a sugar solution. These results agree broadly with the general behaviour of the yeasts during baking; further investigation is, however, necessary in order to check this mode of testing against actual practical experience with the same yeasts.

344. Comparative Fermentative Tests with Brewers' and Distillers' Yeasts in Flour and Sugar Solutions.—The following experiments were made with the view of comparing the fermentative capacity of brewers' and distillers' yeasts in flour and sugar solutions respectively:—

Date, 22nd October, 1885.

No. 1. Yeast mixture, ½ oz.; water, 6 oz. at 25° C.; French compressed yeast, ¼ oz.

No. 2. Sugar, ½ oz.; water, 6 oz. at 25° C.; French compressed yeast, ¼ oz.

No. 3. Flour, 68 grams; water, 6 oz. at 25° C.; French compressed yeast, ¼ oz.

No. 4. Yeast mixture, ½ oz.; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

No. 5. Sugar, ½ oz.; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

No. 6. Flour, 68 grams; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

Date, 23rd October, 1885.

No. 7. Sugar, ½ oz.; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

No. 8. Flour, 68 grams; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

No. 9. Flour, 68 grams; sugar, ½ oz.; water, 6 oz. at 25° C.; compressed English brewers' yeast, ¼ oz.

No. 10. Sugar, ½ oz.; water, 6 oz. at 25° C.; Brighton brewers' yeast, as skimmed, ¼ oz.

No. 11. Flour, 68 grams; water, 6 oz. at 25° C.; Brighton brewers' yeast, ¼ oz.

The following were the quantities of gas evolved in six hours :—

No. 1, ...	91·2 cubic inches.	No. 7, ...	80·3 cubic inches.
No. 2, ...	40·8 ,,	No. 8, ...	0·5 ,,
No. 3, ...	32·3 ,,	No. 9, ...	1·0 ,,
No. 4, ...	115·2 ,,	No. 10, ...	72·0 ,,
No. 5, ...	80·0 ,,	No. 11, ...	1·0 ,,
No. 6, ...	1·9 ,,		

Nos. 1 and 2 call for no special remark, being similar in character to many tests previously made. The quantity of flour in No. 3 is double that used in previous experiments, the object being to get a mixture which should be a nearer assimilation to dough, while still possessing sufficient fluidity to permit the escape of the produced gas. As might be expected, the amount of gas evolved is higher than in tests where 34 grams were used. Nos. 4 and 5 were tests with the compressed brewers' yeast—there is a more rapid evolution of gas than in the corresponding tests with the French yeast ; so far, the verdict would be in favour of the English yeast as being a stronger yeast. This verdict is borne out by the results of commercial use of the yeast for brewing purposes. In Belgium, the fiscal laws require that distillers shall absolutely complete the fermentation of their wort or "mash" within twenty-four hours ; they therefore use the strongest and most energetic yeast obtainable. English brewers' yeast is consequently largely exported to Belgium for distillers' use, having a preference given it over French and other continental yeasts. Next comes test No. 6, the results of which are most remarkable ; the English yeast, which had been by far the stronger in both yeast mixture and sugar solutions, causes practically no evolution of gas whatever from the flour mixture. On the next day some of the experiments were repeated, together with others. No. 7 was a duplicate of No. 5 (with sugar) and yields similar results ; No. 8 was a duplicate of No. 6, and of the two, results in the production of still less gas ; therefore, the results of the first day's experiments were confirmed by those of the second. In No. 9, there was added, in addition to flour, a half ounce of sugar, with the surprising result that in this case also only one cubic inch of gas was evolved in six hours. No. 10, in which a local brewers' yeast was used, showed an evolution of gas in large quantity ; but in No. 11, the same yeast caused an evolution of but one cubic inch of gas in six hours.

In further examination of this point the following experiments have recently been made :—

No. 1. Sugar, 20 grams ; water, 200 c.c. at 30° C. ; distillers' yeast, 1 gram.
No. 2. Flour (soft English), 50 grams ; water, 200 c.c. at 30° C. ; distillers' yeast, 1 gram.
No. 3. Sugar, 20 grams ; water, 200 c.c. at 30° C. ; brewers' yeast (uncompressed), 2 grams.
No. 4. Flour, 50 grams ; water, 200 c.c. at 30° C. ; brewers' yeast, 2 grams.

The following were the quantities of gas evolved at the end of six hours :—

No. 1,	334 cubic centimetres.	No. 3,	516 cubic centimetres.
No. 2,	345 " "	No. 4,	36 " "

It will be noticed once more that whereas the brewers' yeast gave more gas from sugar, yet it was practically inoperative on flour, confirming again the results of the previous series.

Another set of experiments was next made in order to determine the effect of the presence of varying quantities of flour on the fermentation of brewers' yeast and sugar. The following quantities were taken :—

	Sugar.	Flour.	Water.	Brewers' Yeast.
No. 1.	10 grams.	0 grams.	200 c.c.	2 grams.
No. 2.	"	10 "	"	"
No. 3.	"	20 "	"	"
No. 4.	"	30 "	"	"
No. 5.	"	40 "	"	"
No. 6.	"	50 "	"	"

At the end of six hours the following quantities of gas had been evolved :—

No. 1,	320 cubic centimetres.	No. 4,	27 cubic centimetres.
No. 2,	50 " "	No. 5,	17 " "
No. 3,	20 " "	No. 6,	17 " "

The addition of 10 grams only of flour to No. 2 was sufficient to drop the evolution of gas from 320 c.c. to 50 c.c. in the six hours, while 20 grams of flour restricted the evolution of gas to 20 c.c. Beyond this amount an increase of flour did not cause a marked diminution in gas : in No. 4, in fact, the quantity of gas is more, due, doubtless, to some irregularity in the experiment. Nos. 5 and 6 had both evolved 17 c.c. in 4 hours, and remained stationary from that time onwards.

In order to still further elucidate these points, the following experiments were made :—

A, Series.	Sugar.	Flour.	Water.	Brewers' Yeast.
No. 1.	10 grams.	0 grams.	200 c.c.	1 gram.
No. 2.	"	5 "	"	"
No. 3.	"	10 "	"	"
No. 4.	"	20 "	"	"

In all cases fermentation was conducted at a temperature of 25° C. The following are the quantities of gas evolved in cubic centimetres, readings being taken at the end of each hour from the commencement. The figures opposite the brackets are the quantities of gas evolved in each separate hour :—

GAS EVOLVED.

TIME.	No. 1.		No. 2.		No. 3.		No. 4.	
0	0		0		0		0	
		7		6		8		11
1 hour ...	7		6		8		11	
		16		14		12		14
2 hours ...	23		20		20		25	
		2		0		0		0
3 ,, ...	25		20		20		25	
		3		2		0		0
4 ,, ...	28		22		20		25	
		2		5		4		1
5 ,, ...	30		27		24		26	
		20		9		6		4
6 ,, ...	50		36		30		30	

B series, similar to A, except that compressed distillers' yeast was used throughout instead of brewers' yeast; quantities as before, 1 gram.

GAS EVOLVED.

TIME.	No. 1.		No. 2.		No. 3.		No. 4.	
0	0		0		0		0	
		6		9		8		10
1 hour ...	6		9		8		10	
		11		11		12		20
2 hours ...	17		20		20		30	
		48		45		37		47
3 ,, ...	65		65		57		77	
		25		15		9		8
4 ,, ...	90		80		66		85	
		73		37		50		20
5 ,, ...	163		117		116		105	
		84		58		72		37
6 ,, ...	247		175		188		142	

A curious point in both these series of tests is the falling off in gas evolution during the middle portion of the time of fermentation. The fermenting vessels of all the numbers of each series were placed in the same water-bath, and so were subjected to the same conditions of temperature. The two series, however, show the same characteristics in every case, though the tests were made on different days. With brewers' yeast the addition of even smaller quantities of flour exerts in every case a retarding influence in the evolution of gas. The sample of yeast employed in these experiments was in the liquid form, and much weaker than some obtained for the tests described in preceding paragraphs. Some judgment must, therefore, be exercised in comparing the results of one series with others made at other times with totally different yeasts.

Flour also exerted a retarding influence on the fermentation with distillers' yeast.

An attempt was next made to determine if possible which of the constituents of flour exerts the retarding influence. The most important of these are starch, gluten, and soluble proteids. A series of experiments with starch instead of flour was easily arranged. It is obviously impossible to incorporate gluten with water and sugar in the same way as flour, water, and sugar can be mixed, so no direct experiments were made with gluten. In imitation of the soluble flour proteids, mixtures were made of water, sugar, and desiccated white of egg (albumin). Particulars follow of the various fermentation experiments:—

C Series.	Sugar.	Wheat Starch.	Water.	Brewers' Yeast.
No. 1.	10 grams.	0 grams.	200 c.c.	1 gram.
No. 2.	,,	5 ,,	,,	,,
No. 3.	,,	10 ,,	,,	,,
No. 4.	,,	20 ,,	,,	,,

GAS EVOLVED.

TIME.	No. 1.	No. 2.	No. 3.	No. 4.
0	0	0	0	0
	5	5	5	5
1 hour ...	5	5	5	5
	2	3	3	8
2 hours ..	7	8	8	13
	3	2	4	10
3 ,, ...	10	10	12	23
	5	5	8	2
4 ,, ...	15	15	20	25
	17	10	18	15
5 ,, ...	32	25	38	40
	12	10	15	13
6 ,, ...	44	35	53	53

D series, similar to C, except that 1 gram of compressed distillers' yeast was substituted for the brewers' yeast.

GAS EVOLVED.

TIME.	No. 1.	No. 2.	No. 3.	No. 4.
0	0	0	0	0
	9	15	17	20
1 hour ...	9	15	17	20
	6	15	16	19
2 hours ...	15	30	33	39
	13	19	24	27
3 ,, ...	28	49	57	66
	22	24	30	34
4 ,, ...	50	73	87	100
	45	50	47	50
5 ,, ...	95	123	134	150
	35	20	33	35
6 ,, ...	130	143	167	185

With both brewers' yeast and compressed yeast the presence of starch is accompanied by an increased evolution of gas. The increase is somewhat erratic in the brewers' yeast series, but still is very noticeable. With the compressed yeast, a regularly increasing amount is obtained with each increase of added starch. Wheat starch, then, cannot be viewed under these conditions as the agent of retardation : the curious point is its stimulating effect. This can scarcely be ascribed to the starch itself. Possibly a trace of stimulating nitrogenous matter was present in the starch.

E Series.	Sugar.	Albumin.	Water.	Brewers' Yeast.
No. 1.	10 grams.	0 grams.	200 c.c.	1 gram.
No. 2.	,,	0·5 ,,	,,	,,
No. 3.	,,	1·0 ,,	,,	,,
No. 4.	,,	2·0 ,,	,,	,,
No. 5.	,,	5·0 ,,	,,	,,

GAS EVOLVED.

TIME.	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
0	0		0		0		0		0	
		4		5		3		2		2
1 hour	4		5		3		2		2	
		5		5		7		10		4
2 hours	9		10		10		12		6	
		6		6		10		12		9
3 ,, ...	15		16		20		24		15	
		5		4		10		11		10
4 ,, ...	20		20		30		35		25	
		7		10		16		20		25
5 ,, ...	27		30		46		55		50	
		18		10		9		26		35
6 ,, ...	45		40		55		81		85	

F series, similar to E, except that 1 gram of compressed distillers' yeast was subjected for the brewers' yeast.

GAS EVOLVED.

TIME.	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
0	0		0		0		0		0	
		5		4		4		7		2
1 hour	5		4		4		7		2	
		6		6		6		11		3
2 hours	11		10		10		18		5	
		12		10		11		12		12
3 ,, ...	23		20		21		30		17	
		17		9		14		16		13
4 ,, ...	40		29		35		46		30	
		17		11		17		19		30
5 ,, ...	57		40		52		65		60	
		20		10		22		19		42
6 ,, ...	77		50		74		84		102	

With both brewers' and distillers' yeasts, the addition of a small quantity of albumin, 0·5 grams, depressed the evolution of gas; with larger quantities a decidedly stimulating action occurred, due probably to more or less peptonisation of the proteid.

With starch and soluble proteid matter eliminated from among the retarding agents, we must fall back on gluten as the probable effective body in slowing down the fermentation of flour and water. This effect is most likely due to its peculiar physical characters. As to why distillers' yeast is so much better able to overcome this resistance of gluten than is brewers' yeast is a matter still awaiting investigation. On the assumption that the explanation may possibly be found in there being differences in their power of inducing physical alteration, experiments were made to elucidate this point. Two doughs were machine-mixed from the following ingredients:—

No. 1, Spring American Second Patent Flour,	840	grams.
Salt, ...	9	,,
Water, ...	446	,,
Compressed Distillers' Yeast, ...	15	,,

No. 2 same as No. 1, except that 30 grams of liquid brewers' yeast were substituted for the distillers' yeast.

The temperatures of the doughs when made was 83° F.; they were kept warm, and covered with a damp cloth to prevent evaporation. At intervals, portions of each dough were removed, and kneaded to exactly the same extent in a small doughing machine, so as to drive out the whole of the gas. The stiffness of this dough was then tested by the viscometer (see Chapter XXI.), and the percentage of gluten determined. The following are the results:—

COMPARATIVE TESTS WITH DISTILLERS' AND BREWERS' YEASTS.

Time of Test.	No. 1, Distillers'.			No. 2, Brewers'.		
	Viscometer Reading.	Wet Gluten. Per Cent.	Dry Gluten. Per Cent.	Viscometer Reading.	Wet Gluten. Per Cent.	Dry Gluten. Per Cent.
Immediate	110″	26·7	8·3	138″	28·7	9·1
1 hour	94″	28·8	8·7	73″	29·7	8·9
3 hours	173″	26·7	8·5	65″	32·0	9·2
5 ,, ...	96″	28·7	9·1	38″	31·3	8·9
10 ,, ...	50″	27·3	8·7	37″	30·7	9·2
22 ,, ...	101″	28·7	8·9	60″	32·7	9·2

With No. 1, the viscometer result at the end of three hours was somewhat anomalous, but was confirmed by a duplicate test. In each case there is a falling off in stiffness during the ten hours, but considerably more with the brewers' than the compressed yeast. On standing overnight, the viscosity of both had risen. No great alteration occurs during this time in the percentage of dry gluten obtained, but in the case of the brewers' yeast dough the gluten became much softer and more watery, this being shown by a marked increase in weight in the wet state. The greater softening of the gluten may be the cause of brewers' made dough yielding a "runny" loaf; but this does not account for the much slower evolution of gas when a thin batter of flour, water, and sugar is subjected for fermentation. It cannot as yet be said that the problem has received a complete solution.

345. Brewers' Yeast and Ferments.—When brewers' yeast is employed for bread-making purposes it is usual to first allow the yeast to develop in a "ferment," generally composed of boiled potatoes rubbed down through a sieve into water, and a little raw flour added. In order to ascertain the effect of different substances as constituents of a "ferment," the following experiments were made :—

		Water.	Brewers' Yeast.
No. 1.	Sugar, 1 gram, ...	200 c.c.	2 grams.
No. 2.	Boiled potatoes, 5 grams, ...	,,	,,
No. 3.	Filtered potato juice, 10 grams,	,,	,,
No. 4.	Malt extract, 2·5 grams, ...	,,	,,
No. 5.	Diastasic malt extract, 2·5 grams,	,,	,,
No. 6.	,, ,, ,, killed, 2·5 grams,	,,	,,

No. 6 was precisely similar to No. 5, except that the solution had been raised to the boiling point, with the view of destroying the diastase present.

The following were the quantities of gas evolved after six and a half hours' fermentation at 30° C. :—

No. 1,	125 cubic centimetres.	No. 4,	160 cubic centimetres.
No. 2,	25 ,,	No. 5,	76 ,,
No. 3,	16 ,,	No. 6,	74 ,,

After fermentation had ceased, and about twenty hours from the commencement of the experiment, 50 grams of flour were added to each "ferment," and the bottle again immersed in the bath at 30° C., and readings taken of the quantities of gas evolved. At the end of six hours, these were :—

No. 1,	23 cubic centimetres.	No. 4,	43 cubic centimetres.
No. 2,	11 ,,	No. 5,	15 ,,
No. 3,	31 ,,	No. 6,	30 ,,

As a ferment constituent potato juice causes the evolution of less gas than do potatoes, while as a stimulant on the yeast's after-power of inducing fermentation in flour the juice is far the more efficacious. While the gas evolved in the two diastasic malt extract solutions is practically the same, that in which the diastase had been destroyed acted in this case as the more energetic after-stimulant of flour fermentation. Possibly a concentrated solution of diastase may exert some retarding influence on the energy of yeast. In an experiment conducted in this fashion the action of the yeast in the mixture of flour and water is less in all cases, except No. 4, than when the yeast and flour mixture are fermented direct. During the working of the "ferment," the operation was carried on without access of air, a condition which may have had a retarding action on the energy of the yeast.

EXPERIMENTAL WORK.

346. The student who has the opportunity will do well to perform for himself most of the experiments described in this chapter, and compare the results he obtains with those here recorded. He should commence by making duplicate tests with the same yeasts, in order to gain the requisite accuracy and practice in working. The experiments described in the 333rd and following paragraphs, or as many of them as practicable, should be performed. It is recommended that 25° C. be adopted as the standard temperature throughout the experiments, instead of 30° C. Practical directions follow.

347. Apparatus requisite.—Water-bath to hold yeast bottles, sets of yeast testing apparatus, pneumatic troughs, bunsen burner and automatic temperature regulator, thermometer, &c.

The water-bath may conveniently consist of a large iron saucepan (or Scotch "goblet"); to this should be attached a side-tube, by means of which the height of the water in the bath may be regulated: for description of this very useful device see Chapter XXI. Regulate the height of the water in the bath, so that the yeast bottles, when charged, shall be on the verge of floating, the surface of the liquid in the bottle will then be about an inch below that of the water in the bath. During very hot weather, and particularly when working at the lower temperatures, it is advisable to have a stream of cold water running through the bath. For this purpose, lead the end of a piece of bent tube, connected with a water tap, into the bath over the top, on the opposite side to side-tube before referred to: turn on a small stream of water through this bent tube, scarcely more than what would cause rapid dropping from its end. Water will then be continually finding its way in through this tube, and making its exit through the side-tube: thus lowering the temperature when necessary. Do not let the stream from this cold water tube impinge directly on either of the yeast bottles.

The construction and arrangement of the yeast testing apparatus and pneumatic troughs have already been sufficiently fully described.

348. Automatic Temperature Regulator.—The bath is warmed by means of a bunsen burner arranged underneath, and, in order to maintain the temperature at any desired point, an automatic regulator is employed. As an unvarying temperature is necessary for several other chemical operations, a detailed description of such an automatic regulator is given. There are several of these instruments made and sold under various names; but for general purposes the author prefers the following modification, designed by himself, and shown in figure 21.

The instrument consists of a bulb, *a*, about 4 inches long, and $\frac{3}{4}$ inch in diameter; to this is attached a stem, *b b*, about a $\frac{1}{4}$ inch diameter, and 6 inches long. This stem bends over at the top, and is connected with a U-tube, *c d e*, $\frac{1}{4}$ inch diameter, in which are blown 2 bulbs as figured, *f f*, about $\frac{3}{4}$ inch diameter. The one end, *c*, of this U-tube is closed with a stopper, *g*, which is ground in with extreme accuracy. From the centre of the bottom of this stopper, a hole is bored upwards for a short distance, which hole joins another bored inwards through the side of the stopper; this hole, therefore, affords a passage up through the bottom of the stopper and out through its side. A corresponding hole is bored through the side of the neck, *c*, of the U-tube, so that if the stopper be turned so that these two holes coincide, a passage is provided from the U-tube to the exterior; this exit may be closed at will by slightly turning this stopper, *g*. To the other end, *e*, of the U tube, *c d e*, is sealed in a bent tube, *h i j*; below the joint, *e*, this tube, *h i j*, is made much finer, having its smaller end, *j*, $\frac{3}{32}$ inch in diameter, and ground obliquely as shown in the figure. Below the joint, *e*, but as near to it as possible, an outlet tube, *k l*, is sealed into the U-tube, *c d e*. This completes the regulator; the method of using the instrument, and its principle, may be conveniently described together.

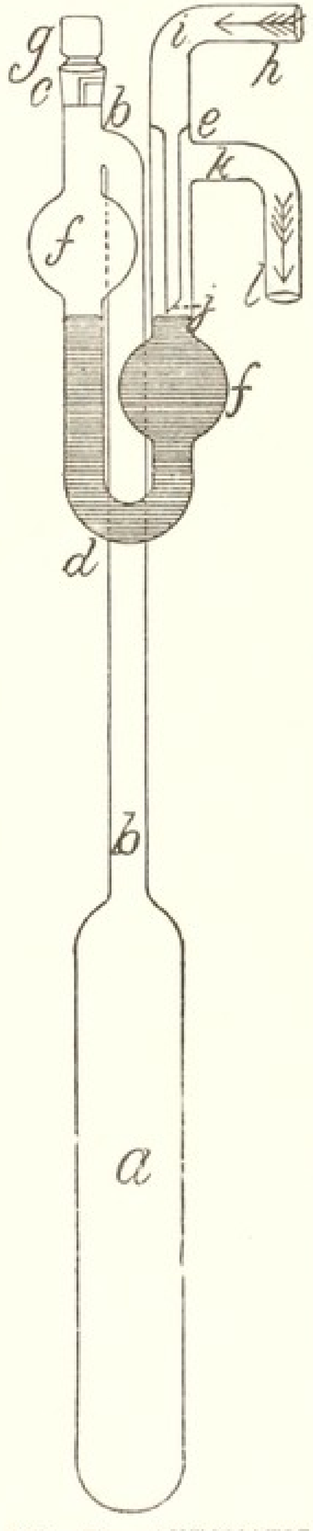


FIG. 21.—AUTOMATIC TEMPERATURE REGULATOR.

By means of a screw-lamp carried on a retort-stand, or any other suitable holder, fix the regulator upright, and so that the bulb, *a*, shall be wholly immersed in the water of the bath, and the ends of the tubes, *h* and *l*, projecting over its side. The regulator should be perfectly rigid when fixed; the clamp is best screwed on to the stem, *b b*. Connect up *h* by india-rubber tubing with the gas tap, and join up *l* to the bunsen burner. Partly fill the U-tube, *c d e*, with carefully cleaned mercury through *c*. Turn on the gas and light the bunsen burner, then continue the filling of *c d e* with mercury until the level rises sufficiently high in the limb *d e*, to very nearly close the end of jet *j*. The quantity of mercury added should be sufficient to just begin, so shut off the supply of gas to the bunsen; it is evident that then a very slight rise in level of the mercury would either considerably diminish or entirely shut off the gas from the burner. Next heat a little india-rubber sufficiently to liquefy it; smear the stopper, *g*, and its neck with this liquid, taking care to preserve a clear passage through the hole in the stopper. Next pour some of the strongest alcohol obtainable through *c*, until the bulb, *a*, its stem, *b b*, and the part of *c* are completely filled with alcohol. Insert the stopper, *g*, so that the hole through it is open; the excess of spirit escapes. It sometimes happens, in filling the instrument with spirits, that the level of the mercury in the U-tube is disturbed, the spirits floating on its surface at *c*, forcing up the level in *e* sufficiently far to entirely close the jet, *j*. Should this happen, the mercury must again be adjusted by removing a small drop by means of a fine pipette. Having made these adjustments, the instrument may be regulated for any desired temperature. Place a thermometer in the bath, so that the height of the mercury can be easily read, and so that its bulb does not touch the bottom. Suppose it is wished to maintain the bath at 25° C., turn the stopper, *g*, so that the hole is open, and light up the burner. The gas finds its way through the tubes, *h i j k l*, in the directions of the arrows. As the temperature of the water in the bath increases, so does that of the spirits in *a*. With a rise in temperature the alcohol expands, and a small portion finds its way out through the hole in the stopper, *g*. Watch the thermometer carefully, and when the temperature stands at about one-tenth of a degree below 25° C., turn the stopper, *g*, so as to close the hole through it. The spirits, in expanding, now find no means of escape, and so drive down the mercury in *c d*, causing a corresponding rise in *d e*; the consequence is that the jet, *j*, is either wholly or partly closed, and the gas either completely or partly shut off from the burner. The bunsen used should have a cap of fine wire gauze fastened on to it, so as to prevent its lighting at the bottom when the flame is turned very low. A small pin-hole burner should be fixed to the bunsen, and fed from an independent supply, so as to re-light it should the regulator turn it completely out; this "pilot" burner must be turned down so as to only give a flame about $\frac{1}{4}$ inch high, and should not be able to appreciably warm the bath. The regulator will at first most likely shut off the gas completely; the bath will then cool slightly, and as the alcohol in *a* contracts, the level of the mercury in *d e* will fall, and so the jet, *j*, will once more be opened, and a passage of gas to the burner permitted. With this regulator properly set. the temperature keeps between two extremes that after a short time closely approach each other; in fact, the mercury so adjusts itself as to partly close the aperture *j*, allowing just sufficient gas to pass to keep the bath at a constant temperature. The end of *j* is cut obliquely in order to prevent the mercury sticking to it, and so acting irregularly. Alcohol is used in *a* instead of air, because it is not affected by changes of atmospheric pressure; when temperatures above the boiling point of alcohol are required, the instrument must be used with air, or else some liquid having a sufficiently high boiling point. Alcohol is preferable to water, because it has a much higher co-efficient of expansion, that is, for an equal rise in temperature it expands much more. With the instrument set as described, it should maintain the temperature closely at 25° C.; if it should be found to be somewhat higher, the instrument may be made more delicate by adding a very little more mercury, or it may be shut off somewhat earlier; thus, if it be found to give a constant temperature 0·4° over that at which the stopper, *g*, is shut off, then all that is necessary is to always shut off at 0·4° below any temperature that may be required. Should the temperature be too low, it may be raised slightly by carefully turning the stopper, *g*, momentarily, until the slightest drop of spirits oozes out; if the temperature is too high, the bath must be cooled down, and again regulated on the rising temperature. If the bath is required to be used for several days at the same temperature, all that is requisite is to turn off the gas when the day's work is done; as the bath cools, the mercury rises in *c d* through contraction of the alcohol; the bulbs, *f f*, are provided in order to allow of this rise without its altering the regulator. When the bath is next required, simply turn on the gas, and the regulator, without any attention, will maintain the temperature at the point for which it was adjusted. The advantage of this form of regulator is that it keeps perfectly constant for a very long time, as there are no parts to shift, or places from which leakage may occur; the stopper, *g*, smeared with melted india-rubber, is perfectly air-tight. Grease will not answer instead of india-rubber, as it is dissolved by the alcohol.

349. Method of Testing.—To make one or more experiments proceed in the following manner:—First, carefully enter in the note book the particulars of each experiment, and number them: place corresponding numbers on the bottles. Regulate the water-bath at the desired temperature, and place in it a flask containing sufficient water for the experiments that are to be made. Having cleaned the whole apparatus, arrange in order the generating bottles required, and weigh out and introduce into them the yeast mixture or other substance to be fermented. Next weigh the yeast, taking care that a good representative sample is obtained. With pressed yeast cut a thin slice off the middle of the slab, avoiding dry and crumbling fragments. Brewers' yeast must first be well stirred, and then weighed out in a counterpoised dish. Break up the pressed yeast carefully in a small evaporating basin, with some of the water which has been raised to the right temperature; for this purpose an india-rubber finger stall placed on the finger is useful. Pour the yeast and water into the bottle; rinse the basin with the remainder of the six ounces of water. As rapidly as possible introduce each sample of yeast, to be tested, in its respective bottle in precisely the same manner. Having introduced the yeast, yeast mixture, or other substance, and water, into the respective bottles, *gently* shake each bottle so as to thoroughly mix the ingredients; then tightly cork each bottle, and arrange the apparatus as shown in figure 15, given at the commencement of the chapter. Remove the glass stopper at *d*, and suck out the air from the apparatus until the water rises in the jar, *f*, somewhat above the zero, then again insert the glass stopper. Pinch the india-rubber tubing on one side of *d* so as to make a slight opening, and thus permit air to enter; in this way lower the water in *f* until its level exactly coincides with the zero. Perform this operation as rapidly as possible with all the apparatus being used, and note the exact time in the note book. As the fermentation proceeds, the surface of the water in the jars will become lower, and in this way a measure of the amount of gas yielded is obtained. At the end of every half-hour or hour from the commencement, read off the volume of gas, and enter the same in the note book. When the jars are nearly full of gas watch them carefully, and as soon as the 100 cubic inches, or 500 c.c., mark is reached, withdraw the plug at *d*, blow into the jar for a few seconds so as to displace carbon dioxide through the bottom, and then suck out the air until the water again rises to the top of jar, re-insert the plug, and rapidly adjust the surface of the water to the zero. This operation should last only a very short time, and does not practically affect the results that are being obtained. The readings may be taken for from, say, two to six hours; or, if wished, until the action ceases. These directions apply equally to the ordinary use of the apparatus for testing the strength of yeasts.

350. Preparation of Yeast Mixture.—It is essential that the substances composing this mixture be thoroughly mixed. The following is the best mode of procedure. First, dry the substances at a gentle heat (100° C.) In the laboratory this is done by placing them in a hot-water oven; then finely powder each in a mortar, and weigh out the right quantities. Then thoroughly mix the first four ingredients; afterwards add the fifth, and again mix; then add the sugar little by little, mixing between each addition. In this way an equal composition of the mixture throughout is assured. Finzel's sugar crystals (coarse crystalline coffee sugar) are almost chemically pure; failing this, the best loaf sugar may be used.

The pepsin necessary for the experiments may be obtained from the chemist.

The malt wort may be prepared by infusing coarsely ground malt with ten times its weight of water for two hours at 65° C.: it is then filtered, diluted down with water until at the right density.

In experiments with flour, the flour and part of the water should first be placed in the generating bottle, and thoroughly shaken before the addition of yeast.

The starch is gelatinised by allowing it to stand in a small beaker, with some water, for about five minutes in the hot water-bath, stirring thoroughly meanwhile.

The experiments on flour infusion, in which the sugar is determined before and after the fermentation, are very important, but had better be postponed until the student has proceeded with his studies of analysis.

In the temperature experiments the tests at the same temperature should be made on the same day, and the complete series with as little interval as possible between.

In addition to the experiments described in this chapter, many others will suggest themselves to the practical baker: these he may arrange for himself, and use the yeast apparatus as a means of measuring the evolution of gas, under any conditions that may be of interest to him. The student will do well, in addition, to perform the following series of tests.

351. Keeping Properties of Different Yeasts.—Procure samples as fresh as possible of different pressed, brewers', and patent yeasts. Test immediately after procuring them; then store in a cool cellar, and test each sample on successive days until they are capable of setting up little or no fermentation. To ensure perfect accuracy it is well to keep each sample of yeast in a weighed vessel; any loss by evaporation may then in the case of the liquid yeasts be made up each day by the addition of distilled water. The pressed yeast may be kept in a stoppered bottle, or, preferably, the portion for each estimation should be taken from the interior of the mass; as a check, moisture should then be estimated in the yeast each day.

352. Use of Testing Apparatus without Temperature Regulator.—In the foregoing descriptions given it has been directed that the yeast bottle stand in a water-bath regulated by an automatic temperature regulator. While such an arrangement is extremely useful, it is not absolutely necessary. For actual bakehouse use the following plan answers well. Select a place somewhere near the oven where the temperature is pretty constant, and, if possible, between 70° and 80° F. Arrange on a shelf, clamped to the wall, a saucepan sufficiently large to take the yeast bottles, and fix the trough for the graduated jar in position. The saucepan will have to be raised sufficiently high by means of blocking ; this should be properly done at the outset, as the apparatus should remain there permanently. When about to use the apparatus, first of all fill the saucepan with water at the desired temperature F., and then make the estimation. A warm place being chosen, the water in the saucepan will not fall very much in temperature during the time necessary for carrying out the experiment. This method of using the apparatus applies more particularly to yeast testing than to the more delicate experiments described in the preceding pages.

CHAPTER XII.

MANUFACTURE AND STRENGTH OF YEASTS.

353. For baking purposes three commercial varieties of yeast are employed, namely, Brewers', Distillers' Compressed, and "Patent" yeasts. These latter may again be subdivided into malt and hop yeasts as used in England, and the Scotch flour barms. Descriptions follow of how these yeasts are manufactured.

BREWERS' YEAST.

354. In the chapter on Fermentation an account is given of the appearance of an actively fermenting tun of brewers' wort. The brewer first treats his malt with water at a temperature of about 65° C. for about two hours, more or less; during that time the starch of the malt is converted into dextrin and maltose. The liquor is then allowed to drain from the grains, or husks of malt, and is transferred to a copper in which it is boiled with hops: the hops are removed and the wort rapidly cooled, either by being exposed to the air in shallow open coolers, or poured over a specially arranged apparatus, consisting of a series of pipes through which cold water is passing, and which is termed a refrigerator. This cooling must be done as rapidly as possible, as a temperature of about 30° C. is particularly suited to the rapid growth and development of disease ferments. On the wort being cooled to 18 or 19° C. (65° F.), about one one-hundred and fiftieth part of its weight of yeast from a previous brewing is added. Fermentation sets in, and after a time yeast rises to the surface, and is skimmed off. The first is rejected because any lactic ferments or other *bacteria* that may be present are, from their small size, floated up to the surface with the yeast on its first ascent. At the time when the fermentation is most active and vigorous, the best yeast is being produced. As fermentation slackens, cells are thrown to the surface which have been grown in a comparatively exhausted medium. Such yeast is weak, and possesses less vitality. For their own pitching purposes, the brewers reserve the middle yeast. Too frequently that sold to bakers is the refuse yeast from either the beginning or ending of fermentation. Bakers who use brewers' yeast should insist on being supplied with that equal in quality to what the brewer himself uses for starting fermentation. He may fairly be asked to pay somewhat more for this; but to the baker, of yeast above all things, the best is the cheapest: one spoiled batch of bread will cost the difference between good and bad yeast over probably many weeks or months, to say nothing of the injury done to the baker's reputation with his customers. The yeast, when skimmed, should be stored in shallow vats, so as to admit of free access of atmospheric oxygen.

Brewers' yeast is much used in the production of what is called "farmhouse" bread: it is supposed to produce a sweeter flavoured loaf than do other varieties. On the other hand, brewers' yeasts darken the colour of bread. Flavour is essentially a question of individual taste rather that science, consequently the opinion of the chemist, like that of every one else, simply depends on the delicacy and experience of his palate. Venturing an individual opinion, the author has tasted some exceedingly well flavoured bread made from brewers' yeast, assisted by compressed yeast; but on the other hand, the bread which of all others he prefers has been made with yeasts of other kinds. With however good a yeast, high-class breads cannot be produced from low grade flours. For bakers' purposes, brewers' yeast is weak, and if used alone must be employed in considerable quantity. It is apt when freely used to impart a bitter taste to the bread: this may be in part obviated by washing the yeast, but even then it is exceedingly difficult to remove the bitter taste. The author has been informed that London brewers' yeast merchants collect the yeast from various breweries, and wash it by stirring it up with a dilute malt wort; it is then allowed to settle, and the supernatant liquid poured off. To a certain extent this removes the bitterness. From samples of brewers' yeast, as supplied by London yeast merchants to bakers, that the author has examined, he cannot speak very highly of this class of yeast. Compared with yeasts obtained direct from good breweries, the yeast merchant's yeast has been much weaker and more impure. Particularly in summer time brewers' yeast is found to be very unreliable and uncertain in its actions. Even those bakers who prefer brewers' yeast, when they can procure it good, find themselves compelled to resort to compressed yeast during the hot summer months.

In selecting a brewers' yeast for bakers' purposes, scrupulously avoid those breweries where large quantities of sugar or other malt substitutes are used instead of malt itself. Such brewing mixtures contain a deficiency of appropriate nitrogenous matters, and, although the resultant beer is sounder, and better meets the present requirements of the public, the yeast produced is, from the bakers' standpoint, weak and impoverished through ill nourishment.

In some breweries the beer is allowed to finish its fermentation in large casks, arranged so that the bung-hole is very slightly on one side: the yeast slowly works out of the bung-hole and flows in a shallow stream down the outside of the cask until it reaches the bottom, when it drops in a gutter arranged to receive it. A number of these casks are usually arranged side by side, and connected together by a pipe at the bottom; they are consequently technically termed "unions." The one gutter receives the yeast from the series of unions and conveys it to the proper receptacle. The yeast from these unions is found to make far better bread than that skimmed from large fermenting tuns. The reason is that the yeast gets thoroughly ærated during its flow down the side of the cask. For baking purposes, the thorough æration of yeast is essential.

355. Microscopic Examination of Yeast.—This operation requires a fair amount of experience before a trustworthy judgment can be formed. In microscopically examining yeast, there are two distinct points to be observed: first, the presence or absence of disease ferments, *bacteria*, &c.; second, the appearance of the yeast cells themselves For satisfactory work, a power of six or eight hundred diameters is necessary: the objective must be a good one, giving not only magnification, but also clear and accurate definition. The author uses a microscope in which several objectives are fastened to one "nose-piece," so that the powers may be changed instantaneously, without the trouble of unscrewing the one objective and then replacing it by another. Working with this instrument, it is his practice to first examine the yeast with a magnification of about 440 diameters, and then, having seen the aspect of a fairly large field, he observes more closely a few typical cells with a magnifiying power of about 1000 diameters. It is doubtful whether any except microscopists of long experience can work with much higher powers to advantage.

First, with regard to the presence or absence of foreign ferments. The fewer of these the better the yeast. A yeast for bakers' purposes needs to be judged by a somewhat different standard to that adopted by the brewer. To the latter, the presence of lactic or butyric ferments or other disease organisms means that, during the period the beer is stored before it is all consumed, there is ample time for changes to go on which will result in either a marked deterioration or spoiling of the beer. But if this change does not make itself perceptible until, say two or three weeks have elapsed, it follows, as bread is fermented, baked and eaten within about three days, that under ordinary circumstances such changes cannot take place in bread. This explanation is necessary, because it is well known as a matter of fact that many bakers do succeed in producing very good bread, who use a yeast in which there is frequently an abundance of foreign organisms. It will in such cases, however, be found that they take special precautions which serve to prevent an injurious action of these during fermentation. Summing up, yeasts may be used by bakers which could not possibly be employed by the brewer, because the fermenting process of the former is so much shorter; nevertheless an excess of disease ferments may set up injurious action even during the time of panary fermentation unless special precautions are taken. It is consequently safely laid down that the fewer of these foreign organisms the better. The presence or absence of disease ferments affords a valuable indication as to the previous history of the yeast, apart from their own specific action on the dough. A yeast largely contaminated with foreign organisms has been badly made: unsound malt will very likely have been used for its manufacture, and the whole process of fermentation conducted in dirty vessels. As in a brewer's yeast the presence of disease ferments tells us this of its previous history, the yeast should be condemned, because, when carelessly produced under such unfavourable conditions, the yeast itself is likely to be unsound, or at least very uncertain in its quality.

Secondly, with reference to the yeast cells themselves, the actual shape of the cells will vary with its origin. Ordinary English brewers' yeast consists of round cells, but Burton yeast is oval; so also is that in other districts where very hard water is used. With any yeast the cells should be about equal in size; not irregular, with some very large and others small. The cells should be isolated, or at most only attached in pairs: where they occur in large colonies, the yeast is too young, and has not had time to thoroughly mature. The cells should appear plump and not shrunken. The cell walls should be of moderate thickness: if very thin the yeast is too young, and has not attained maturity; on the other hand, very thick integuments denote an old, worked out yeast. Thin cell walls may also be due not only to very young yeast, but also to the yeast being over kept long enough for the breaking down of the walls to have commenced: under these circumstances the protoplasm of the interior of the cells is seen to be broken down and frequently exhibits a "Brownian" movement. If in this condition, the yeast is far gone, and will be found weak and exhausted for bread-making. As in this operation yeast does not bud or reproduce, but does its work in virtue of the energy and vitality of the original cells introduced, it is in the highest degree important that these cells should be strong, healthy, and, as far as is possible, in full maturity; when in this condition, the contents of the cells should show slight granulations. Each cell should have one, or at most two, vacuoles; but when placed in a drop of clear beer wort on the slide, the fluid should rapidly penetrate the cell walls, causing the contents to become lighter, and the vacuoles to disappear. These changes occur but slowly in old cells that have been worked for a long time.

In order to facilitate comparison, yeast, various disease ferments, starch, and other impurities associated with yeast, are shown together in figure 22.

For the examination of yeast under the microscope, dilute it down with water until so weak as to simply give a milky appearance to the water, put a minute drop on a slide, and then gently place on a cover. Note the size, shape, and internal appearance of the yeast cells, also search the field carefully for foreign ferments.

In Plate II., Chapter IX., illustrations have already been given of different varieties of yeast employed by the baker. The drawings of brewers' yeast for this plate were made in the summer, and represent samples of brewers' yeast during practically the hottest weather of the year. The specimens marked *a* and *b* were taken from two London samples of yeast, as sold to London bakers by yeast merchants. A considerable number of disease ferments are present in both, marking them as being in an unhealthy condition. It is to be feared that often sufficient care is not taken for the storage and preservation of yeast, especially during the hot weather, by those who collect brewers' yeast for redistribution among bakers. On examining these two samples, the writer procured, for purposes of comparison, some yeast from one of the neighbouring Brighton breweries: this is figured in section *c*. It was found to be far away purer than either of the London samples; one or two *bacteria* are shown in the sketch, but there were several microscopic fields that contained no foreign ferments whatever. In general aspect, the cells of section *c* were firmer in outline, the walls being thicker while the interior matter showed more distinct and darker granulations. It should be added that in these drawings the estimated magnification is only approximate. In every case where it is wished to ascertain exact dimensions, the eye-piece micrometer should be called into requisition.

FIG. 22.—YEAST AND ITS IMPURITIES (after Bělohoubek).

a, *a*, Large grains of wheat starch ; *a′*, broken grain of wheat starch ; *a″*, wheat starch ; *b*, *b*, grains of wheat, rye, or barley starch partly transformed by the action of diastase ; *c*, *c*, small grains of starch of the above-mentioned grains ; *d*, *d*, yeast cell *(Saccharomyces cerevisiæ)*, with one vacuole ; *e*, *e*, yeast cells of the same species, with a greater number of vacuoles ; *f*, *f*, yeast cells, same species, with small buds ; *g*, *g*, same with larger buds (young cells) ; *h*, *h*, yeast cells, with abnormal vacuoles ; *i*, *i*, dead yeast cells, same species ; *k*, *k*, yeast cells, same species, in the vacuoles of which are swimming small particles of protoplasm ; *l*, *l*, yeast cells *(Saccharomyces exiguus)*; *m*, *m*, cells of *Mycoderma aceti* ; *n*, *n*, lactic ferments ; *o*, *o*, *bacteria* of the *vibrio* class ; *p*, *p*, *Bacterium termo* ; *q*, *q*, acetic acid ferment ; *r*, *r*, various *Sphæro-bacteria* ; *s*, *s*, gluten cells of maize ; *t*, hair of wheat. Magnified 380 diameters.

MANUFACTURE OF COMPRESSED YEASTS.

356. These yeasts are now so widely and successfully used that some account of their origin and mode of manufacture claims a place in this work. The author frequently receives letters from bakers asking him to furnish recipes for the production of a good compressed yeast ; from these it is evident that many bakers know very little as to the actual manner in which compressed yeasts are prepared for the market. These yeasts find their way into this country from France, Holland, and Germany. They are not, as has been stated, low or bottom yeasts of lager beer fermentation, but are distillers' yeasts, and are formed as the principal product in the manufacture of spirits from malt and raw grain ; the spirits being used to an enormous extent in the manufacture of liqueurs, perfumes, wine, and brandy. This manufacture can only be successfully conducted on a very large scale, and cannot be imitated

by the baker who simply wishes to make yeast for his own consumption.

Being desirous of giving as accurate an account as possible in this work of the manufacture of compressed yeast for bakers' purposes, the author explained his wishes to Mr. Bischof, London, the importer of Encore Yeast, to whom he was indebted for the substance of the account of yeast manufacture given in a preceding work on the *Chemistry of Wheat, Flour, and Bread.* Mr. Bischof entered into communication with Messrs. Lesaffre et Bonduelle of Lille, who are the manufacturers of the Encore Yeast. They, with great courtesy, which the writer here desires to acknowledge with his best thanks, gave him (the writer) an invitation to visit Lille, and spend as much time as he desired at their various yeast factories, thus investigating for himself the whole process, and seeing it at leisure and in every stage. It may be mentioned that Messrs. Lesaffre et Bonduelle have three large yeast factories aud distilleries in Lille. They are among the few largest manufacturers of yeast in the world, and have a weekly output of yeast which probably equals that of any other European firm, averaging about 70 tons.

In the following description, resulting from notes made on the spot, the plan adopted is to take the raw grain at its entrance to the factory and follow it through its consecutive stages until it emerges finally in the highly transformed condition of yeast. The Lille factories being of about the same capacity, a description of the one will serve for all. Being situated by the canal side, the grain required is brought by barge and directly discharged by steam elevators into the granaries at top of the building. For spirit and yeast making purposes it is necessary to have as the sustaining product of fermentation, carbohydrates, and also abundance of healthy nitrogenous nutriment. If yeast be the object of manufacture, brewing sugars are inadmissible, because by reducing the proportion of proteid matter they would cause the production of an unhealthy and weak yeast. Among the grains found in the granaries are barley, rye, and maize. Rice is very rarely employed, because of its comparatively non-nitrogenous character. Naturally, one of the legitimate considerations of the distiller is to obtain his requisite carbohydrate and proteid as cheaply as possible, and hence the particular grain chosen is somewhat governed by the market price at time of purchase. Prior to its further employment, the barley is malted, which process has already been described: this operation Messrs. Lesaffre et Bonduelle conduct for themselves, having malting floors of large extent. A part of the malting plant is laid out on the ordinary system, and a portion is arranged as "pneumatic" maltings. As previously explained, the operation of malting destroys the parenchymatous cell-walls, and thus renders the interior of the barley more readily amenable to diastasic action. At the same time diastase itself is developed, and the whole of the nitrogenous matter is rendered more soluble and in part peptonised, thus being converted into a form of proteid specially adapted for assimilation by yeast. The grain, having been thus prepared, passes to the mills, where a part is reduced by steel rolls, and the rest by millstones, into a moderately fine meal.

The first step in the fermentation process is the preparation of what, in the bakers' phraseology, may be termed a "ferment" ("bubb"), that is, a preliminary fermentation of a relatively small proportion of the grain. Malt and rye are taken together for this purpose, and mashed at a convenient temperature, so as to obtain as complete a transformation as possible of the starch into maltose. The mash thus produced is allowed to stand in the tubs at a temperature most suitable for the production of lactic acid, that is, about 35° C. The lactic acid germs on the skin of the malt rapidly develop, and a marked acidulation ensues. This is a most interesting step in the fermentation, and while the immediate result is the production of lactic acid, yet its ultimate effect is the prevention of development of the lactic acid ferment. This organism is peculiarly sensitive to the effect of its own product, and as little as 0·15 per cent. of lactic acid added to a mash is sufficient to prevent lactic fermentation taking place, although, on the contrary, if lactic fermentation be once started, it will proceed until something like 1·5 per cent. of lactic acid has been formed. The reason of this inhibitory effect is that the addition of lactic acid is a deterrent not only to lactic fermentation, but also to the multiplication of lactic acid *bacteria*, so that, by its addition in the earlier stage, any reproduction of these organisms, and consequently any but the smallest possible production of lactic acid, is prevented. This first development of lactic acid, then, in what may be for convenience called the "ferment," serves to check undue development of acidity in the main fermentation. It also further serves the useful purpose of peptonising and otherwise breaking down the nitrogenous matters of the grains in the mash, so as to render them available as yeast foods.

Sufficient acidulation being produced, the mash is then cooled by the immersion therein of cooling coils of copper tube, through which cold water is being passed. When at the desired temperature, without filtering of the "grains" (husky fibre of the grain used), the "pitching" yeast is added, and fermentation allowed to proceed for 10—14 hours, according to the temperature. This is regulated by the foreman in charge, according to time when the "ferment" will be wanted, and the general requirements of the factory.

Next, the preparation of the other materials required in the mash tun may be considered. The raw grain, consisting principally of maize, is first cooked by high pressure steam in a special steam cooking vessel (cuiseur) until thorough gelatinisation has been produced. From this vessel the cooked maize is passed into the saccharification tun, and there mashed, first with the rye; after which the malt is added and saccharification continued, until the hydrolysis of the carbohydrates to maltose is as complete as possible. While the brewer finds it advantageous to retain dextrin and some amount of maltodextrins in his wort, the distiller has practically no use for anything except the maltose, and so pushes the diastasis to its utmost limit. The finished wort is next passed to the refrigerators, of which there are several of different patterns. Thus there is the arrangement of a large shallow copper vessel, with an outer jacket, through which cold water passes, and having a number of fan-like arms revolving above the surface of the liquid, which rapidly cause it to become cool. Another form of refrigerator is that of Laurence, in which a copper pipe is bent again and again on itself so as to form a vertical rack, with connected horizontal pipes in a series one over the other. Cold water passes through the pipe, and the wort is allowed to trickle over the outer surface, thus being rapidly cooled and at the same time ærated. The wort thus being cooled as rapidly as possible, is conveyed to the fermentation vats and the pitching "ferments" added. Air is driven through the wort by mechanical means in order to thoroughly ærate it, and this operation is repeated from time to time as fermentation proceeds, as found necessary. The grains contained in the mash rise to the surface and there act as a non-conductor of heat. In from three to four hours after pitching, the carbon dioxide forces itself up in a sort of cauliflower head through the grains and "breaks." Fermentation is allowed to continue for from ten to twelve hours from the commencement, and then workmen start skimming off the yeast. To do this they use a long lath and "bay" up the whole of the yeast at one end of the vat, and then ladle it off in scoops, pouring it into a wooden gutter, by which it is conveyed away for washing and purification. This skimming is carried on practically continuously for about twelve hours; the fermentation is then complete, the maximum amount of yeast and alcohol having been formed. The worts are carried away to the distillery department, and there are distilled, the rectified spirit passing over, and being stored in bond until sold.

The skimmed yeast is first mixed with water, and is then passed through a series of mechanical sieves, by which the grains are removed. The yeast is then washed by decantation two or three times, and again sifted through finer sieves. This washing process requires discrimination, as it is desirable to wash thoroughly, in order to remove wort; while, on the other hand, washing in excess weakens the yeast by removing the interior contents of the cells. At the final decantation, when the yeast has settled completely, there is a layer on the top of immature and young cells; these, being practically valueless, are removed and rejected from the main body of the yeast.

In mixed yeasts it is at this stage that any starch is added, the starch being worked up into a creamy mass with water, and then mixed with the yeast. The two together then pass along to the filter presses. **Encore Yeast is, however, one of those brands which is sent to this country in the form of absolutely pure yeast cells,** and so no starch mixing occurs.

The carefully washed and purified yeast is next taken to the filter presses, where the mixture of yeast cells and water is pumped through a series of filtering cloths; these retain the yeast and the water drains away. As much water as possible is thus eliminated from the yeast, which, on the press being dismantled, is removed from the surface of the cloths and conveyed to the packing room; here it is pressed down into tubs in order to prevent discolouration by air, and as soon as practicable is made up into convenient packages for distribution to the consumer. The secrets of successful yeast manufacture are raw materials of the highest quality, absolute cleanliness during the whole process of manufacture, and finally eternal vigilance. This last is the invariable price of excellence in yeast. Cleanliness of vessels is ensured by washing and scalding with live steam. As an additional precaution, all vats and tubs are periodically treated either with sulphurous acid or bisulphite of lime, both of which are absolutely harmless and most efficient antiseptics. All floors are kept clean by continual rinsings with water, the pathways consisting of raised planks, under which the water passes freely. In the yeast settling rooms, where, being in the quiescent stage, the risk of contamination is greatest, the floors and walls are continually treated with solution of chloride of lime, thus most effectively destroying all disease germs. Such is in outline the process of manufacture employed in the production of one of the most widely used and highest character yeasts imported from the continent into the United Kingdom.

357. British Compressed Yeasts.—Recently, considerable progress has been made in the manufacture of compressed yeasts by British distillers, who have applied certain modifications to spirit distilling processes which have resulted in an economic production of yeast suitable for bakers' purposes. Others have made the manufacture of yeast their principal object, and have treated the spirit produced as a bye-product. Hence it is that a fair proportion of the yeast now used is manufactured within the United Kingdom.

358. Characteristics of Compressed Yeasts.—A good sample of compressed yeast has the following characteristics—it should be only very slightly moist, not sloppy to the touch; the colour should be a creamy white; when broken it should show a fine fracture; when placed on the tongue in should melt readliy in the mouth; it should have an odour of apples, not like that of cheese; neither should it have an acid odour or taste. Any cheesy odour shows that the yeast is stale, and that incipient decomposition has set in.

Viewed under the microscope, compressed yeast consists of somewhat smaller and more oval cells than those of brewers' yeast. In the best varieties are found only traces of foreign ferments; other brands contain them in large numbers. The yeast cells themselves should possess the same characteristics as have already been described while treating brewers' yeast. A drawing of compressed yeast is given in Plate II. The cells were found, on measurement, to have the following dimensions—

Longer diameter,	...	10 mkms. =	0·0004 inch.
Shorter diameter,	...	7·6 mkms. =	0·0003 ,,
Diameter of round cells,		7·6 mkms. =	0·0003 ,,

The sample in question was remarkably free from disease ferments, one only being seen in the field sketched, while several fields showed no foreign organisms whatever. The granulations show very distinctly. The yeast in question was a very pure one, and yielded exceedingly good results when subjected to strength tests.

In general character, the compressed yeasts are steady and trustworthy in their action; they produce sweet, well-flavoured breads, to which, when in good condition, they do not impart any yeasty taste. Their good qualities stand out most distinctly in summer time, when other yeasts so frequently fail entirely to produce a satisfactory loaf of bread. Their being produced in such large quantity causes their manufacture to be entrusted to men who bring the highest skill that practical experience and science can furnish to bear on every detail of manufacturing processes. The many good properties of compressed yeast lead it to be safely indicated as the yeast of the future.

359. Admixture of Starch with Yeast.—This question, which like many others has two sides to it, has of late been attracting much attention both from the baker and the yeast manufacturer. This is largely due to the action of certain local authorities in instituting proceedings under the Food and Drugs Adulteration Act for the addition of starch to yeast. In order to constitute an offence under this Act it is necessary (1) that the substance itself be, according to the legal definition, an article of food; (2) that the substance added, starch, be injurious to health; or (3) that the addition has been fraudulently made to increase the weight, or conceal the inferior quality of the article.

It is matter of history that in the earlier production of compressed yeast for commercial purposes starch was invariably used. This is simply following a common practice, for frequently in pharmaceutical and other preparations starch is employed as a drying agent: for this purpose it is well adapted, being neutral in its qualities, inert and absolutely harmless. Yeast from its peculiar slimy nature cannot be pressed well, hence the addition of starch permits not only the more rapid, but also the more complete removal of water. With improvements in yeast manufacture, the difficulty of pressing has been diminished, as purer yeasts are "cleaner" in the sense of freedom from external sliminess, and so filter more readily. With these improvements, stress of competition among yeast manufacturers has led them to appeal to the buyer more and more on the ground of freedom from impurities in general, and starch in particular. Therefore, many yeasts are now offered to buyers as consisting of pure yeast cells only.

It is stated that yeast is found on the market with quantities of starch varying from 5 to as much as 75 per cent., and evidently the whole of the larger amount is not added simply for the purpose of effecting more rapid and easy filtration. If the addition of starch in any quantity be permissible, the question arises as to what should be the quantitative limit. The first consideration here is that of the advantage or otherwise of the presence of starch at all The author has for many years held the opinion, expressed publicly in his former works on this subject, that the presence of starch in small quantity in yeast is for certain requirements a distinct improvement. This opinion is based, first, on the fact that everything else being equal, a yeast with a small percentage of starch keeps longer. It is not pretended that a high-class unmixed yeast may not be superior in its keeping qualities to a low class and unsound mixed sample; but that one and the same yeast, if mixed with a small quantity of starch, has superior keeping powers to those it possessed when free from this admixture, especially during hot weather. This conclusion is based on personally keeping such samples of yeast under observation in the author's laboratory, and also on the testimony of bakers in provincial districts whose yeast is comparatively old when it reaches them. Second, the presence of starch diminishes the moisture present in yeast, which doubtless is one great reason of its better keeping qualities. Third, starch when present modifies the nature of the yeast, and thus renders it more suitable to particular requirements. Thus, W. Gintl says, "that although the fermentation is undoubtedly more feeble at the commencement, yet it afterwards becomes more vigorous than with pure yeast." A curious exemplification of this is the experience of certain London bakers who set a sponge over-night; they find that a mixed yeast causes such a sponge to be just ready when required next morning. It may be suggested, why not use an unmixed yeast and less of it? But in the experience of these users, the effect produced is not the same, but renders them liable to sour bread. The probable explanation is that the mixed yeast is comparatively dormant for some time, and only commences active fermentation at a considerable interval from the time of the sponge being set. The pure yeast, on the other hand, has a higher initial activity, and finishes its work sooner, causing the sponge to be "ready" too long a time before being "taken." For certain purposes, therefore, this modification in character of the yeast meets an actual want. (It is not contended here that the use of a mixed yeast is the *only* way out of the difficulty, or even the *best* way, but simply that is the way preferred by the bakers referred to; as such, it is a justification of those yeast merchants who cater for their requirements.)

It almost follows, as being incumbent on one advancing opinions of the nature of those preceding, that a discussion should ensue on the question of the quantitative limit of such admixture. Probably this may be dealt with most conveniently in connection with the history of the controversy on the whole question. Stock read a paper on the subject before the Society of Public Analysts, in April, 1887, in which he set himself to answer the questions—

1st. Is the addition of starch to yeast a necessity?
2nd. If necessary, what end does it serve?
3rd. What is the quantitative limit?
4th. Does the addition come within the meaning of the Food and Drugs Act?

His answer to the first and second questions is that with healthy yeast such addition is unnecessary, and that the added starch makes bad yeast look like good, and impedes the development of the lactic bacterium. It follows that he fixed no quantitative limit, and held the very decided opinion that such addition came within the scope of the Adulteration Act. Mr. Stock's paper shows no evidence whatever of his being acquainted with the actual result of the addition of starch on the keeping qualities of yeast, its percentage of moisture, or its fermenting properties in the bakehouse. The most valuable result of the paper was the contribution to the discussion made by Mr. Otto Hehner, since President of the Society, who said, "I would like to have seen some information as to the reasons which induce Mr. Stock to say that there is no use or necessity for the presence of starch in yeast, and why he asserts it to be only required in yeast of bad quality.

I may state that my experience is diametrically opposed to that of Mr. Stock. . . . With yeast we expect to get a certain effect; the effect only is aimed at; I should say, if a sample containing 90 per cent. of starch did its work properly and well, it should be preferred in preference to a pure but weak article. I would, of course, oppose any deception in this matter, but analysts, as such, are not, in my opinion, in a position to judge of the requirements of the baker."

The next important contribution to this controversy was a paper by Laurence Briant, appearing in the *Bakers' Quarterly Trade Review*, June, 1888. Briant points out that "ordinary pressed yeast contains from 70 to 75 per cent. of moisture, and that if starch be introduced, the proportion present is considerably smaller, and, within certain limits, it can be shown that the starch only replaces a proportion of the moisture, and reduces that in the yeast itself, so that it is possible that the percentage of yeast may be even greater instead of smaller. The starch abstracts moisture from the yeast cells themselves, so that it is possible that the addition of starch may increase the proportion of actual yeast in the sample, as shown by the following figures:—

Sample.		Yeast.	Starch.	Moisture, Ash, &c.
No. 1.	...	24·60 per cent.	None per cent.	75·40 per cent.
,, 2.	...	25·10 ,,	None ,,	74·90 ,,
,, 3.	...	26·15 ,,	5·70 ,,	68·15 ,,
,, 4.	...	24·08 ,,	12·15 ,,	63·77 ,,
,, 5.	...	20·50 ,,	17·20 ,,	62·30 ,,

It will be seen that the yeasts containing starch are decidedly drier. In No. 3 sample it will be further seen that the percentage of starch introduced has actually increased the quantity of real yeast present, so that the purchaser, although buying a proportion of starch for yeast, would nevertheless obtain more yeast than he would have, had the sample been perfectly pure. . . . There is one direction in which the use of starch is really commendable, namely, by the reduction it effects in the percentage of moisture in the sample, and the consequent increased keeping quality imparted thereto. . . . The drier the yeast, the better it will keep, and it is in this sense that the use of starch in yeast may be of service to the baker."

In addition to Briant's analyses given above, the author may quote some of his own, recently published. Two samples of yeast of the same make were examined, the one unmixed, the other mixed with starch. The following were the results:—

	No. 6 Unmixed.	No. 7. Mixed.
Starch, ...	0·00 per cent.	19·20 per cent.
Water, ...	72·88 ,,	60·40 ,,

Again there is evidence that the yeast containing starch is very considerably the drier. Briant calls all that is not moisture or starch "yeast," and in order to make the figures above given comparable with Mr. Briant's series, an addition must be made to percentage of water. As yeast usually contains about 2 per cent. of ash, this figure may be taken. The above analyses then become—

	Yeast.	Starch.	Moisture, Ash, &c.
No. 6.	26·12 per cent.	0·00 per cent.	74·88 per cent.
No. 7.	18·40 ,,	19·20 ,,	62·40 ,,

Analysing these figures, 5·70 per cent. of starch resulted in the presence of *more* dry yeast solids than the pure yeast contained; 12·15 per cent. of starch resulted in the yeast solids being practically the same as in pure yeast. Another 5 per cent. of starch added drops the yeast solids 4 per cent.; and, comparing No. 7, another 2 per cent. of starch results in a further disappearance of 2 per cent. more of yeast solids. In the whole of these analyses the fact stands out very prominently that the presence of starch means the comparative absence of water. Take the last two analyses: the quantity of water less in the one compared with that in the other is 72·88 – 60·40 = 12·48 per cent. But, in addition to this, the starch itself will retain in a state of absorption some water; and even if this be taken as only one-third of its own weight, that amounts to 6·40 per cent. of water abstracted from the yeast, so that the mixture as a whole is drier, and so also is the yeast part of it. Another question here arises, and that is how far such analyses may be taken as evidence of to what extent the added starch replaces yeast, and to what extent it replaces water. The difficulty is this: suppose 80 parts of yeast be added to 20 parts of starch, the two thoroughly mixed, and called No. 1; let a second mixture be made by taking 100 parts of yeast, 20 parts of starch, mixing, and then squeezing out some of the liquid present until the weight of No. 2 mixture is 100. Both these mixtures contain 20 per cent. of starch, but No. 1 contains only 80 per cent. of the original yeast, while 100 per cent. of the original yeast remains in the second, less 20 parts of yeast liquid which have been squeezed out. In an actual experiment made by the author on these lines, 30 grams of yeast were taken, mixed with 6 grams of starch, and squeezed between folds of dry filter paper until 31 grams only of the mixture remained. Moisture was then determined on both the original yeast and the mixture: the composition was as follows, the percentage of starch in No. 2 being obtained by calculation:—The composition of the mixture of 80 parts of yeast and 20 parts of starch is also given as obtained by calculation:—

	No. 1. Pure Yeast.	No. 2. Yeast and Starch dried to near original weight.	No. 3. 80 Parts Yeast. 20 ,, Starch.
Starch,	0·00 per cent.	19·35 per cent.	20·00 per cent
Water,	73·50 ,,	60·86 ,,	58·80 ,,

In the first place it should be noticed that No. 2 analysis, as compared with No. 1, almost exactly corresponds with Nos. 6 and 7, showing most conclusively that if the *whole* of the starch added had simply replaced water, the composition would have been just as was actually found by analysis. The analyses, in fact, do not prove any replacement whatever of yeast by starch. On the other hand, it must be pointed out that equally they, considered alone, do not prove the absence of such replacement, as No. 2, quoted above, in which no yeast has been displaced, agrees very closely indeed with No. 3, in which 20 parts of starch have simply taken the place of 20 parts of yeast. The reason, of course, is that what is displaced when the mixture is squeezed is the liquid contents of the cells, which consist principally of water. In order to have any bearing on whether or not the starch replaces yeast cells or simply water, analyses such as quoted should also be supplemented by other tests, among which one of the best is the yeast apparatus; if the sample gives off a low proportion of gas, that is a proof either of the yeast being weak or else containing large quantities of foreign matter; to the baker, both these come much to the same thing. Other tests of value are the determination of the amount of nitrogenous matter present, and also the actual counting of the yeast cells present in the sample by the hæmatimeter. But, after all, what we require in a yeast is gas-evolving power, combined with keeping qualities: if both these are present in a high degree, then a small percentage of starch is a matter of indifference.

In suggesting a limit, beyond which the presence of starch should be considered by the baker in the light of an adulterant, the maximum of 20 per cent. is suggested, which amount will usually, so far as the author's experience goes, coincide with an actual increase of weight of the mixed yeast by about 8 per cent. over the weight of the same yeast if supplied pure. A form of contract under which yeast is sold by certain manufacturers is that the quantity of yeast that shall make 100 kilograms of pure yeast shall, when mixed with starch, have its weight increased by an amount not making the whole exceed 110 kilograms, that is an increase of 10 per cent. Such an increase of weight will usually be accompanied by the presence in the mixture of about 20 per cent. of starch. Of this quantity rather over half will have replaced water, making the yeast proportionately drier; the remainder will constitute an addition to the weight of probably about 8 per cent. This is not an unreasonable addition, considering the great improvement it makes in the yeast: and usually yeast manufacturers make no secret of such admixture, and arrange for the same in the price charged. It goes without saying that the sale of a mixed yeast, as unmixed, constitutes a fraud on the purchaser.

An important point to bear in mind, in event of any attempt at prosecution under the Food and Drugs Act for selling yeast mixed with starch, is that a recent judgment of the High Court declares baking powder is not a food, and that decision has been held to also exclude yeast from the legal food category.

360. Guichard on the Analysis of Yeast.—Since the preceding was written, a communication has appeared in the Bull. Soc. Chim., 1894, from T. Guichard, on the composition and analysis of yeast. He estimates water by drying thin shavings at 120° C., and finds pure yeast to contain 71 per cent. of moisture. By suspending yeast in a mixture of alcohol and chloroform, he finds its specific gravity to be 1·180. The various other determinations made do not add materially to our knowledge of the composition of yeast. Guichard finds that "the results of chemical analysis are not sufficient to test its quality; for this reason the fermenting capacity of a sample should also be examined. For the purpose the following new (?) process is proposed." An apparatus is employed, consisting of a small bulb with a lateral orifice. The bulb is further provided with a long vertical tube, over which is placed concentrically a wider tube, divided into 100 c.c. This tube is filled with water, which through a lateral opening is displaced by the carbon dioxide generated during fermentation. In the bulb is placed 0·5 gram of the yeast to be examined, diluted with 0·5 gram of water, 0·5 gram of sugar dissolved in 5 c.c. of water, and 1 gram of washed sawdust. The side-tube to the bulb is closed with an indiarubber stopper, and the apparatus placed in a water bath at 30° C. The quantity of carbon dioxide is then read every quarter of an hour for two hours and a half. The different readings may be marked on a system of co-ordinates, and a curve is thus obtained, rising rapidly to a maximum, and falling again with equal rapidity. The flatter the curve the poorer the fermentative quality of the yeast. Otherwise the quantity of carbon dioxide evolved is taken as a measure of the quality of a yeast. The strongest yeast examined evolved 86·2 c.c. of carbon dioxide in two and a half hours.

The process is the same as that now adopted for many years by the author: the form of apparatus is one likely to be very convenient for use in a chemical laboratory. But the author inclines very strongly to flour and water as a fermenting medium for yeast testing, and prefers a smaller proportion of yeast to fermentable matter.

"PATENT," OR BAKERS' HOME-MADE YEASTS.

331. Some of the best, and at the same time some of the worst bread the author has ever tasted has been made with, what is commonly termed by the baker, "patent" yeast. This is just what any one familiar with the delicate nature of yeast as an organism would be led to expect. Brewing, whether considered as a science or an art, is a subject of which the average baker, among even those who make their own yeast, knows little or nothing. On the other hand, the manufacturers who produce pressed yeasts for the bakers' special use are men of the highest scientific education, who have made yeast manufacture, on a sufficiently large scale to permit them to spend adequate sums on the most efficient plant, their life study and business. In the majority of instances, the baker's other business engagements prevent his giving yeast-making anything like adequate attention; the consequence of entrusting this operation to unskilled and indifferent hands is that a most irregular and unsatisfactory product is yielded. For these reasons a number of bakers find it pays them better to buy their yeast of the skilled and professional manufacturer, rather than depute the task of making it to an ignorant and possibly prejudiced journeyman. Still there is no reason why a baker should not be able to make a thoroughly good and satisfactory yeast for himself. It is only necessary that he shall bring to bear on its production the following requisites:—sound materials, proper manufacturing apparatus, knowledge of the principles of fermentation, practical experience of brewing, and lastly, constant attention and supervision. As already stated, bakers' yeasts may be divided into two varieties—malt and hop yeasts as used in England, and flour barms as employed in Scotland.

362. Bakers' Malt and Hop Yeasts.—These consist essentially of small mashes of malt and hops, fermented either by the addition of some yeast from a previous brewing, or allowed to ferment spontaneously: the latter is known as "virgin" yeast. The hops present tend to prevent disease fermentations, as their bitter principle is inimical to bacterial growth and development. In virgin yeasts, particularly, it is necessary to use hops largely, and also plenty of malt; as lactic and other foreign ferments flourish far better in a dilute saccharine medium than in a stronger one. The reader will already be familiar with the general outlines of the fermentation of a hopped wort: as an introductory to directions for the preparation of patent yeast a careful study of the following experiment, made by the author, will be of service. The student will do well to repeat the experiment for himself: sufficiently full directions are therefore given to enable him to do so.

Take two quarts of water and half an ounce of good hops; set these to boil in a large glass flask or other *clean* vessel; boil for half an hour, and then cool down to 65° C. (149° F.) Scald out a large glass beaker, or failing this, a vessel of copper or enamelled ware; wood will not answer well. Weigh out 12 ounces of ground malt and mix with the hops and water in the beaker. Maintain the whole at a temperature of from 65° to 70° C. (149° to 158° F.) for two hours; this may be done by standing the beaker in a hot water bath. By the end of this time the saccharification of the malt should be complete. Have ready another glass vessel perfectly clean and scalded. Strain the wort, from the grains, through calico into this second clean vessel; cool down as rapidly as possible to 25° C. (77° F.) In the meantime have ready a large water-bath, carefully regulated at a temperature of 25° C. by means of an automatic temperature regulator. Also thoroughly clean and scald six glass beakers of about 16 ounces capacity, and have ready glass covers for each beaker. Pour the filtered wort into these beakers, placing about an equal quantity in each. Label both beakers and cover with numbers from 1 to 6. Let No. 1 remain in the condition of plain wort; to No. 2 add 1 gram (15 grains) of good brewers' yeast; to No. 3 add 0·7 gram (10 grains) of good compressed yeast. Prepare Nos. 4, 5, and 6 in exactly the same manner, so as to form a corresponding set. Cover each beaker with its glass cover and stand the whole in the water-bath. Let the first series remain undisturbed, but ærate those of the second by, some five or six times a day, pouring the contents of each beaker into a clean empty beaker, and then back again several times. After each æration replace the covers and stand the beakers again in the bath.

After about 24 hours examine each sample under the microscope. In the author's experiment, No. 1 at that time contained no yeast; figure 23 represents its appearance after three days. (This, and also several figures which follow, are simply fac-similes of rapid sketches made in a laboratory note-book.)

The most careful examination of field after field revealed not a single

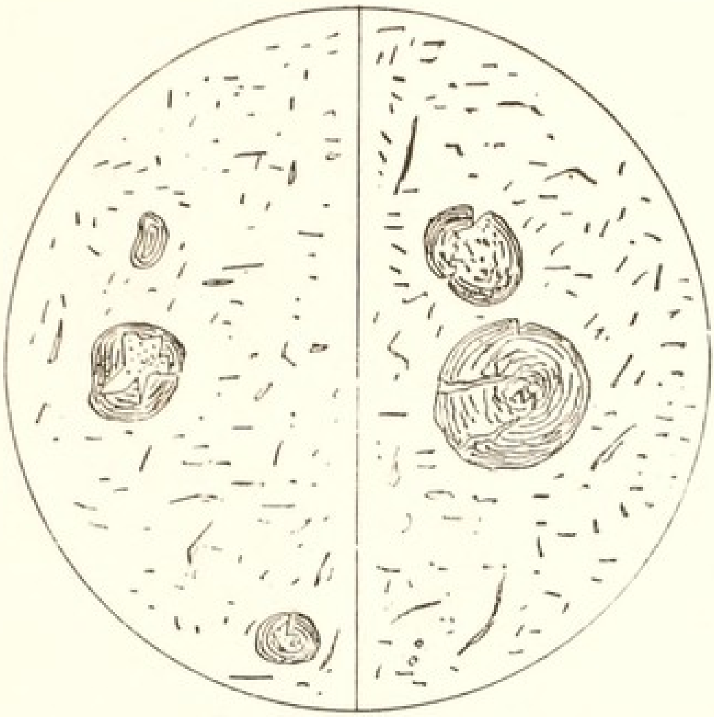


FIG. 23.—MALT WORT ALLOWED TO FERMENT SPONTANEOUSLY.

Left half of field taken from ferment; right from the same after being sown in warm "yeast mixture" for about three hours. Magnified about 440 diameters.

yeast cell, while the whole liquid was swarming with *bacteria*; a slight froth had formed on the top. The left hand side of the figure shows the wort as taken from the beaker, one or two grains of starch being visible. A portion of this wort was then sown in Pasteur's Fluid (Yeast Mixture), and again examined at the end of three hours, being maintained for that time at 26·6° C. (80° F.); its appearance is shown in the right hand portion of the figure. (The student is recommended to employ a fermenting temperature of 25° C.) This result was obtained not merely once, but also in a complete duplicate series of experiments. The mode of procedure is the same as that employed by those bakers who are in the habit of allowing their yeast to ferment spontaneously—except that chemically clean vessels are employed throughout. Another interesting point is that although yeast was being used in the room at the time, and even beakers, containing actively fermenting worts, were standing side by side in the same water-bath, yet the loosely fitting glass covers were sufficient to prevent the entrance of yeast cells or spores into beaker No. 1 from external sources.

Within twenty-four hours after being pitched, each sample was thus examined under the microscope. Nos. 2, 3, 5, and 6 were in a state of vigorous fermentation. Subjoined are sketches made in Nos. 5 and 6 respectively.

Figure 24 shows the yeast to be in an actively budding state. Notice that buds of different sizes, *d*, are attached to the various cells. The interior of the cells is free from granulations; a few show, however, as for instance *c*, a distinct vacuole. In the centre of one group an old or parent cell, *a*, is seen. The irregular fragment marked *b* is a small piece of cellulose from the malt.

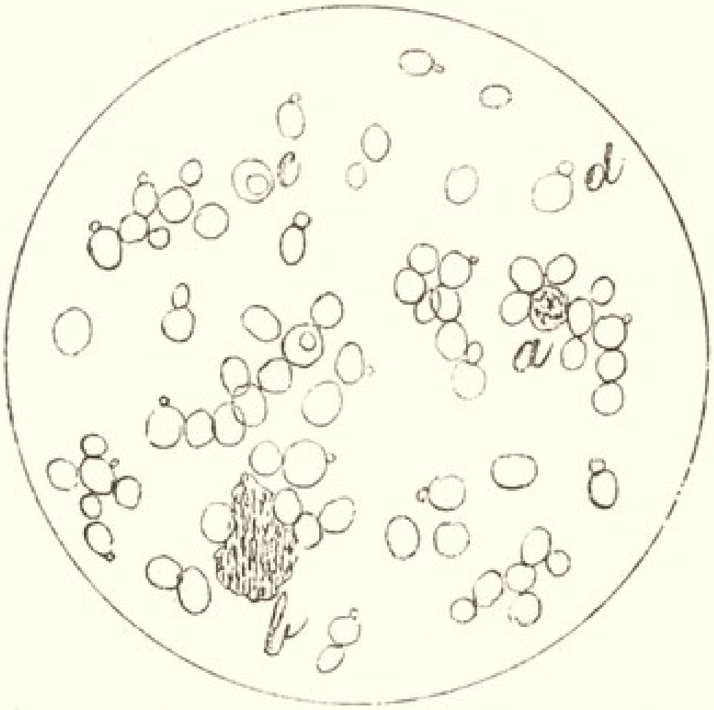


FIG. 24.—BREWERS' YEAST, 24 hours after being sown in Malt Wort. Magnified about 440 diameters.

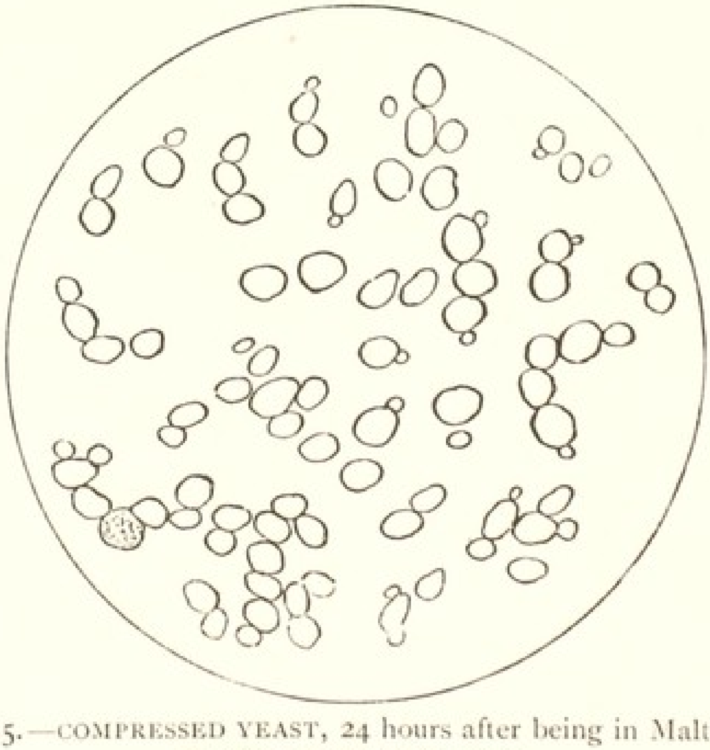


FIG. 25.—COMPRESSED YEAST, 24 hours after being in Malt Wort. Magnified about 440 diameters.

The appearance of figure 25 is very similar to that of the preceding one. An example of an old cell is to be seen toward the left, while the field generally is occupied by new cells, perfectly free from granulation, and containing no vacuoles. In general aspect the cells are more ovoid in shape, and smaller, than those of the brewers' yeast.

At the end of three days the yeasts were again examined, having been maintained at a temperature of 26·6° C. (80° F.) for this time; a sketch was then made of No. 2 sample of brewers' yeast.

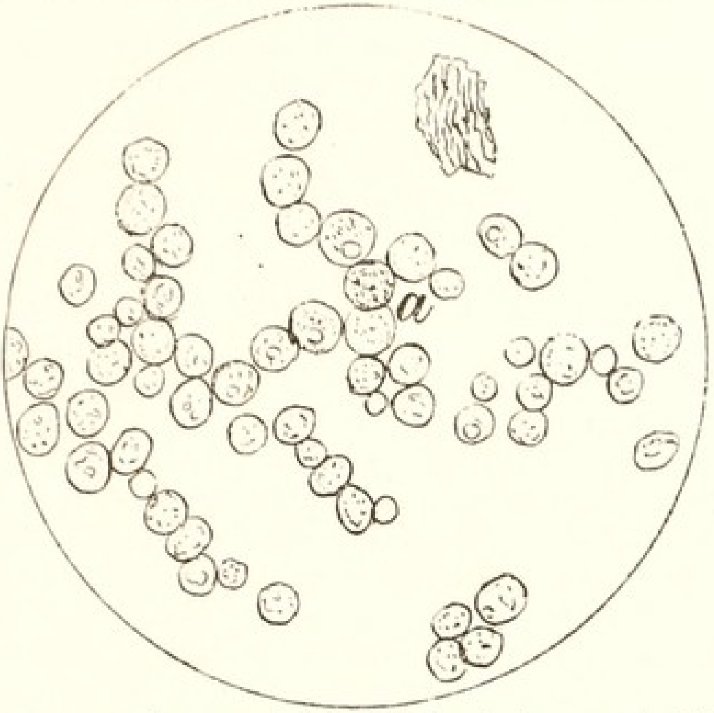


FIG. 26.—BREWERS' YEAST, three days after being sown in Malt Wort. Magnified about 440 diameters.

After this lapse of time the fermentation had very nearly ceased. Instead of observing a field covered with perfectly new cells, the majority of which were actively budding, the aspect of the yeast is far more quiescent. Here and there an old cell is still to be seen, as at *a*. The new cells, however, have begun to assume somewhat the same appearance. In some of them vacuoles are to be seen, but only in a few. The sketch does not faithfully represent the appearance of the vacuoles, as these really only appear as lighter parts of the cells, and are not circumscribed with a dark line, such as one has to use in sketching them in these figures. All the cells are more or less filled with faint, but distinct, granulations.

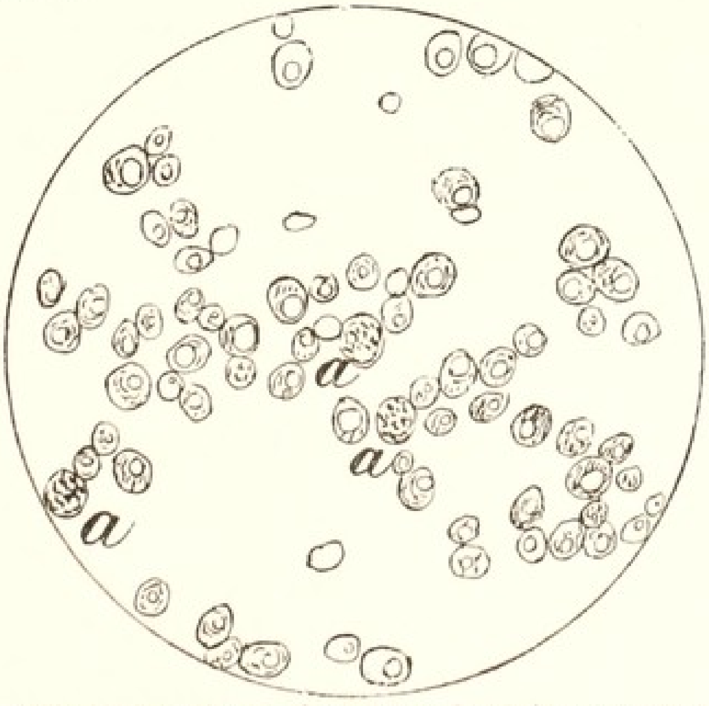


FIG. 27.—COMPRESSED YEAST, three days after being sown in Malt Wort. Magnified about 440 diameters.

There is at the end of this time a marked difference in appearance between the pressed as compared with the brewers' yeast. The vacuoles show much more distinctly, so also the interiors of the cells are much darker; the sketch shows several of parent cells, as at *a, a*.

Particular attention is drawn to the fact that whereas samples Nos. 1 and 4, which were allowed to ferment spontaneously, swarmed, after three days, with *bacteria;* the whole of the other four specimens which had been sown with yeast showed, on observation, no foreign ferments whatever. It is possible that some may have been discovered by careful and systematic examination, but the main point is that, compared with Nos. 1 and 4, they were to all intents absent. Now, save by the addition of yeast, all the samples were exposed to precisely the same conditions; the only conclusion to be drawn is that the presence of yeast growth is more or less inimical to that of foreign or disease ferments. The practical lesson to be learned from this is that bakers who prepare their own malt and hop yeasts, by sowing them with small quantities of pure yeast, not only induce a healthy growth of pure yeast ferments, but also retard the growth and development of disease ferments. The most probable explanation of this lies in the fact that, under the conditions of the experiment, there is a more or less acute struggle for existence between the two organisms, and yeast, being the more vigorous and hardy, grows and develops at the expense of the *bacteria*.

After standing some time the vessels of yeast were covered with a film of *Mycoderma cerevisiæ;* a growth which has been described in Chapter IX., and illustrated in Figure 14.

Nothing has as yet been said about the difference between the series of beakers that were allowed to remain undisturbed, and those which were ærated from time to time. Before doing so it would be well to describe the results of determining the amounts of gas evolved by the respective samples on being tested in the yeast apparatus. At the time these experiments were made, the author was working with that older form in which the gas bubbled up through the water.

After standing three days these samples of yeast were tested by being inserted in the testing apparatus. Half an ounce of yeast mixture was taken, to this was added six ounces of the thoroughly stirred yeast. At the end of three hours the following quantities of gas were found to have been evolved from each:—

	Cubic Inches.
No. 1. Spontaneous ferment, undisturbed, ...	3·1
No. 2. Pitched with brewers' yeast, undisturbed, ...	16·8
No. 3. Pitched with pressed yeast, undisturbed, ...	35·6
No. 4. Spontaneous ferment, agitated, ...	3·7
No. 5. Pitched with brewers' yeast, agitated, ...	18·6
No. 6. Pitched with pressed yeast, agitated, ...	42·8

The experiment shows very clearly that the agitation has resulted in the yeast being in every instance more vigorous in action. In the case of the spontaneous ferment there was a distinct, though slow, evolution of gas. The samples pitched with the pressed yeast had, by the bye, more than twice the capacity for causing the evolution of gas than had those which were pitched with brewers' yeast. It is plain that agitation in some way increases the vigour of yeast. Those students who have carefully read the section of Chapter IX., dealing with the influence of oxygen on fermentation, will clearly understand the cause of such increase in fermentative power.

When yeast is being made by bakers from malt and hops, although fermentation goes on, it is not the fermentation, as such, that is wanted. The change required is not the production of beer, but the growth and development of yeast; hence the operation should be so conducted as to induce the greatest yield of yeast in the most active and vigorous form. Æration, or "rousing," as it is often termed, is, as will now be well understood, of considerable service. In brewing large quantities of yeast, it would obviously be difficult to ærate by pouring from vessel to vessel; the same object may be served by from time to time thoroughly stirring the fermenting yeast. This free access of air not only stimulates the growth of yeast, but in addition is inimical to the development of disease ferments; so much so, that by careful working with plenty of air a yeast can be made to give moderately good results, that would be absolutely unusable if fermentation were conducted in closed vessels. It follows that yeast is better brewed in comparatively shallow and open tubs than in deep and closed ones.

The careful performance throughout of this experiment will not only be an instructive exercise on fermentation, but will also afford good practice with the microscope.

363. Formula for Manufacture of Malt and Hops Patent Yeast.—The following formula for the manufacture of patent yeast is taken from "The Miller,"—40 gallons of water and 2 lbs. of sound hops are boiled together for half-an-hour in a copper, and then passed over a refrigerator, and thus cooled to a temperature of 71° C. (160° F.) The liquor passes from the refrigerator to a stout tub; 1½ bushels (about 63 lbs.) of crushed malt are then added, and the mixture thoroughly stirred. The mash is allowed to stand at that temperature for 1½ hours, filtered from the grains, and then rapidly cooled to 21° C. (70° F.) The passage over the refrigerator serves also to thoroughly ærate the wort. Spontaneous fermentation is then allowed to set in, and the yeast is usually ready for use in 24 hours, but is in better condition at the end of two days. All fermenting tubs, and other vessels and implements used, are kept clean by being from time to time thoroughly scalded out with live steam. The result is the production of a yeast of very high quality.

364. Suggestions on Yeast Brewing; what to do, and what to avoid.—The quantities given above are larger than those required by many bakers, but the formula may be adopted for smaller brewings by taking a half, or quarter, or some other proportion of each ingredient. In connection with brewing, the first consideration is the room; this should not be in the same part of the bakehouse as the ovens. Select, if possible, a room having an equable temperature of from 65 to 70° F. Stout tubs of appropriate size should be used for brewing; these should be about the same width as depth. Before commencing, clean all tubs and implements with boiling water. The hops are better boiled in a copper; iron vessels are apt to discolour them, especially if the vessels are in the slightest degree rusty. Let the hop liquor cool down to the temperature given, *before* adding the malt, as a temperature much higher than from 65 to 70° C. destroys the diastasic power. On no account *boil* the malt: some bakers place malt and hops together, and boil the two, under a mistaken idea that they get more extract from the malt. The result is that diastasis is arrested long before the whole of the starch is converted into dextrin and maltose. For the same reason, fifteen minutes is too short a time for the mashing to be continued. The baker not only requires to saccharify his malt, but it is also necessary for him to convert as large a proportion as possible of his dextrin into maltose. This is hindered either by using too high a temperature, or mashing for too short a time. Starting with a mashing liquor at 65 to 70° C., and mashing for from 1½ to 2 hours, gives about the best results. The cooling after removal from the grains, which may be washed or "sparged" with a small quantity more water, must be done quickly, so as to have the wort for as short a time as possible at a temperature of from 35 to 40° C., as at that temperature bacterial fermentations proceed most vigorously. The wort at 21·5° C. (70° F.) may either be pitched with a small quantity of yeast reserved from the last brewing, or by the addition of a small quantity of good fresh compressed yeast. If wished, the fermentation may be allowed to set in spontaneously, as suggested in the preceding paragraph, in which case a "virgin" yeast is produced. It is doubtful, however, whether this is to be recommended in most cases. The risk of spoiled yeast is greater, and at times alcoholic fermentation does not set in at all, or too late to prevent its being preceded by excessive lactic and other foreign fermentations. The temperature should not be allowed to rise, during fermentation, much above 21 to 22° C. In summer time there is a great tendency for a rapid rise to set in; this may be controlled by placing an attemperator in the wort, and passing a stream of cold water through. An attemperator consists of a properly arranged series of pipes, through which hot or cold water at will may be passed. Temperatures must in all cases be got right by actual use of the thermometer. From time to time, stir the fermenting wort so as to rouse or ærate it: should it happen to be sluggish, throw in a handful of raw flour. When the yeast is made, keep it freely exposed to air. In making patent yeast it is very poor economy to stint either malt or hops: a weak wort produces a much less healthy and vigorous yeast than does a strong one, beside being much more subject to disease fermentation, and consequent acidity. And, when made, the dilute yeast shows no saving, because so much more of it has to be taken in order to do the same work.

365. Specific Gravity of Worts, and Attenuation.—In addition to taking the temperature of his worts, the brewer also tests the density or specific gravity of each sample. This is done as a means of estimating the amount of soluble extract obtained from the malt. The maltose and other soluble carbohydrates, yielded on mashing, increase the specific gravity of the wort. Taking the density of water as 1000, each gram of carbohydrate in 100 c.c., or, what amounts to the same thing, each lb. of carbohydrate in 10 gallons of the wort increases the density of the solution 3·85. Thus, suppose that a wort is found at 15·5° C. (60° F.) to have a specific gravity of 1011·5, then

$$\frac{1011{\cdot}5 - 1000}{3{\cdot}85} = 3 = \text{weight in lbs. of}$$

sugar and other solid matter in 10 gallons of the clear wort. As the density of a liquid varies with its temperature, all densities are best taken at the uniform temperature of 15·5° C.

The Inland Revenue Act of 1880 assumes that 2 bushels of average malt, weighing 84 lbs., will produce a barrel (36 gallons) of wort having a density of 1057. Accepting this estimate as correct, and assuming that the 40 gallons of water employed in the previously given recipe, together with the small extra quantity used in sparging or washing the grains, yield after loss through evaporation 40 gallons of wort; then the wort produced ought to have a density of 1038·3, which is equal to almost exactly 10 lbs. of solid extract per 10 gallons of wort. Working with comparatively imperfect methods, and in small quantities, the baker cannot expect his malt to yield the full extract, but as a matter of practice he ought at any rate to get nothing less than a density of 1030. One of the most important sources of loss arises from imperfect sparging of the grains; these should be washed once, and may then with economy be put into a small press and squeezed dry. Of course, if with extra washing water the volume of the wort is increased, then the density will naturally fall. Testing the density of his wort is not only of importance to the baker, as a measure of the degree of efficiency with which he is extracting the valuable matters of his malt, but is also a test, of the highest value, of the regularity of his work. If one day a wort of comparatively high density is being attained, and on another one of low density, something is wrong, and must be righted. The baker should always endeavour to have his worts at the same density when ready for pitching: 1030 may be taken as a very good standard to work at. If it is found in practice that the densities fall below this, mash with comparatively less water; if the densities run too high, dilute the wort with water until of the right density before pitching. The necessary quantity of water to add may be easily calculated, on remembering that the volume of the wort is in inverse proportion to the density, less 1000. Thus, supposing that the 40 gallons of wort are found to have a density of 1035, then

as 30 : 35 :: 40 : 46 gallons.

The wort will have to be made up to 46 gallons, therefore 6 gallons of water must be added. The quantity of wort produced should always be measured; to do this, determine once for all the capacity of the fermenting tubs in the following manner:—Prepare a staff about an inch square; pour water into the tub, gallon by gallon, and at each addition put in the staff and mark on it the height of the water. This operation once completed, the quantity of wort made can at any time be determined simply by plunging the staff into the tub and reading off the number of gallons as marked on it.

For practical purposes, the density of a wort is best determined by a hydrometer, this instrument is made either of brass or glass. It has a weighted bulb at the bottom, and a long graduated stem; accompanying the hydrometer is a tall glass jar, known as a hydrometer jar. Fill this jar with wort at the right temperature, and place in the hydrometer; as soon as it comes to rest, read off the graduation which coincides with the level of the liquid; the number gives the density. For the baker, the most convenient hydrometer is one graduated in single degrees, from 1000 to 1040. The hydrometer is also sometimes known as a saccharometer.

As fermentation proceeds, the density of the liquid becomes less, and at the same time it loses its sirupy consistency—hence the brewer states it to have become "attenuated."

366. Microscopic Sketches of Patent Yeast.—In Plate II. are given microscopic sketches made of patent yeasts collected in the South of England.

The sketches marked respectively *a* and *b* were drawn from samples of patent yeast, both obtained in the same town, but from different bakers, during the summer. The sample marked *a* was evidently prepared in a strong wort; in fact, at the time of examination the yeast was still sweet through presence of maltose in considerable quantity, and had a high density. The yeast was not free from disease ferments, but still compared remarkably favourably in this respect with all other samples examined. One specially noticeable point about the sample was the elongated shape of the cells; some were not merely ovoid, but even decidedly pear-shaped. One sketched shows this peculiarity in a very marked manner. This yeast was at the time yielding very good results; the bread was sweet and of good flavour. One is in doubt with regard to sample *b*, whether it should be viewed as an example of alcoholic or bacterial fermentation; certainly the latter ferments are about as plentiful as yeast cells. The yeast contained very little either of maltose or hops; in fact, it had evidently been brewed with as little as possible of these ingredients employed. Readers will probably not be surprised that yeast *a* produced a far superior loaf of bread than did yeast *b*. The sample *c* is likewise of considerable interest; it was also taken during the summer. The baker was in the habit of, at the close of his yeast brewing, setting aside a portion for the purpose of pitching his next lot of wort. This pitching yeast was stored in a corked bottle. This also was a yeast brewed in a poor wort, although not so bad as sample *b*. Notice particularly, in *c*, the chain of elongated cells; these are often noticed in yeast grown without sufficient aliment, and the sketch shows a striking example.

SCOTCH FLOUR BARMS.

367. Flour Barms, Thoms' Formulæ.—The following descriptions of Scotch Flour Barms are from the pen of Mr. Thoms of Alyth, a well-known authority on Bread-making:—

"There are many kinds of flour barms used in Scotland, in fact all are flour barms; but for the present I will treat of two of the latest and best. These are 'Parisian Barm' and 'Virgin Barm.' Virgin differs from Parisian only in being spontaneously or self-fermented. Parisian barm was introduced from Paris to Scotland, by a baker near Edinburgh, about thirty years ago. It is essentially a leavening ferment; a scientific modification of the systems of ancient Egypt and present France. After its introduction to Scotland its use spread rapidly, and it alone is used in all the machine bread factories there, and in a number of the best establishments in the north of Ireland. The Parisian is easier to make, but easier to spoil. All that is required is skill to select the materials, and knowledge, founded on experience, to guide the process of fermentation, which results in inert flour and water, infusions of malt and hops, being converted into the vital, self-propagating and carbonic acid producing substance we call barm, which makes fermented bread light and vesiculated.

368. "Virgin Barm: Things Required.—A 30 or 32 gallon tub; a small tub or vessel for malt-mashing; 10 lbs. malt; 3 oz. hops, and a jar in which to infuse them; about 40 lbs. flour, of which one-third should be American Spring straight and two-thirds Talavera wheat flour, or sound red Winter; 2 or 3 oz. salt; 8 or 12 oz. sugar; a handful of flour; and about 18 gallons of boiling water. (The gallon here means the Imperial, holding 10 lbs. water at a temperature of 60° F.)

369. "How to Use or Manipulate them.—Mash the malt for 1½ hours in 3 gallons of water after it has been cooled to 160° F.; infuse the hops the same time in 1 gallon of water poured over the hops at a boiling temperature; then strain the malt and hop infusions into the barm tub: now sparge or wash the draining malt grains with another gallon of water at a temperature of 190° or 200° F. Note, the malt grains are not pressed in any way, only allowed to drain. When the water has about stopped running from the grains, the liquor in the tub should show a temperature of 140° or 146° F., then well and thoroughly mix in the flour with the hands. The next stage is scalding this mixture or thin batter with 7 gallons of boiling water, and stirring sharply with a stick. Begin by pouring in 2 gallons, and stirring it well up and from the bottom and all round, then add another 3 gallons and give more and sharp stirring, and finish with another 2 gallons and more stick work. The scalded batter is then a thick jellyish paste. The water used in malt and hop infusions and sparging is 5 gallons, in scalding 7 gallons, making in all 12 gallons. I mentioned 18 gallons because it is desirable to have more boiling water than required.

370. "Fermentation.—The barm tub and contents are left in the brew-house uncovered for 21 hours or so. During that time the mixture undergoes several changes. The scalding water bursts a proportion of the starch granules of the flour, converting them into starch paste: the diastase of the malt inverts or hydrates this paste into a sugar, maltose, and a brown, gummy body, dextrin. The mixture, after scalding, tastes very sweet; in half an hour after it is sweeter, and thinner, and browner. These changes continue for several hours, then a distinct acid taste is felt. At the end of 21 hours the mixture is strained from one tub into another, so as to ærate it. When it has cooled down to 84° F., mix in the salt, sugar, and a handful of flour, and keep the tub lightly covered, or uncovered, in a place where the now slightly fermenting mixture will not fall below a temperature of 80° F., or rise over 84° F. Supposing this is done 24 hours after brewing, then during the next 24 hours stir up the mixture three times—the number of times depends on the fermentation being free or sluggish—and note the heat, and at the end of the 24 hours again strain gently from one tub to another. In another 12 hours stir up again; it will then be in vigorous fermentation, and will rise and then fall. When nearly full down, or when a lighted match will burn within three or four inches of the surface, remove the tub to a cool place. This will be on the third day after brewing. This barm could be used in a sponge the same day, but it is far better on the fourth and fifth day after brewing.

371. "Parisian Barm.—The materials, and quantities and manipulation, are the same as for Virgin. Only in about 24 or 27 hours after brewing, and when the mixture has cooled down to 84°, 86° F. in winter, and 76°, 78° F. in summer, instead of putting in salt, sugar, and flour, and letting it self-ferment, it is stored or set away, with, in winter, about 1½ gallons old barm, or Virgin; in summer, about 1 gallon; and the tub is best kept uncovered during and after fermentation, where the temperature is between 60° F. and 70° F. In this case active fermentation is about over in 16 to 24 hours, when it is better to remove the tub to a cooler place. With this barm, as with Virgin, and every other yeast, it is not advisable to use it in sponge immediately or shortly after it has dropped. They should be left undisturbed in a cool place at a temperature between 40° F. and 60° F. Barm at this stage should be kept in shallow tubs, or coolers, where a large surface is exposed to free oxygen."

372. Microscopic Character.—Viewed under the microscope, Scotch flour barms always show a certain proportion of lactic ferments as a normal constituent. Thoms argues that their presence is beneficial, and states, in favour of that view, that when he has taken steps for brewing barm in which lactic ferments are absent, that the bread is of inferior quality. The probable function of lactic ferments during panification will be dealt with in a future chapter. Scotch bread has always a *slight* acid flavour, totally distinct from what is understood in England as "sourness" of bread, but more resembling in type the flavour of buttermilk. Germans immediately notice this characteristic of Scotch bread. It should be explained that this peculiarity is not quoted as a fault: in fact, those accustomed to bread of this flavour find something lacking if the acidity be absent.

373. Strength of Various Yeasts.—There follow particulars of the strength of various samples of yeast, when treated in the yeast apparatus. The first series have been made with yeast mixture, and water at 30° C.: in those of the second, sugar and water at 25° C. were adopted. A quarter ounce of compressed brewers' yeasts was taken for each test, and six ounces of the patent yeasts, water then being dispensed with. The evolved gas is measured in cubic inches. The same brand is throughout represented by the same letter; thus giving an opportunity of comparing one and the same yeast over a considerable time.

374. First Series.

		Cubic inches of gas evolved in 6 hours.
No. 1.	Compressed Yeast, A, 27th April, 1885,	170·2
No. 2.	Brewers' Yeast, A, from London yeast merchant, 1st May, 1885. *Gas read at the end of five hours,*	65·9
No. 3.	Compressed Yeast, B, 5th May, 1885,	177·8
No. 4.	Dublin Patent Barm, 6th May, 1885,	83·6
No. 5.	Ditto, another sample, 6th May, 1885,	43·2
No. 6.	Brewers' Yeast, A, 7th May, 1885,	98·5
No. 7.	Compressed Yeast, A, 7th May, 1885,	175·0
No 8.	Brewers' Yeast, A, 14th May, 1885,	92·0
No. 9.	Dublin Patent Barm, another sample, 14th May, 1885,	178·0
No. 10.	Dublin Patent Barm, 4th sample, 14th May, 1885,	44·5
No. 11.	Dutch Pressed Yeast, from Dublin, 21st May, 1885,	171·8
No. 12.	French ,, ,, ,,	178·6
No. 13.	Brewers' Yeast, A, 29th May, 1885,	80·3
No. 14.	Patent Barm, from near Dublin, 29th May, 1885,	58·3
No. 15.	Brewers' Yeast, A, 11th June, 1885,	85·5
No. 16.	Brewers' Yeast, A, 25th June, 1885,	74·8
No. 17.	Compressed Yeast, A, 25th June, 1885,	167·5

It will be observed that the pressed yeasts keep pretty uniform with regard to gas evolved. The samples of the same merchant's brewers' yeast vary rather more, while the patent barms exhibit wide ranges of difference.

It must not be forgotten in comparing these results that a quarter-ounce of the brewers' and pressed yeasts are employed for each test, while 6 ounces of the patent yeasts are taken. Thus, 6 ounces of No. 10 produce 44·5 cubic inches of gas, while $\frac{1}{4}$ ounce of No. 11 produces 171·8 cubic inches. With fermentation proceeding under exactly the same conditions, about ninety times as much by weight of No. 10 would be required as of No. 11 to produce the same amount of gas.

375. Second Series.

		Cubic inches of gas evolved in 6 hours.
No. 1.	Compressed Yeast, A, 2nd July, 1885, ,	72·0
No. 2.	Compressed Yeast, B, ,,	98·0
No. 3.	Compressed Yeast, B, 8th July, 1885,	93·5
No. 4.	Compressed Yeast, A, 14th July, 1885,	62·5
No. 5.	Compressed Yeast, B, 15th July, 1885,	93·2
No. 6.	Compressed Yeast, A, ,,	81·7
No. 7.	Patent Yeast, Brighton, 15th July, 1885,	19·6
No. 8.	Compressed Yeast, B, 24th July, 1885,	95·5
No. 9.	Compressed Yeast, A, ,,	82·5
No. 10.	Brewers' Yeast, B, ,,	79·5
No. 11.	Brewers' Yeast, C, ,,	69·3
No. 12.	Scotch Flour Barm, ,,	45·4
No. 13.	Patent Yeast Brighton, 24th July, 1885,	27·3
No. 14.	Compressed Yeast, B, 29th September, 1885,	78·2
No. 15.	Compressed Yeast, C, ,,	75·5
No. 16.	Compressed Yeast, A, ,,	60·0

No. 17.	Compressed Yeast, B, 7th October, 1885,	72·8
No. 18.	Compressed Yeast, A, ,,	48·4
No. 19	Compressed Yeast, D, 7th October, 1885,	52·8
No. 20.	Compressed Yeast, B, 8th October, 1885,	65·0
No. 21.	Compressed Yeast, B, soaked in water at 25° C. one hour before testing, 8th October, 1885,	72·0
No. 22.	Compressed Yeast, B, 12th October, 1885,	81·0
No. 23.	Compressed Yeast, B, 14th October, 1885,	79·3
No. 24.	Compressed Yeast, A, ,,	49·0
No. 25.	Compressed Yeast, E, ,,	42·0
No. 26.	Compressed Yeast, F, ,,	34·0
No. 27.	Compressed Yeast, A, 19th October, 1885. *Gas read at the end of three hours,*	21·2
No. 28.	Compressed Yeast, B, 19th October, 1885. *Gas read at the end of three hours,*	35·3
No. 29.	Compressed Yeast A, 20th October, 1885,	39·0
No. 30.	Compressed Yeast, B, ,,	78·7

This series of tests affords an opportunity of comparing the one yeast over a considerable period of time. On being subjected to such a test, some yeasts are found to behave very regularly, whilst others fluctuate considerably. All yeasts hitherto examined evolve more gas in summer than in winter. This does not depend on the fermentation being conducted at a higher temperature, because, in the yeast testing apparatus, the fermentation is maintained throughout at a constant temperature. In order to show the effect of warming yeast before its use, Nos. 20 and 21 were tested on the same day; the only difference was that the latter sample was allowed to stand, mixed with water at a temperature of 25° C., for an hour before being tested. The results show that about ten per cent. more gas is evolved by the warmed yeast.

The conditions under which the Scotch Flour Barm was examined were scarcely fair to it, as it was three or four days old when it arrived here, and had travelled at the very hottest part of the summer.

CHAPTER XIII.

PHYSICAL STRUCTURE AND PHYSIOLOGY OF THE WHEAT GRAIN.

376. Functions of the Wheat Grain.—The wheat grain is that part of the plant on which falls the task of performing the functions of reproduction, hence all its parts are specially adapted to that purpose. The germ, or embryo, of wheat is that portion of the seed which ultimately develops into the future plant. The main body of the grain, composed principally of starchy matter, is termed the "endosperm:" its function is to supply the germ with food during the first stages of its growth. Besides these there are the various outer and other coverings, destined for the adequate protection of the seed, which together constitute the bran. The physical structure of the wheat grain requires for its systematic study the use of the microscope: the descriptions following therefore include practical directions for microscopic observation. The arrangement adopted is that most easily followed by the student in a course of actual microscopic work. For earlier studies it is well to obtain from the dealer ready-mounted longitudinal and vertical sections of a grain of wheat. In every case, practise sketching what is seen: as before stated, the accompanying figures are facsimiles of those which the student should himself make.

377. Longitudinal Section of Whole Grain.—In the first place, examine the longitudinal section of the grain of wheat with the 3-in. objective; the whole of the grain will then be in the field. Try, in the next place, to make a sketch of it. For this purpose the student should use a camera lucida if he should possess one. Trace in the outline and other principal lines with a hard pencil; then go over them with a lithographic pen and liquid Indian ink. It will be impossible to get in all the details; the effort should be rather to show what is essential; thus the object of the sketch with the low objective is to get an idea of the general shape and arrangement of the different constituent parts of the grain. When the drawing is complete, mark underneath the number of diameters to which it has been magnified.

In Plate VI. is given a section through the crease of the grain, which is shown in elevation by shading on the left-hand side of the figure. The whole of the figure has been obtained by careful tracing in the author's laboratory from typical slides, and is throughout a faithful representation of the grain. The germ is seen at the lower end of the figure, and a fair idea of its size, compared with that of the endosperm, which constitutes the remainder of the grain, may be obtained. Enclosing both germ and endosperm is the bran. With the low power, which the student has been directed to use, the square cells of the bran lining the interior, and known as aleurone cells, are just visible. The name commonly given to these is, by the bye, a misnomer; they are not "gluten" cells, for the reason that they contain no gluten. The more minute examination of the grain is best made by the aid of the higher powers, and shows more of the details drawn in Plate VI., to which reference is made in the paragraphs which follow.

The various parts of the grain are fully indicated on the plate itself.

378. Transverse Section of Wheat Grain.—Examine next a transverse section of a grain of wheat; the section, below figured, Figure 28, was cut from a grain of Kubanka wheat, and passes through the germ.

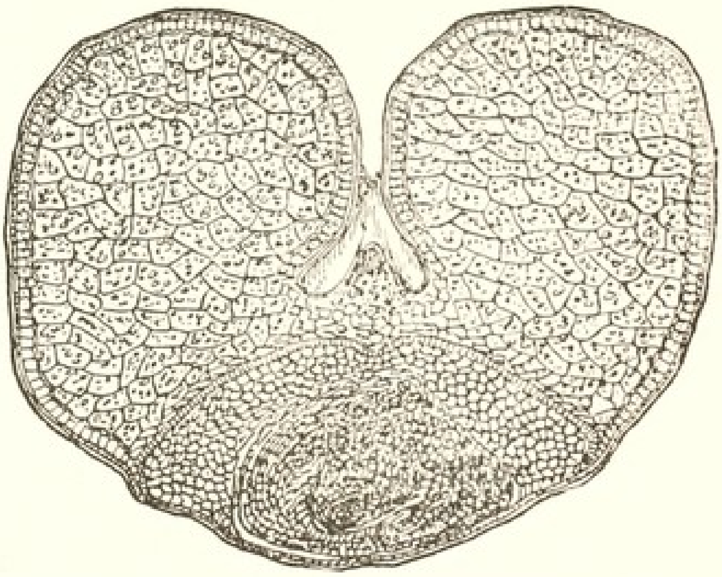


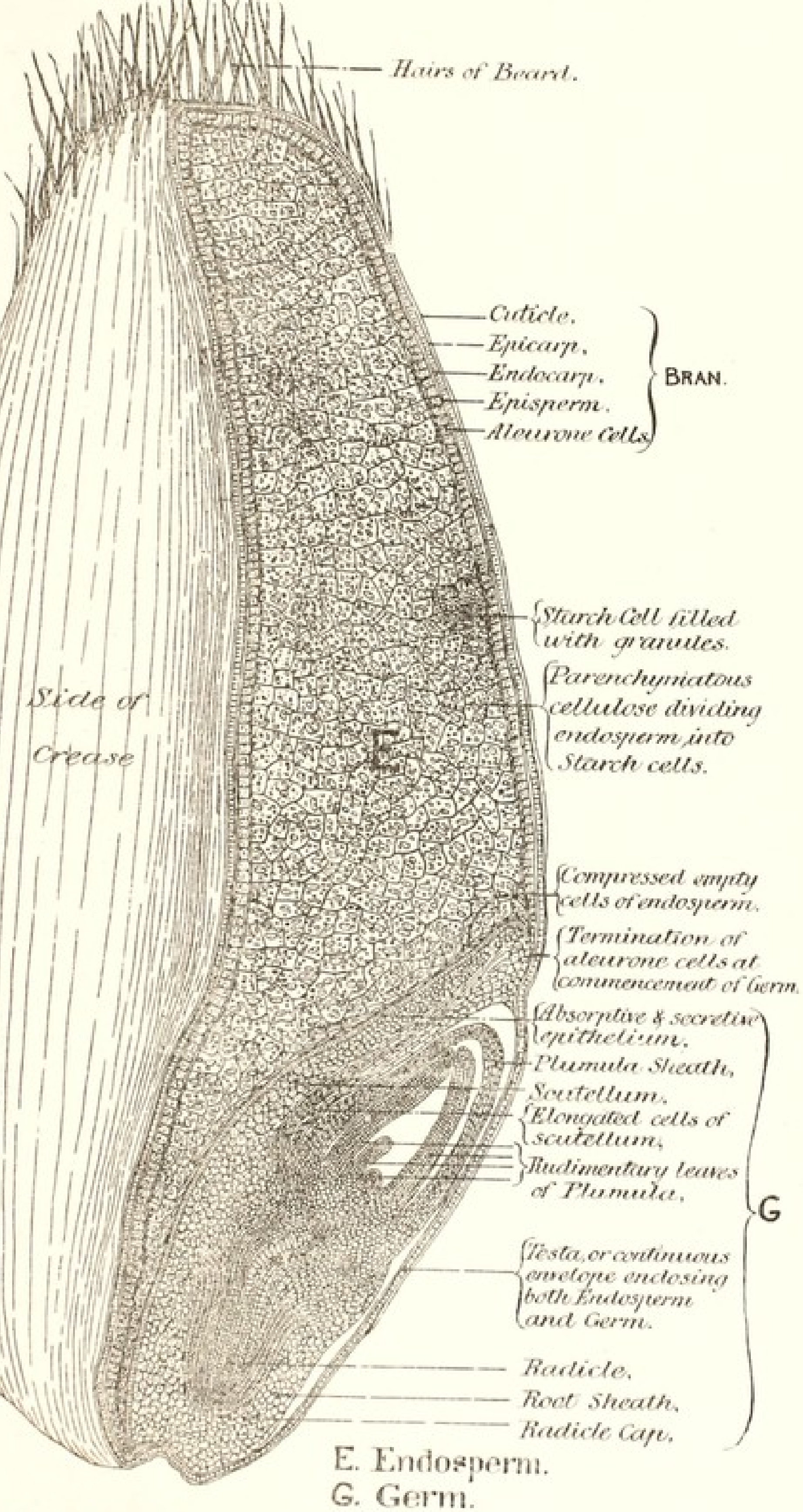
FIG. 28.—TRANSVERSE SECTION OF GRAIN OF WHEAT, magnified 13 diameters.

On examining carefully such a section as that shown, the pigment-containing cells are seen in a line passing completely round the grain, and forming a thick spot of colour in the crease. Notice that the aleurone cells of the bran do not continue round the germ. Observe also as much as possible of the structure of the germ itself, and the relative dimensions and positions of germ and endosperm.

Examine the same section in the next place with the 1-inch objective (Fig. 29). The outer skins of the bran are here seen more plainly; the square aleurone or cerealin cells are also plainly visible. Notice that near the bottom of the crease, the cells, instead of being in single line, are in double, becoming more numerous and irregularly arranged as the bottom is approached. The crease distinctly bifurcates at the bottom; the pigment layer of the grain becomes considerably enlarged, and its section is seen at the middle of the fork as a dark yellow spot of considerable size. With this power the starch granules also become visible.

379. Section Cutting and Mounting.—It has been assumed that, for the purposes of making these studies and sketches, the student has had in his possession sections that he has purchased ready mounted. He will probably at this stage of his work wish to prepare and mount

PLATE VI.



LONGITUDINAL SECTION THROUGH A GRAIN OF WHEAT.

Magnified about 20 diameters.

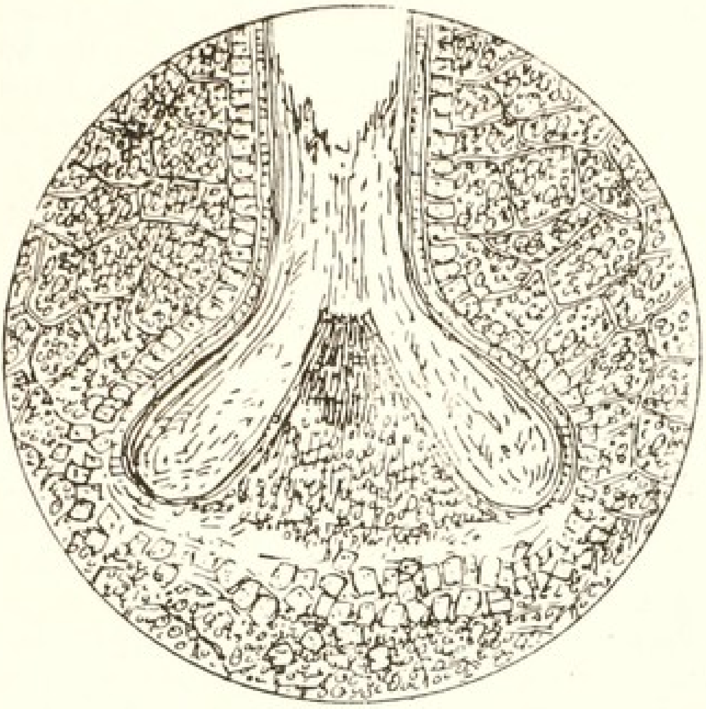


FIG 29.—VIEW OF CREASE IN GRAIN OR WHEAT, as shown in a transverse section, magnified 110 diameters.

sections of his own. Wheat in its ordinary state is too brittle to permit of its being cut in thin sections. In the first place, therefore, soak a few grains in water for about twenty-four hours; the water may be luke-warm, say at a temperature of 80° to 90° F. When the grains have become moderately soft, sections may be cut from one of them. For this purpose a very sharp razor, which has been ground flat on one side, is generally used. Take one of the grains between the thumb and finger, cut off one end, and then proceed to slice off sections as thin as possible. Some little practice will be necessary before they can be successfully cut of the requisite thinness.

This operation is rendered easier by the use of a section cutting table. This little piece of apparatus consists of a plate of brass, the surface of which has been turned perfectly plane; in the centre is fixed a tube containing a piston, which may be raised by means of a screw. The object whose section it is wished to procure is first cast into a block of either cocoa butter or solid paraffin. In either case the temperature of these must only just be raised to the melting point. This block of solid paraffin or other substance is next trimmed down so as to go into the tube of the section cutting table. Adjust the screw at the bottom so that the grain is in about the right position, then draw the razor across the top of the tube and cut off the upper part of the grain; screw up the piston at the bottom of the tube very slightly, and cut off a section by again drawing the razor across the plane surface of the table. In this manner thin sections may be cut with comparative ease. Having thus obtained the sections, wash them in a little spirits of wine and transfer to a slide. If it is only wished to examine them without there being preserved, they may be mounted in a mixture of water and glycerin in equal volumes, protected with a cover slip, and at once placed under the microscope. When, however, it is wished to make a permanent mount, they may be embedded in glycerin jelly (Deane's medium). Having washed and prepared a section, and also the slip and cover, place a very little of the glycerin jelly on the slide, warm very gently, and the jelly becomes liquid. Place the section carefully in the liquid medium, taking care that it is thoroughly immersed. Remove all air bubbles, place on the cover as carefully as possible, gently squeeze out any superfluous medium, and allow to cool. The jelly will then again become solid. Clean the edge of the cover glass, and coat round with asphalt varnish.

380. The Germ.—The appearance and general characteristics of the germ itself should now be carefully studied; for this purpose use the one-inch adjective.

In Plate VI. the germ is shown very distinctly, and the whole of its parts named and indicated by reference marks. This should be carefully studied. Notice that the aleurone cells of the bran terminate at the junction of the endosperm and germ, and only the "testa" or envelope of the true seed encloses the embryo. The "plumule" is that part of the young plant which penetrates to the surface during growth, and then constitutes the growing stem and leaves of the plant. It consists of four rudimentary leaves enclosed within the plumule sheath. The radicle, or rootlet, on commencing its growth, forces its way downward into the earth.

The nature of the other portions of the germ had best be described when dealing with their functions in connection with the act of germination (paragraph 386).

381. Endosperm and Bran.—Attention must next be directed to the structure of the endosperm and the branny coatings by which it is enveloped. For this purpose a very thin section should be selected and then examined under the $\frac{1}{8}$-inch objective.

The bran of wheat is divided into the outer envelopes of the grain and those of the seed proper. Following these in the order of the letters given in figure 30:—

a—is the outer "epidermis," or "cuticle." According to Mège Mouriès this constitutes 0·5 per cent. by weight of the whole grain.

b—is the "epicarp," and amounts to about 1·0 per cent. of the grain.

c—is the last of the outer series of the envelopes of the grain, and is known as the "endocarp." It is remarkable for the well-defined round cells of which it is composed. The endocarp amounts to 1·5 per cent. of the grain.

d—is the first of the envelopes of the seed proper; it is that to which reference has already been made as the "testa;" it has also received the name of "episperm." The colouring matter of the bran occurs principally in the episperm.

e—is a thin membrane lying underneath the testa, and enveloping the aleurone cells. This membrane and the testa together form two per cent. of the grain.

f—is the layer of "aleurone" cells, so called from the proteid of that name which they contain. As may be seen from the figure, the cells are almost square in outline; one is at times replaced by two lesser

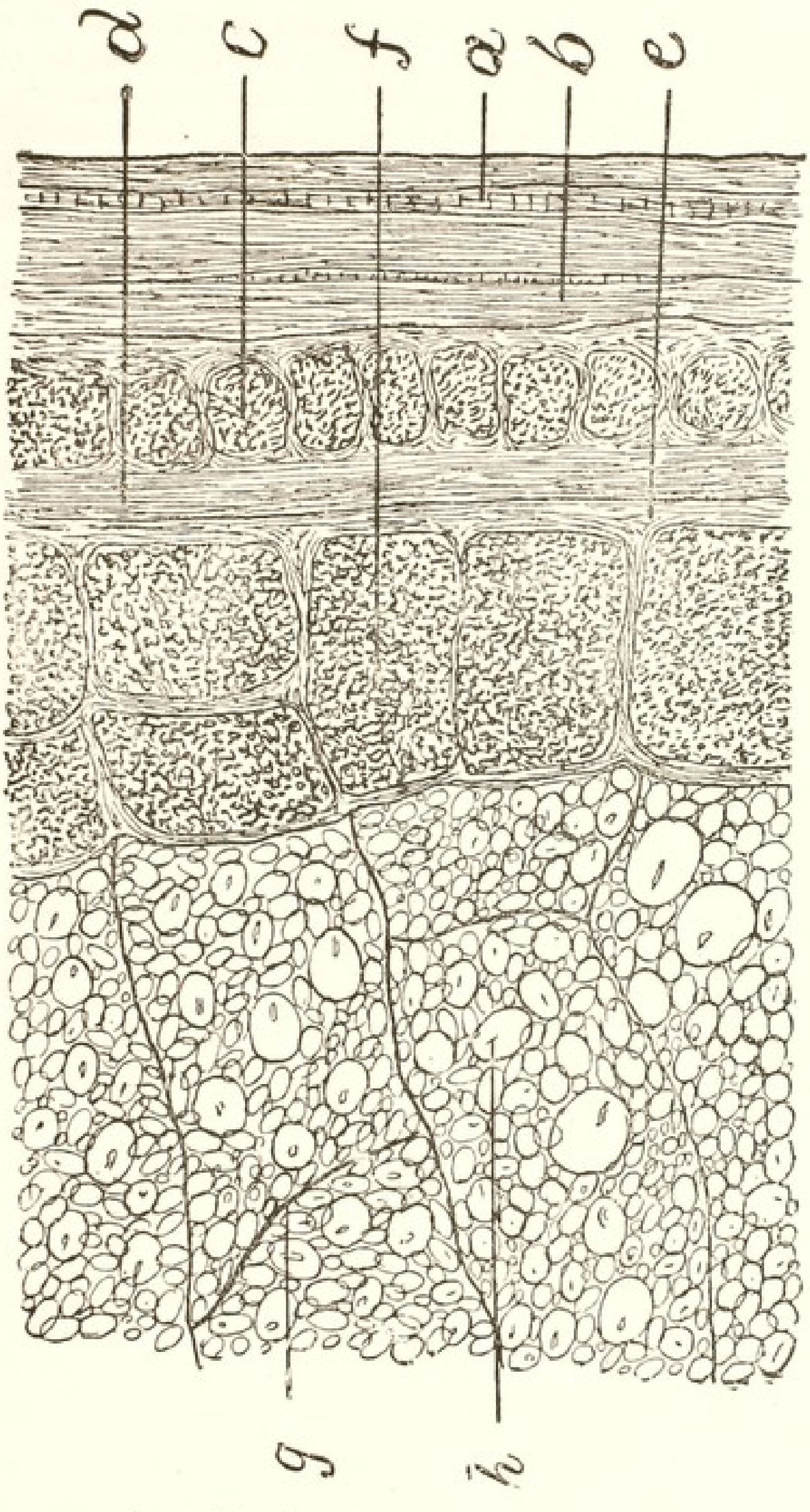


FIG. 30.—LONGITUDINAL SECTION THROUGH BRAN AND PORTION OF ENDOSPERM OF GRAIN OF WHEAT, magnified 440 diameters.

ones, as occurs immediately above the cell *f*. Notice particularly that this layer does not envelop the germ, but only encloses the endosperm.

g—represents the layer of parenchymatous cellulose by which the interior of the endosperm is divided up into a number of cells of comparatively large size, these in turn being filled with starch granules, and embedded in gluten.

h—shows the "hilum" of an individual starch granule.

In order to complete the investigations of the appearance, when viewed under the microscope, of the various coatings of the wheat grain, it is not only necessary to examine these skins in section, but also, so far as possible, as seen on the flat. The bran of wheat can be split up with comparative ease into three layers, which can be successively peeled off from the endosperm. The first of these consists of the epidermis, or cuticle, and also epicarp. Following these are the endocarp and episperm, which usually peel off together. The inner and last skin consists of that containing the cerealin cells.

Take a few grains of soft red wheat and soak them for a few hours in warm water; when they are sufficiently softened, take one, and with a fine pair of forceps strip off the outer skin and place it in a watch glass. When the whole of the outer skin has thus been removed, carefully strip off the middle layer in the same manner, and also reserve it for examination. The division of the inner layer from the endosperm is often only accomplished with difficulty; in case they do not separate well, let the grain soak some time longer.

Next proceed to examine these several coatings. Mount each on a slide in a drop of water (or preferably, when wished to examine the mount for some time, in a drop of glycerin), so that it is practically freed from bubbles, and lying flat and without creases. Put on a glass cover and press gently down. Examine with either a quarter or eighth-of-an-inch objective.

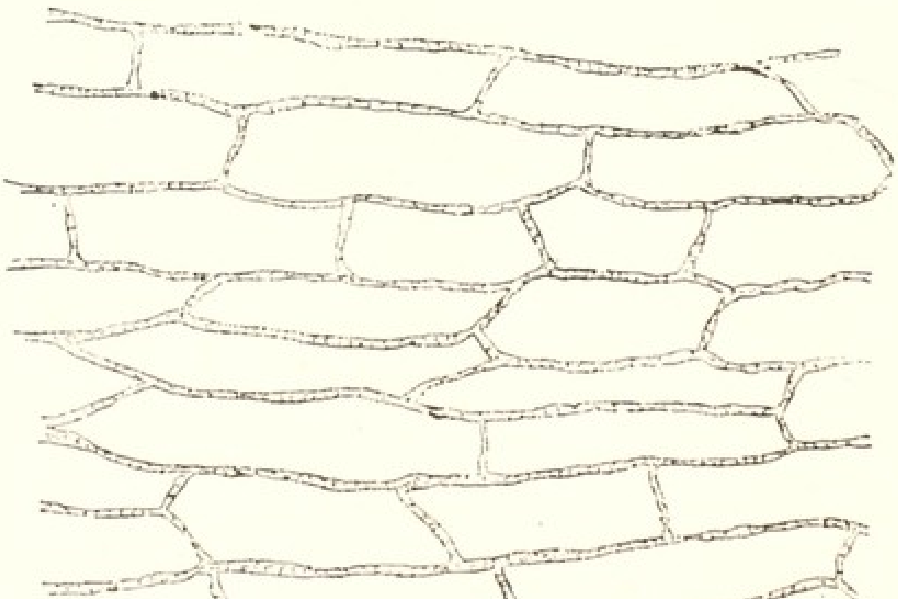


FIG. 31.—OUTER LAYER OF THE BRAN OF WHEAT, magnified 250 diameters.

Observe in the outer layer that it consists of a series of cells, some four to six times long as broad, and arranged longitudinally in the direction of the length of the grain. A portion of the outer layer is shown in figure 31. Notice at the one end (of the actual section, not the figure) the beard of the grain, and note particularly the attachment of each hair to the skin (the root). Observe also the canal extending about half the length of the hair. Figure 32 is a drawing of such hairs.

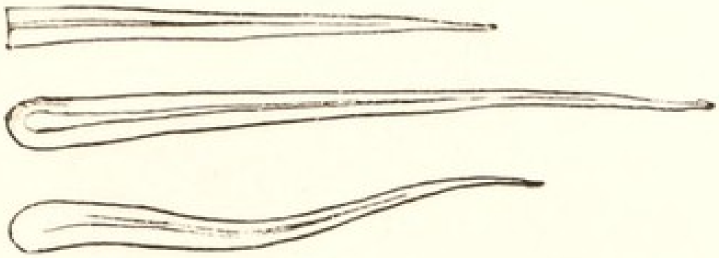


FIG. 32.—BEARD OF GRAIN OF WHEAT.

Next observe the appearance of the second layer of skin that has been detached; this is shown in figure 33.

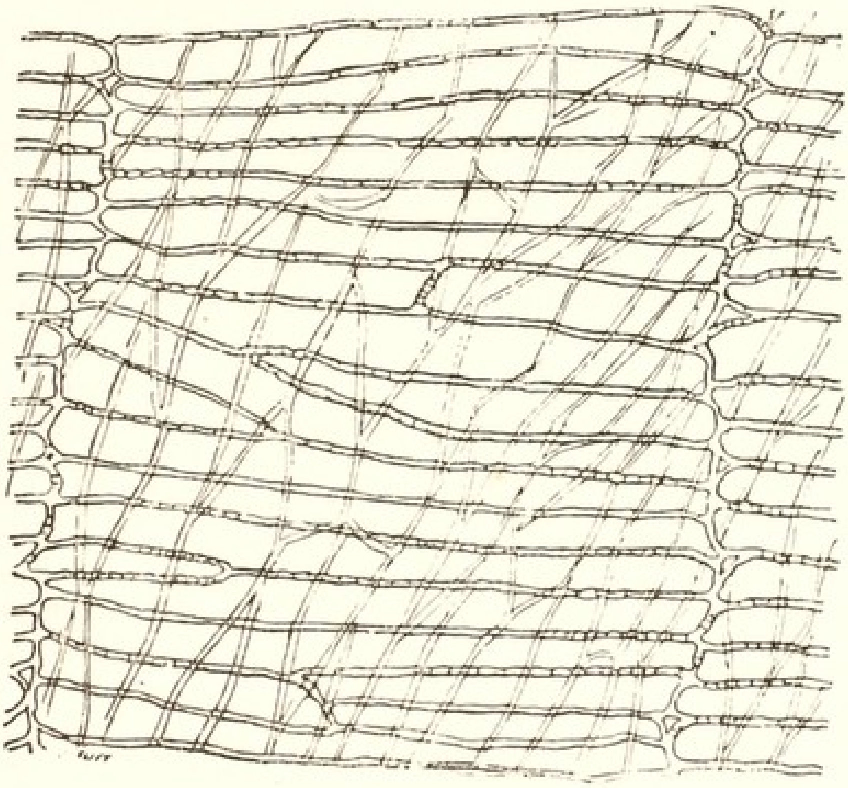


FIG. 33.—MIDDLE LAYER OF THE BRAN OF WHEAT, magnified 250 diameters.

In this will be seen two layers of cells that are not both in focus at the same time, the one layer being, in fact, underneath the other. There are in the first place a series of long cells arranged transversely to the longitudinal section of bran shown in figure 30, where they are marked *c*. Because they are thus arranged around the grain of wheat they are frequently termed "girdle" cells. The great difference between looking at the same thing in one direction and then in another is strongly exemplified in this study of these particular cells in plan and in section. An instructive lesson may be gained by comparing the section illustrated in figure 30 with a similar section cut transversely instead of longitudinally. Such a section is given latter in the series. The colour-containing cells underlie those to which reference has just been made.

In the next place examine the inner, or aleurone cell, layer of the bran.

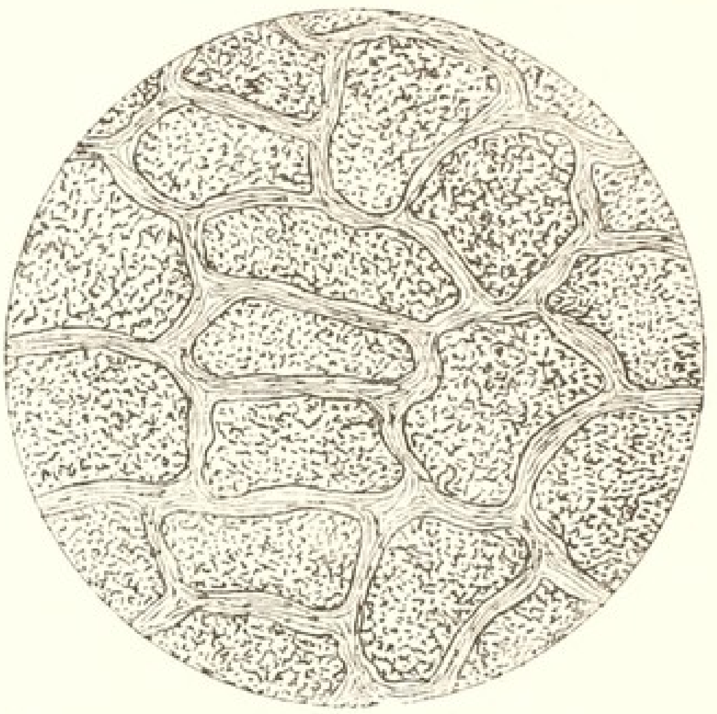


FIG. 34.—INNER OR ALEURONE LAYER OF THE BRAN OF WHEAT, magnified 440 diameters.

The aleurone or cerealin cells of the bran are often referred to as being cubical; that this, however, is not the fact is well shown in figure 34. They certainly have a square or rectangular outline when seen in section, whether longitudinal or transverse, but the skin, viewed on the flat surface, shows that the cells are irregular in outline, each accommodating its contour to that of those surrounding.

There follows a sketch of the transverse section through the bran of wheat; this should be carefully compared with the longitudinal section, figure 30.

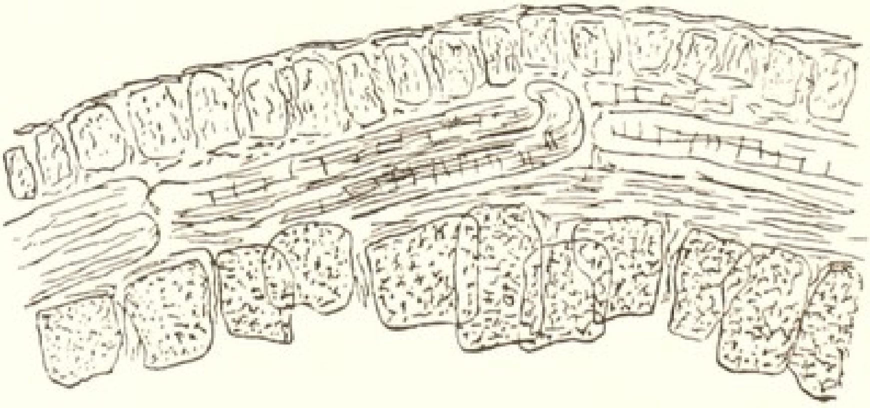


FIG. 35.—TRANSVERSE SECTION THROUGH BRAN OF WHEAT, magnified 250 diameters.

The actual section from which this drawing has been made is not so good a one as the longitudinal section, from which figure 42 was drawn. Viewed with a moderately high power it is difficult to get very much of the thickness of the section in focus at the same time; still sufficient is noticed, on careful observation, to show the general structure of the bran. The outline of the aleurone cells is more irregular than was the case in the longitudinal section; they are also noticed to be, in several instances, overlapping each other. Looking at the cells of the middle skin of the bran they are seen to be of considerable length, justifying the remarks made about them when studying their appearance as seen on the flat. While, however, these middle cells are seen lengthwise, it follows of necessity that the ends of the cells of the outer skin must be presented to the eye. This sketch, taken with the others, gives a tolerably complete idea of the microscopical structure of a grain of wheat.

A careful study of these sections of the wheat grain and of the various layers into which the bran can be divided should give the miller in particular a clearer and more real idea than he can otherwise have of the nature of these outer integuments of the wheat grain, which it should be his object to remove. The study should not merely be confined to the drawings given in this work, but should extend to the actual slides themselves under the microscope.

382. Bran Cellulose.—The bran of wheat consists largely, as is well-known, of cellulose or woody fibre, together with a considerable proportion of soluble albuminous matter. Cellulose may be obtained in a fairly pure state by alternate treatment with hot dilute solutions of acid and alkali. The actual structure of the cellulose of the different layers of the bran possesses considerable interest, and may be studied in the following manner:—Strip off the different layers of skin as before directed, put pieces of each in a separate test-tube, and first digest for an hour with dilute sulphuric acid; pour off the acid, and digest with caustic soda solution for another hour. Make up solutions of 1 part respectively of acid and alkali, and 20 parts of water. Wash the resulting cellulose, and mount carefully on a glass slide: examine under the microscope.

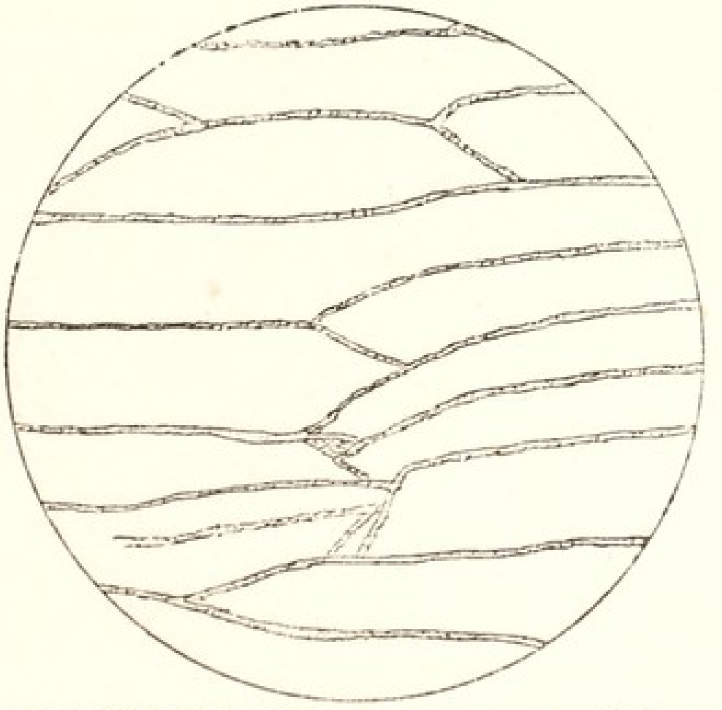


FIG. 36.—CELLULOSE OF OUTER SKIN OF BRAN, magnified 250 diameters.

This is rendered almost transparent, and presents no striking differences in structure from the original skin.

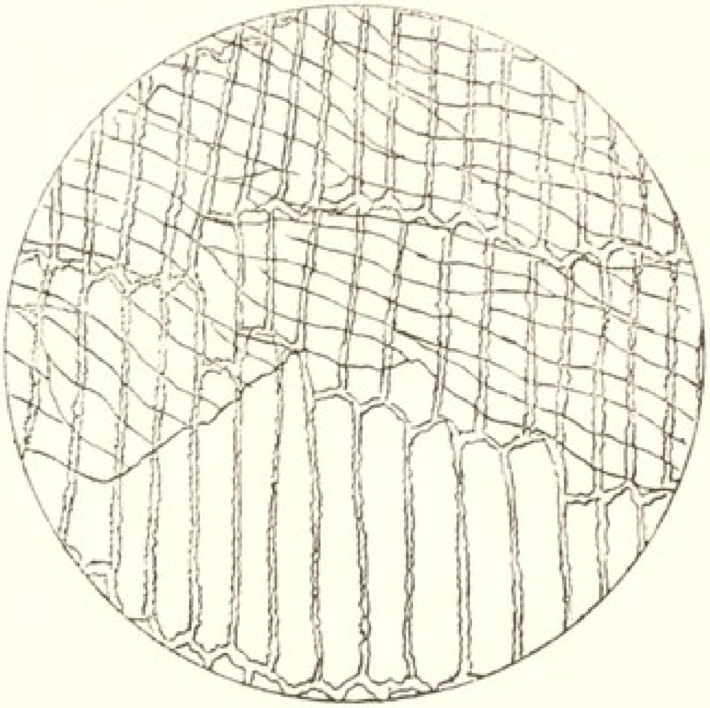


FIG. 37.—CELLULOSE OF MIDDLE SKIN OF BRAN, magnified 250 diameters.

In this again the resemblance to the skin before treatment is very noticeable. One special point of interest occurs in this drawing; the two layers of cells to which reference was made when previously speaking of the appearance of this layer have become separated. The upper cells extend over the whole field, while the lower or pigment layer is stripped from the one portion. The result is that the distinction between the two is seen very clearly.

As the aleurone layer or inner skin of the bran contains so large a

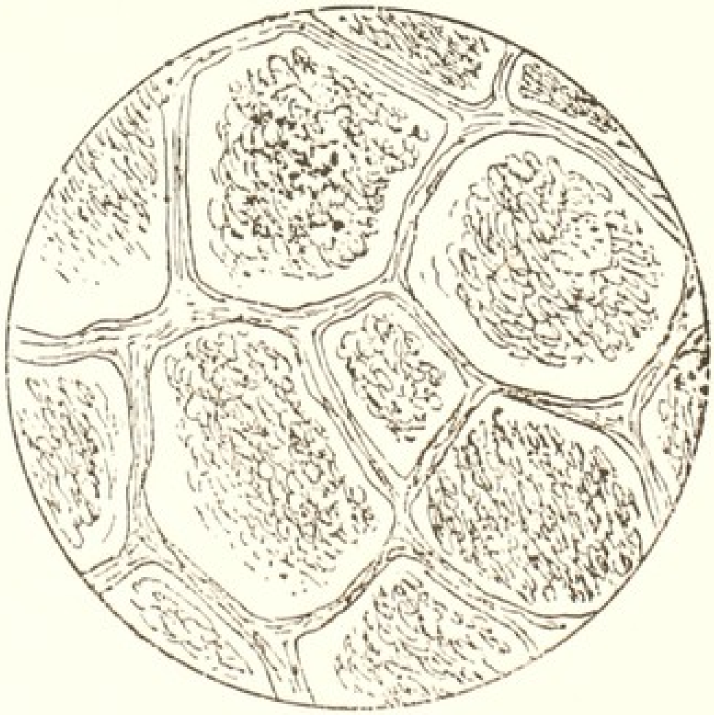


FIG. 38.—CELLULOSE OF ALEURONE LAYER OF BRAN, with portion of proteid remaining, magnified 440 diameters.

quantity of proteid matter, it will readily be imagined that treatment with alkali will cause considerable difference in its appearance.

In figure 38 such a specimen is shown; it will be noticed that a portion only of the proteid remains, the greater part having been removed by the action of the caustic soda.

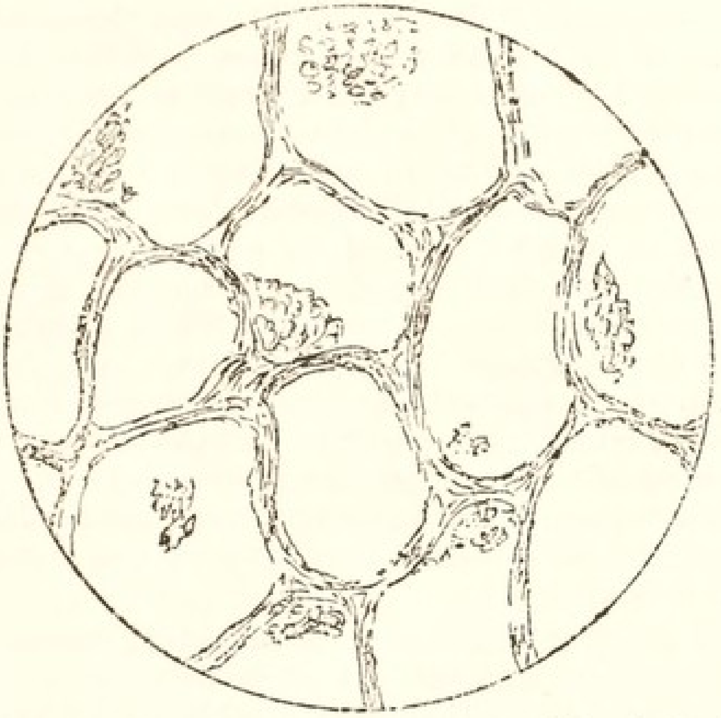


FIG. 39.—CELLULOSE OF ALEURONE LAYER OF BRAN, with only the slightest trace of proteid still remaining in some of the cells, magnified 440 diameters.

This figure shows in most striking fashion how small a proportion of the interior layer consists actually of cellulose. Reviewing the whole three layers, one finds that the outer one is largely composed of cellulose, and consequently is condemned as an article of human food, even by the Bread Reform League. The middle layer contains less cellulose, but contains a higher proportion of colouring matter. The proportion of cellulose in the inner layer is still less, but the amount of proteid is high. This proteid body is injurious to the flour, inasmuch as it exerts considerable action on broken starch granules. There are therefore cogent reasons for the non-admission of any part of the bran into the flour.

383. Cellulose of Endosperm.—On taking a grain of wheat and carefully cutting off the bran so as to have a piece of the endosperm only, and treating this interior portion of the grain with acid and alkali, a trace of cellulose is obtained which shows no distinctive organisation under the microscope. The student will do well to verify this fact for himself. Let him also treat small quantities of different varieties of flour in a similar fashion, and examine the remaining cellulose. Such an inspection is calculated to teach much concerning the success of the operation of milling. He will be able to see whether or not the number of small particles of bran in the flour is large. He will also learn whether or not the bran itself is intact, or whether portions of one or other of the surfaces have been removed and ground up into the flour.

PHYSIOLOGY OF GRAIN LIFE.

384. Protoplasm.—In explaining the nature of yeast, Chapter IX., reference has already been made to the fact that the interior of the cells is filled with "protoplasm," and that this material is the "ultimate form of organic matter of which the cells of plants and animals are composed." Protoplasm has also been defined as the "physical basis of life," and for that reason merits in this place some little examination. Yeast may be viewed as an unicellular plant, whereas wheat and the higher plants generally are multicellular in nature, so that yeast serves as an introduction to their study. From what has been already described of the life-history of yeast, the following conclusions as to the nature of its protoplasm may be drawn:—First, that protoplasm is the seat of those chemical changes which are inseparable from the life of the organism. **Such chemical changes, collectively, are termed the metabolism of the organism.** Those processes which go to the building up of more complex chemical compounds are termed **constructive metabolic processes**, while those in which complex compounds are broken down into simpler compounds or elements are termed **destructive metabolic processes.** Vines classifies the fundamental properties of the protoplasm of the yeast plant as follows:—

"1. It is *absorptive*, in that it is capable of taking up into itself the substances which constitute its food.

"2. It is *metabolic*, in that it is capable of building up from the relatively simple chemical molecules of its food the complex chemical molecules of the organic substances present in the cell; and in that it is capable of decomposing the complex molecules of these substances into others of simpler composition.

"3. It is *excretory*, in that it gives off certain of the products of its destructive metabolism.

"4. It is *reproductive*, in that portions of it can become separate from the remainder, and lead an independent existence as distinct individuals."

The protoplasm of certain more highly organised unicellular plants have, in addition, other distinct properties, such as *contractibility*, *irritability*, &c. In the lower multicellular plants all the cells appear to be exactly alike, but in most the constituent cells vary and have special functions allotted to them: such groups or arrangements of cells constitute what is known as an *organ*. Thus, certain cells are absorptive in their nature, while others are excretory: others, again, are charged with the functions of reproduction, and these are known as the reproductory organs. The seed or grain of wheat is one of the most important among these latter, and it is only such other functions of the plant as are directly associated with seed life that can be touched on in this place.

Like other parts of plants, the seed is built up of parenchymatous cells containing modified protoplasm, which consists of a series of meshes or net-work enclosing within them, in the ripe seed, grains of starch. The net-work portion is composed of proteids, and of these an exhaustive description has already been given. The insoluble proteids constitute what Reinke named the *plastin* of the cell, while the more soluble portions are the *globulins* and *peptones;* of which latter, seeds usually contain considerable quantities. The plastin is probably the organised protoplasm of the cell, while the globulins and peptones are unorganised or dead protoplasm. The higher plants, such as the cereals, contain in certain of their cells differentiated protoplasmic bodies, which may contain colouring matter, in which case they are known as *chlorophyll-* or *etiolin-corpuscles;* or they may be colourless, in which case they are *starch-forming corpuscles* or *amyloplasts.*

385. Constructive Metabolism of Plants.—The roots serve as the absorbing medium through which the plant obtains water and substances which may be in solution in water. From the atmosphere plants absorb carbon dioxide. Much of the oxygen of this carbon dioxide is returned to the atmosphere in the free state, the carbon being used in the constructive metabolism of the plant. In addition to the carbon dioxide and water, the plant has at its disposal for metabolic purposes salts containing nitrogen and sulphur.

A most important point in the study of metabolism is that the assimilation of carbon from carbon dioxide is confined to those portions of plants which contain green colouring matter (or closely allied matter to be subsequently described). Further, the decomposition of carbon dioxide can only take place in the presence of light. On treating green leaves of plants with alcohol, the green colouring matter is dissolved out, and has received the name of *chlorophyll.* Within the leaves this chlorophyll exists in cells or corpuscles known as chlorophyll-corpuscles, the chlorophyll itself having apparently a similar composition to other protoplasm. Etiolated plants—that is, plants grown in the absence of light—contain corpuscles in which the colouring matter is yellow, not green; this matter has received the name of *etiolin*, and is doubtless closely allied to chlorophyll in properties. On exposure to light, the etiolin corpuscles absorb carbon dioxide and exhale oxygen, the etiolin being converted into chlorophyll. Investigation of a most careful and exhaustive nature demonstrates that **the absorption of carbon dioxide and exhalation of oxygen, with the formation de novo of organic matter in plants, is essentially a function of chlorophyll (including etiolin), and cannot occur in its absence.**

But little can be stated positively as to the exact nature of the chemical changes induced by chlorophyll, but they may be summed up in the statement that it produces, by synthesis, proteid matter. The first step is probably the formation, from carbon, hydrogen, and oxygen, of comparatively simple substances, such, perhaps, as formic aldehyde, CH_2O (the simplest possible carbo-hydrate), and its polymers. (Glucose and other of the higher carbo-hydrates may be viewed as polymers of formic aldehyde, thus $6CH_2O = C_6H_{12}O_6$, glucose.) The next upward step might be the production of nitrogenous substances of the amide type (asparagin, &c.), and finally, by further synthesis, the still more complex proteids. Differences of opinion exist as to the manner in which starch is formed by the plant—there is first the observed fact that the chlorophyll-corpuscles of a growing plant exposed to light contain starch grains, and that these disappear during darkness. Vines is of opinion that "the starch which makes its appearance in the chlorophyll-corpuscles, when constructive metabolism is in active operation, is not the first product of the synthetic processes, but only an indirect product: protoplasm is the substance which is formed in the chlorophyll-corpuscles, and it is only in consequence of the decomposition of the protoplasm formed that starch is produced." In a paper contributed to the Journal of the Chemical Society, in 1893, by Brown and Morris, these chemists advance the view that cane sugar is first formed as an up-grade product of constructive metabolism, and that the starch is formed within the chlorophyll-corpuscles from this compound. There is proof that proteid matter is capable of being so decomposed as to result in the splitting off of a carbohydrate molecule from its substance, as in the production, for example, of the cellulose cell-wall of yeast from its protoplasm.[1] On the other hand, Brown and Morris have shown that the chloroplasts of the leaf can form starch when fed directly with cane-sugar solution, and claim that "both under the natural conditions of assimilation and the artificial conditions of nutrition with sugar solutions, the chloroplasts form their included starch from antecedent sugar." However, in whatever manner formed, chlorophyll causes, in the presence of light, the production both of proteids and carbohydrates, including starch, within the leaf. The final process of constructive metabolism is the conversion of dead proteid matter into living organised protoplasm; but our knowledge of the difference between these is very slight. Vines points out "that the primordial utricle of dead cells readily allows of the passage into it and through it of substances which could not enter or pass through it in life. This is in accordance with the well-known fact that it is impossible to stain living protoplasm; it is when protoplasm is dead that colouring matters can penetrate into it."

Having traced the synthesis of protoplasm and other organic matter in the leaf, the next problem is the mode of their translocation or transference to other parts of the plant. Brown and Morris have proved the existence in leaves of a diastase, which they term leaf diastase, or "translocation diastase," from its functions as an agent in the translocation of chlorophyll products. They show that by the agency of this diastase the starch (which during darkness disappears from the chlorophyll corpuscles of the leaves) is converted into maltose. They further are of opinion that the cane-sugar which the leaves may contain is converted into dextrose and lævulose. Probably also the proteids are changed by analagous processes into peptones, and from these into amides, in which form the nitrogenous organic substances are most likely distributed through the plant. The diastase and proteolytic enzymes, then, pour into the various vessels of the plant a solution of maltose, dextrose, lævulose, and peptones and amides. These are

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[1] Pavy, in some recent investigations of the chemical pathology of diabetes, shows that glucose may be formed from proteids during human digestion.

carried to the new parts of plants for the purpose of forming buds, roots, &c., and to the seed portion, there to be stored up as provision for the young plant during its first stages of growth, and before able to obtain nutriment by the action of its own chlorophyll.

The physical structure of the wheat seed or grain has been already described, the embryo of the plant being at the lower end, near where the seed is attached to the ear, and the upper portion being the endosperm, the whole being enclosed within the cuticle known as bran. Of the formation of the seed as the plant grows, we cannot here speak; but assuming the seed to have formed its outer envelope, it before ripening is found, on examination, to be full of a milky looking fluid, which consists of the sap which is being supplied by the vessels of the plant.

Within the seed a synthetical process proceeds, by which is caused the formation of proteid matter from the sugar and amides supplied by the sap. From this is derived the starch of starchy seeds, while the residuum of the proteid forms what are known as *aleurone-grains.* Vines points out that comparatively little is known of the manner in which starch is formed in seeds, but it is assumed that it is produced in the same way as in other parts of the plant. Schimper has observed that in the parts of the plant not exposed to light, the formation of starch is effected by certain specialised portions of the protoplasm, which are termed *starch-forming corpuscles* or *amyloplasts.* These amyloplasts resemble in nature the chlorophyll corpuscles or *chloroplasts*, and act by conversion of protoplasm, from which the starch-molecule is cleaved off by decomposition. They differ, in that amyloplasts act in the absence of light, and can only commence the production of starch from comparatively complex substances, whereas chlorophyll corpuscles synthesise this body from simple inorganic compounds. The grains of starch as at first formed are very minute, but grow by deposition of further starchy matter, such growth continuing either within the amyloplast, or frequently outside it, the latter being the case in the wheat grain. The mark on the starch corpuscle known as the *hilum* indicates the point of first growth in an externally formed starch grain, and is gradually separated from the amyloplast by the deposit of more starch in stratified layers, finally leaving the hilum at the far end of the longer axis of the ovoid starch corpuscle.

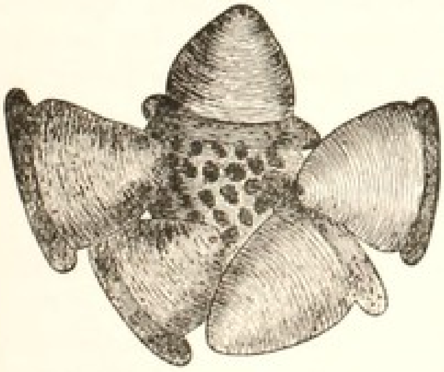

FIG. 40.—GROUP OF AMYLOPLASTS.

After the separation of the starch, there remains behind in the seed a small proportion of sugar; part of which consists of sucrose, and is probably an up-grade sugar, and the remainder of glucose or allied sugar produced by the subsequent degradation of the cane sugar. In some seeds the non-nitrogenous matter is stored up as oil instead of starch—comparatively little fatty matter is present, however, in wheat, except in the embryo itself.

The residual matter of the protoplasm, after the separation of starch, is stored up in the form of small granules, known as *aleurone-grains.* These form the matrix in which the starch grains are imbedded, and constitute the proteid matter of the endosperm. The series of cuboidal cells forming the interior layer of the bran are also filled with aleurone, and have the name *aleurone-layer.*

During the growth of the seed from the milky stage before referred to, the sap continues to bring supplies of maltose and nitrogenous matters, which undergo the constructive metabolic process just described; while under the influence of a ripening sun the water is evaporated. Gradually the contents of the seed acquire a firmer consistency, until at last the solid ripened grain of wheat is produced. In this condition the seed is in a resting stage, and may without injury be subjected to desiccation and extremes of temperature, which would be fatal were it in its active state. Under the influence of moisture and warmth, active changes are set up in the resting seed, and the development of the new plant commences.

386. Germination of Wheat and Barley.—In order to understand the phenomena of germination, reference should at this stage be made to the section of the wheat germ given in Plate VI. Although in the resting stage the wheat germ contains no starch, yet within twenty-four hours of the seed being kept in a moist state, starch is found in abundance within the germ, although no alteration has occurred in the endosperm, being doubtless produced by dissociation of the protoplasm of the embryo. This is followed by an elongation of the radide, which at this stage contains starch, as do also the leaves of the plumule. The plumule, with its further growth, first bursts through the envelope, and finds itself in contact with the "pericarp," or outer skin of the grain (enveloping the testa). The pericarp is next ruptured, and the growth of the plumule proceeds outside the grain. On looking at the figure of the germ (or, still better, an actual section under the microscope), there will be noticed a series of elongated cells, constituting what is known as the *scutellum:* between this and the endosperm is a series of cells of another type, arranged with their longest diameters directed toward the endosperm; these latter form what is called the absorptive and secretive *epithelium.* At the time when the radicle breaks through its sheath, the cells of the scutellum lying next the epithelium begin to show starch granules, which gradually pervade the tissue of the germ: these may be taken as the first indication of the passage of reserve material from the endosperm to the germ, while the epithelium is regarded as the absorptive contrivance by which the germ thus derives sustenance from the endosperm. The first visible effect on the endosperm is the breaking down of the parenchymatous cell-walls, and following on this we have the starch corpuscles attacked. There are, in the first place, minute pittings on the surface of the grains of starch, which increase both in size and number until the whole granule is completely dissolved, with the formation of maltose. The dissolution and assimilation of the starch of the endosperm proceeds gradually, the more remote parts being last to suffer attack. The proteid matter of the endosperm is at the same time converted into peptone, and probably amides, by a proteolytic enzyme. By means of the epithelium, these are transferred to the growing plant. The aleurone cells of the bran show no signs of change until the reserve starch is nearly exhausted, when they begin to suffer attack, the cell-walls undergoing dissolution. Doubtless the function of the aleurone cells is to provide proteid nutriment for the plant at a comparatively late stage of its growth, hence the highly resistant cell-walls. In their researches on the *Germination of the Gramineæ*, Brown and Morris demonstrate that the epithelium of the germ secretes diastase during germination, and this is the agent of transformation of the contents of the endosperm. They also, as has been previously mentioned, have shown that the diastase of germinating grain is *cyto-hydrolytic* (cellulose dissolving) as well as *amylo-hydrolytic*. They consider the former action to be due to a distinct and separate enzyme from diastase proper, and that it also is secreted by the epithelium.

Two varieties of diastase have been described in the chapter on Enzymes, that from raw grain, and ordinary or malt diastase—the former is probably identical with the diastase of translocation, by which the starch of the chloroplasts is converted into sugar ; while the latter is essentially a diastase of germination, and is only secreted by the epithelium of the scutellum. The power to liquefy starch-paste and to erode starch-granules always accompany each other, and, in fact, are never separable, being in each case functions of germination diastase, or *diastase of secretion*. Raw grain diastase is produced during the production of the embryo in the growing and unripe seed, and probably then acts as translocation diastase for the purpose of preparing nutritive matter for the developing embryo. The portion of such diastase remaining unused in the ripe seed constitutes the diastase of raw or ungerminated grain.

The changes just described are those which wheat undergoes during germination, and occur in an incipient form in sprouted or "growy" wheat, in which the diastase of secretion, together with cytase, will have more or less broken down the parenchymatous cell-walls, and also possibly have eroded some of the starch. A useful test for growy wheat is to examine the germ for starch ; if any such granules are found within a section when viewed under the microscope, it may safely be concluded that the wheat is unsound. The changes to which malt owes its properties are practically the same ; when germination has proceeded sufficiently far, its further course is arrested in malting by kiln-drying the grain.

EXPERIMENTAL WORK.

387. The experimental work undertaken in connection with the subject-matter of this chapter should consist in following its detailed directions for microscopic examination of wheat.

CHAPTER XIV.

CHEMICAL COMPOSITION OF WHEAT.

388. Principal Constituents of Cereals.—Proximate analysis of the cereal grains shows that they contain as their principal constituents—fat, starch, cellulose, dextrin, sucrose, raffinose, and possibly other sugars; soluble proteid bodies, consisting of albumin, globulin, and proteose; insoluble proteid bodies, consisting of glutenin and gliadin, which together constitute gluten; mineral matters, consisting principally of potassium phosphate and water.

The following, according to Bell, is the average composition of the different members of the cereal family:—

Constituents.	Wheat.		Long-eared Barley.	English Oats.	Maize.	Rye.	Carolina Rice, without Husk.
	Winter.	Spring.					
Fat	1·48	1·56	1·03	5·14	3·58	1·43	0·19
Starch ...	63·71	65·86	63·51	49·78	64·66	61·87	77·66
Cellulose ...	3·03	2·93	7·28	13·53	1·86	3·23	Traces
Sugar (as Cane)	2·57	2·24	1·34	2·36	1·94	4·30	0·38
Albumin, &c., insoluble in alcohol ...	10·70	7·19	8·18	10·62	9·67	9·78	7·94
Other nitrogenous matter, soluble in alcohol ...	4·83	4·40	3·28	4·05	4·60	5·09	1·40
Mineral matter	1·60	1·74	2·32	2·66	1·35	1·85	0·28
Moisture ...	12·08	14·08	13·06	11·86	12·34	12·45	12·15
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The following is a series of later analyses by Clifford Richardson of the various cereals. It will be noticed that the water runs very considerably lower than in Bell's analyses, a result due probably to the greater dryness of the American climate.

AVERAGES OF DETAILED ANALYSES OF CEREALS.

No. of Analyses.	Wheat. 27	Barley. 14	Oats. 18	Maize. 21	Rye. 17
Fat	2·30	2·67	7·87	5·54	1·83
Starch	67·88	62·09	56·91	66·91	61·87
Cellulose	1·90	3·81	1·29	1·41	1·47
Sugar, &c.	3·50	7·02	6·07	2·18	7·57
Dextrin and Soluble Starch ...	2·30	3·55	3·47	2·18	4·75
Proteids insoluble in 80 per cent. alcohol	7·45	7·86	13·43	4·96	9·07
Proteids soluble in 80 per cent. alcohol	3·58	3·66	1·82	5·84	2·53
Mineral matter	1·84	2·87	2·22	1·54	2·06
Moisture	9·25	6·47	6·92	9·34	8·85
	100·00	100·00	100·00	100·00	100·00

Before giving detailed analyses of various samples of wheat, a description of the effect of each constituent on the character of the wheat will be of interest.

389. Fat.—As far as is at present known, the quantity of fat in wheat is not a very important element in determining its value. Fat is of course an important food stuff, and as such is of service. The germ of flour contains a very high percentage of fat, and when removed must necessarily lessen the percentage of this body present.

390. Starch.—This makes up the principal part of the grain, and in the analyses above given varies from 63·71 to 67·88 in the different wheats. In these analyses the starch was probably determined by difference; that is, the percentage of the other constituents was subtracted from 100, and the remainder considered to be starch: the quantity of starch will therefore naturally be the complement of the other bodies, rising when they fall and falling when they rise. Starch is of course of great importance as being the principal food-stuff of bread: in sound wheat the starch granules are whole, while in wheat which has sprouted, or heated unduly through damp, the starch granules are pitted, and often fissured. The result is that their contents become more or less changed into dextrin and sugar.

391. Cellulose.—This substance is of considerable service to the plant; but to the miller it has no value, as being useless as an article of food, he endeavours to keep it out of the flour. As the cellulose is found principally in the bran, the thinner skinned wheats will yield, on analysis, less cellulose. Judging the cellulose alone, the less quantity present the better is the wheat.

392. Dextrin and Sugar.—Dextrin exists in sound wheat in but small quantity; but when hydrolysis of the starch has set in, the percentage may considerably increase: in wheats or flours the presence of large quantities of dextrin would be decidedly objectionable. Sugar is always present to a slight extent in wheat. Bell states that the sugar corresponds in properties to cane sugar, as it does not reduce Fehling's solution, but may be readily inverted by sulphuric acid. Bell extracts the sugar with 70 per cent. alcohol, and so prevents any action on the sugar of the proteids. The author finds that on extraction with water, the sugar invariably produces more or less precipitate with Fehling's solution; the amount of precipitate being increased by treatment with sulphuric or hydrochloric acid. Paragraph 338, chapter XI., gives some results of sugar determinations in the aqueous extract of flour. The explanation of these results seems to be that, in perfectly sound wheat or flour, small quantities of cane sugar, only, exist. In unsound wheats or flour, in which the starch has been subjected to diastasis, maltose may also be detected. Wanklyn makes the useful suggestion that estimations of sugar should be made in both aqueous and alcoholic extracts: unsoundness in flour would be indicated by the presence of an increased amount of maltose in the alcoholic extract.

Assuming the correctness of Bell's statement that sound wheat sugar does not reduce Fehling's solution, an alcoholic extract of sound wheat should give no precipitate with that reagent. Any maltose therefore in an alcoholic extract is the measure of diastasis of the starch of the grain that had occurred previous to analysis. If the flour be then mixed with water, and allowed to stand for a definite time, and then the maltose estimated in the aqueous extract, the difference between the amount obtained in this estimation and the former one would be a measure of the quantity of soluble starch, arising from fissured granules, present in the flour. A series of comparative estimations of this kind would be of service.

As the sugar of a flour affords the saccharine body necessary in fermentation, the presence of this compound in small quantity may be tolerated, but as before pointed out, it should consist principally of cane sugar, the presence of much maltose being evidence of unsoundness.

393. Soluble Proteids.—In technical wheat analysis no attempt is made to separate the albumin from the globulin. In the following analyses these bodies are estimated in a portion of the aqueous extract of the flour, by either what is known as the albuminoid ammonia process, or by Kjeldahl's process; of which latter, in common with other analytic methods, a description is given hereafter. As has been already stated, these bodies have a serious action on starch, and also on gluten; under the influence of yeast, during fermentation, they act on the starch and convert that body into dextrin and maltose. In the paragraph on artificial diastase, No. 239, this action is somewhat fully described. A relatively low percentage of soluble proteids is usually to be preferred as indicating soundness both in flours and wheats In the case of wheat it is somewhat difficult to form a judgment, because the bran and germ contain considerable quantities of soluble proteids; as these are removed in the operation of milling the proportion differs somewhat in the wheat from that in the dressed flour. It is in damp years and wet climates that inferior wheats are grown; the excess of moisture, and lack of warm, dry sunshine, leave the grain damp, and also leave the proteids in the soluble condition, instead of thoroughly ripening the grain, and thus causing them to assume the insoluble form.

From time to time attention has been directed to the problem of artificially drying wheats. With some samples of wheat this is practically a necessity, as otherwise they are absolutely unfitted for flour producing purposes. A gentle kiln-drying at a temperature of from 100° to 120° F., by driving off the excess of water, arrests its degrading action on the gluten, and causes the wheat to yield a sounder and stronger flour. The drying is necessarily accompanied by loss of weight; against this must, however, be set the improved quality of the flour. In connection with this, attention is directed to the paragraph on artificially drying wheats and flours, in the next chapter.

394. Soluble Extract.—In the following analyses by the author the percentage of "soluble extract" is in most cases given. This represents the proportion of the wheat or flour soluble in cold water The sample is shaken up with water repeatedly during half an hour, then filtered from the solid matter, the clear liquid evaporated, dried at 100° C. (212° F.) and weighed. This extract consists of soluble proteids, sugar and dextrin, and potassium phosphate. Considerable importance attaches to the amount of soluble extract, as being the measure of the amount of degradation of the gluten and starch of the wheat or flour; consequently an excess of soluble extract indicates unsoundness. On the other hand, a very low percentage of sugar in a flour or wheat is accompanied by an absence of that sweetness characteristic of the best flavoured wheats and flours.

395. Insoluble Proteids, Gluten.—The insoluble proteids are, for practical purposes, estimated by doughing the flour, and washing away the starch, leaving behind the tough and elastic gluten. The gluten of wheat is of great importance, as being that constituent which imparts to wheaten flour its remarkable property of rising into a light and spongy loaf. The gluten is usually weighed both in the moist or wet state, and also when dry; it weighs from 2·7 to 3 times as much when moist as dry. As the gluten of wheat is that constituent which causes the flour to be a strong flour, wheats to be of high quality should contain a high percentage of gluten. This, however, is not of itself sufficient; the glutens of different wheats vary not only in quantity but in quality—some glutens are tough and elastic, others are soft and "rotten." These latter yield weak flours, and consequently bread which is not well risen; further, the quantity of water they are capable of retaining is but small. They as a result produce a comparatively low number of loaves from a sack of the flour. The gluten then should not only be present in considerable quantity, but should also be highly elastic.

Between the amount of gluten and of soluble proteids in a wheat a close relation exists. With an increase of total proteids, both the soluble and insoluble varieties will simultaneously rise in amount. In interpreting analytical results, high soluble proteids should not be considered alone—they are the natural concomitants of high total proteids and gluten. But where the soluble proteids are high, and the gluten low, then distinct evidence of a low grade or unsound wheat is afforded.

The aleurometer is an instrument designed for the purpose of estimating the elasticity of gluten; the higher the figures obtained by its use, the more elastic the gluten is supposed to be.

396. "True Gluten."—It is difficult, and in many cases impossible, to wash away the whole of the starch from flour or wheat meal without also washing away some of the more soluble parts of the gluten itself. In consequence, gluten determinations will vary according to the thoroughness of the washing, and this differs in different hands. As a check, therefore, on gluten determinations in cases of importance, the author advises the making of a nitrogen estimation on the dried gluten, and deducing therefrom the amount of proteid it contains; this latter, being calculated as a percentage on the whole wheat or flour, is denominated percentage of "true" gluten. The amount should be at least 80 per cent. of the crude dry gluten. With even considerable differences between percentages of crude gluten, the amounts of true gluten agree very closely. In the further chapters on flour, data of various estimations are given.

397. Gliadin.—The estimations of proteids soluble in 80 per cent. alcohol are practically, in the case of wheat and wheaten flour, estimations of gliadin. As affording evidence of the quality of gluten, gliadin estimations may possibly prove of value. It is probable that soft, ductile, tenacious glutens may contain a high percentage of gliadin, but a sufficient number of estimations has not as yet been made to permit the drawing of any definite conclusions.

398. Ash.—This gives the quantity of mineral matter present in a wheat or flour; the ash consists principally of potassium phosphate, a substance of considerable value from a nutritive point of view; the mineral matter of wheat is contained principally in the bran.

399. Water.—The water of wheat is found to be mostly associated with the starch of the grain; that body is extremely hygroscopic, and can only be obtained actually free from water by prolonged and careful drying. The quantity of water in flour and wheat does not vary within very wide limits, the highest percentage being about 15, and the lowest about 8 per cent. The question of importance is the influence of the water on the quality of the grain or flour, and the interpretation to be placed on such results as are here given. As may readily be supposed, a wheat that is grown either in a naturally damp climate, or during an unusually wet season, contains more water than one grown under the opposite conditions. Taken into consideration without reference to the other constituents of the grain, a large proportion of water is to be deprecated, for the very simple reason that water is scarcely worth purchasing at the price given for wheat or flour. This, however, is not the only objection to the presence of a large percentage of water; a much more serious objection is based on the fact that such high proportions show that the wheat is unsound, and that in all probability the other constituents will not be of the most promising character. In the first place, damp wheats and flours favour the development of those organisms which produce mustiness and acidity. In the presence of excess of moisture, too, the gluten of flour is rendered soluble in part, and also loses its elasticity. Further, more or less of the starch will be found to have been degraded into dextrin and maltose by diastasis.

400. Analyses of English and Foreign Wheats.—The analyses embodied in the following tables are selected from those of a number of wheats analysed by the author.

ENGLISH AND SCOTCH WHEATS.

No.	Name and Description.	Weight per Bushel.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Height of Aleurometer	Remarks.
						Wet.	Dry.	Ratio of Wet to Dry.		
1	Fine Rough Chaff	64.5	14.50	6.46	1.45	19.1	6.64	2.9	26	
2	Very Fine Old Rough Chaff, 1882 ...	65.0	13.16	6.66	1.37	17.5	6.00	2.9	...	Gluten and moisture both low; was a weak wheat when harvested.
3	Fine Red Lammas	64.5	14.0	7.26	1.69	23.9	7.26	3.12	30	Above average of gluten.
4	Old Red Lammas and Nursery (mixed)	63.5	14.62	6.33	1.42	21.25	7.7	2.76	37	Percentage of gluten raised by addition of Nursery.
5	Mixture used for "Seconds" Flour, consisting of 1 Saxonska, 1 Kubanka, 1 New Zealand, 1½ White English, 1¼ Red ditto	62.5	13.60	6.73	1.64	24.5	8.7	2.8	28	Consists of half Foreign.
6	Fine Herts, White	63.5	14.82	6.75	1.16	14.5	5.19	2.8	...	Weakest in gluten of English wheats; moisture highest.
7	Fine White, Oakshott's Pedigree ...	63.75	13.72	7.60	1.57	18.25	5.93	3.0	25.5	High extract; a sweet weak wheat.
8	Fine English, White Victoria ...	64.0	14.0	8.06	1.66	23.0	7.73	3.0	35	Extract highest of series; sweet and moderately strong.
9	Nursery, Sussex	...	15.56	5.4	1.67	23.37	8.12	2.86	39	High in gluten and very sound.
10	Fluff, Sussex	...	16.04	5.53	1.30	22.42	7.86	2.86	25.5	Moisture high, but extract low.
11	Golden Drop, Sussex	...	15.18	5.60	1.65	18.42	6.64	2.77	...	
12	Pricked Ear, Sussex	..	14.91	5.06	1.30	18.55	6.38	2.9	31.5	
13	Essex Revitt, 1883, fine average quality	59.47	15.54	6.72	1.40	Trace	...	...	...	There was only the slightest amount of gluten in these wheats; No. 14 contained, if anything, the more.
14	,, ,, Harvested damp	58.08	15.68	6.70	0.82	Trace	...	...	...	
15	Webb's Challenge, Berks	62.06	15.66	6.93	1.01	19.8	6.41	3.0	31	These wheats contain very nearly the same amount of gluten; No. 16 contains less moisture and more extract.
16	,, Oxfordshire ...	63.17	14.50	7.3	1.69	18.37	6.25	2.9	...	
17	Rough Chaff, Didcot	62.79	15.10	6.12	1.69	27.6	8.21	3.3	35	Highest gluten of series.
18	Scotch West Country	59.47	16.18	6.93	1.42	14.75	5.00	2.94	28	Moisture highest and gluten lowest of series.
19	Fine Kent Red	64.18	13.03	6.80	1.88	23.5	8.46	2.8	...	Grown on good heavy land in Suffolk, 1883; fairly farmed; delivered by farmer at 66 lbs. per bushel.

ENGLISH AND SCOTCH WHEATS—*Continued.*

No.	Name and Description.	Weight per Bushel.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Height of Aleurometer	Remarks.
						Wet.	Dry.	Ratio of Wet to Dry.		
20	Essex Rough Chaff, White ...	63·26	14·07	5·50	1·69	26·0	8·90	2·9	...	Grown in good heavy land in Essex, 1883; fairly farmed; delivered by farmer at 66·5 lbs. per bushel.
21	Red Chaff	...	13·20	6·51	2·17	14·5	5·03	2·8	...	Grown in Devon, about two miles from sea; considered by sender to have probably been injured during the blooming period.
22	English Red ...	...	14·81	5·48	1·40	20·7	7·61	2·7	...	Grown in the neighbourhood of Boroughbridge.
23	Rough Chaff ...	65·0	13·70	5·74	1·43	23·2	7·24	3·2	...	Grown at Hampstead.
24	Red Square Head	64·0	13·18	5·54	1·45	16·62	5·75	2·9	...	
25	Red Lammas ..	64·0	13·52	5·38	0·90	25·25	8·09	3·1	...	
26	Wheat from the Vale of Taunton	...	13·35	6·44	1·21	18·00	6·62	2·7	...	Wheat of splendid quality, but in opinion of miller who forwarded it not very strong.
27	Scotch E. Lothian	60·3	13·93	6·68	1·76	18·42	6·86	2·7	...	
28	Rough Chaff, grown at Newbury	...	14·18	5·44	1·28	18·10	6·33	2·8	...	
29	Red Lammas ...	65·2	13·22	5·00	1·40	19·00	6·69	2·8	...	
30	Herts, White ...	...	13·12	6·12	1·16	21·20	7·62	2·8	...	
31	Nursery, grown at Lickhampstead ...	...	13·40	5·60	1·08	20·50	7·07	2·9	...	
32	Rough Chaff ,, Compton, Berks	...	12·60	5·12	2·84	15·50	5·54	2·6	...	
33	Trump ,, Newbury	...	13·00	4·52	1·12	18·50	6·25	2·9	...	
34	White ...	62·98	12·30	5·36	1·80	23·70	8·61	2·7	...	
35	Red ...	61·30	10·40	5·96	1·40	17·50	6·06	2·9	...	
36	Red Chaff, from Sidbury, Devon	62·0	15·54	4·00	1·32	17·20	6·21	2·9	...	
37	Red Nursery ,, ,,	64·0	16·22	3·98	1·06	14·80	5·33	2·8	...	
38	Square Head, from S. Coast, Devon	64·0	16·20	3·57	0·91	14·50	5·00	2·9	...	

Nos. 1-18 inclusive were analysed in April, 1884; they are, except where otherwise mentioned, 1883 wheats.

Nos. 19-27 inclusive were analysed in September, 1884, and are all 1883 wheats.

Nos. 28-38 inclusive were analysed in November, 1884, and are all 1884 wheats.

Reviewing Nos. 1-18 as a whole it may be remarked that the moisture is high; as might be expected No. 18 heads the list. The soluble extracts and proteids average a somewhat high figure. Taking the glutens throughout these are lower than in foreign wheats, the highest figure being only 8·21. As might be expected the Revitts are exceedingly low; the trace of gluten was so small that it was practically impossible to recover it from the bran. Of the other wheats, Nos. 6 and 18 contain the lowest quantities of gluten.

Samples Nos. 19-27 call for no special remark, representing as they do the class of wheats largely used, particularly in the south of England, in the manufacture of flour. It is interesting to note the variations in the character of the same variety of wheat when grown in different localities, and under different conditions. Nos. 19 and 20 were considered by sender, a miller whose flours are familiar in the London market, to be exceptionally fine samples of their kind. No. 21 is of interest as showing the composition of a wheat damaged during growth.

The English wheats of the harvest of 1884 were of exceptionally fine quality. The samples given were selected from the South and Western Counties. Compared with the series of English and Scotch wheats of 1883 harvest the moistures run much lower, the average being 13·55 against 14·82 in the 1883 wheats. The same remark applies to the soluble extract and soluble proteids. The average of the glutens is also somewhat lower, being 6·40 against 6·87. The lowest gluten of the 1883 series was 5·00 in a Scotch West Country wheat; this had also the highest moisture; like the Scotch sample, No. 38 in the new series is grown in a damp climate, S. Devon, and yields the same percentage of gluten. The highest gluten, 8·61, is yielded by a sample of white wheat, the highest of the 1883 wheat being a sample of rough chaff grown at Didcot, and containing 8·21 of gluten.

FOREIGN WHEATS.

No.	Name and Description.	Weight per Bushel.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Height of Aleurometer.	Remarks.
						Wet.	Dry.	Ratio of Wet to Dry.		
39	Hard Minnesota	63·7	13·32	6·80	1·22	25·87	9·29	2·78	41	An interesting wheat; gluten and moisture both somewhat high.
40	Wheat Mixture, from 3 English, 3 Californian, 1 Red American, 1 No. 1. Calcutta	64·1	12·60	6·22	2·83	20·5	6·91	2·96	42·5	
41	No. 1. Minnesota, Hard Spring ...	61·4	13·46	6·80	1·1	25·92	9·03	2·8	51	
42	No. 2. Minnesota, Hard Spring ...	59·7	13·82	6·97	2·03	23·75	8·54	2·78	35	More water and less gluten than No. 41; soluble proteids very high.
43	Red Fyfe, Manitoba	63·9	12·36	7·12	1·01	24·75	8·88	2·8	39	Forwarded by Ed. of "The Miller."
44	Walla Walla, Oregon	60·0	11·1	5·78	1·5	11·7	4·2	2·8	...	Instances of low moisture and low gluten occurring together.
45	Walla Walla, Oregon, 1883 Harvest	58·7	11·14	6·33	0·67	17·55	5·79	3·0	29	
46	Californian, 1883 Harvest	60·0	10·1	7·65	0·87	24·12	7·97	3·0	45	Low moisture; does not, however, coincide with high gluten.
47	No. 1. Winter American	61·3	13·24	6·00	1·57	17·00	5·69	2·98	...	Run considerably lower in gluten than Nos. 39, 41, and 42.
48	No. 2. Winter American	60·1	13·18	6·46	1·79	20·87	7·00	2·97	30	
49	No. 2. Chicago Spring	59·9	12·05	6·60	1·88	23·92	8·41	2·84	36	Intermediate between the weak and strong American wheats.
50	Saxonska	60·76	12·04	7·06	1·45	28·0	10·0	2·8	50	Strong dry wheats, the former forwarded from Scotland, the latter from South of England.
51	Saxonska, 1883 Harvest	59·56	11·84	6·46	1·45	27·25	9·36	2·9	37	
52	Kubanka, 1883 Harvest	61·59	12·15	7·3	1·06	30·33	10·8	2·8	51	High gluten.
53	Taganrog, Ghirka	60·2	11·6	7·84	1·57	29·5	10·69	2·8	39	Gluten very high.
54	Red Dantzic	58·18	14·7	7·2	1·96	26·25	8·92	2·94	45	A weak, damp wheat.
55	New White Indian	60·58	12·28	6·33	1·3	19·25	6·83	2·82	28·5	Gluten very low; water average.
56	New Australian	61·13	10·9	7·18	1·35	23·42	7·87	3·0	39·5	Water and gluten both low.
57	New Zealand "*Growy*"	59·3	13·12	7·74	1·5	16·92	5·68	2·98	26	Gluten low; soluble extract high.
58	Hard Calcutta	57·99	10·50	7·26	1·80	16·5	6·82	2·4	...	
59	No. 1. Calcutta	60·95	10·62	7·84	1·57	8·5	3·16	2·7	...	Very low in gluten.
60	No. 2. Calcutta	60·03	10·76	8·34	1·45	13·0	5·05	2·6	...	Gluten low.
61	No. 1. Bombay	63·90	10·32	5·74	1·64	19·0	7·10	2·7	...	Very like No. 64, but contains more moisture.

FOREIGN WHEATS—*Continued.*

No.	Name and Description.	Weight per Bushel.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Height of Aleurometer.	Remarks.
						Wet.	Dry.	Ratio of Wet to Dry.		
62	Soft Red Bombay	64·55	10·69	5·29	1·23	21·5	7·51	2·9	...	Highest gluten of the Indian wheats.
63	Hard White Kurrachee	58·18	9·63	5·78	1·21	14·7	5·74	2·7	..	Moisture very low, gluten also low, showing that dry wheats are not always the strongest.
64	Red Kurrachee	61·04	10·07	5·58	1·09	19·0	7·16	2·6	...	Is very similar in character to No. 62.
65	White Jubblepore	64·27	10·35	5·23	1·42	18·0	6·55	2·7	...	
66	Low Persian	58·64	10·12	6·05	1·26	22·5	8·70	2·6	...	The Persian wheats run distinctly higher in gluten than the Indian wheats.
67	Hard Persian	61·13	10·46	5·91	1·28	26·0	9·50	2·7	...	Gluten and moisture both higher than No. 66.
68	Clean Persian	61·41	10·97	5·54	1·16	30·0	10·63	2·8	...	Gluten and moisture still higher; the gluten is equal to that in some of the strongest Russian wheats.
69	Australian	62·70	10·26	6·00	1·26	26·5	9·60	2·7	...	
70	,, ...	...	11·74	5·80	1·52	29·0	9·48	3·0	..	
71	Kubanka	...	13·18	6·34	1·35	28·7	10·01	2·8	..	
72	Milwaukee	...	11·62	5·44	1·21	21·7	8·69	2·5	...	
73	Red Königsburg	61·50	11·72	6·00	1·40	27·20	9·61	2·8	...	
74	Spring American	60·76	12·50	6·32	1·52	20·80	7·85	2·8	..	
75	Algerian	...	10·96	6·00	1·12	26·20	9·62	2·7	...	The upper of the two sets of gluten estimations given was made immediately on doughing the meal; the lower after the dough had stood for an hour.
						29·20	10·44	2·9	...	
76	Persian	60·21	11·22	5·60	1·32	16·00	6·20	2·4	...	
						22·70	8·30	2·7	...	
77	No. 1. Club Calcutta	...	11·42	...	...	16·80	5·90	2·8	...	
						21·80	7·65	2·8	...	
78	No. 2. Club Calcutta	...	11·43	...	...	16·30	6.20	2·7	...	
						21·20	7·15	2·9	...	
79	No. 1. American Hard Fyfe Wheat	65·00	11·17	4·85	1·40	32·00	11·40	2·8	...	
						24.00	9·86	2·5	...	
80	No. 1. Hard Wheat, Canadian ...	65·10	12·31	6·16	2·00	28·00	10·22	2·7	..	
81	Persian Wheat	...	11·26	6·60	0·80	26·05	9·00	2·9	...	

The foreign wheats are naturally more varied than those grown in England and Scotland. The Russian wheats, as a class, show a higher percentage of gluten than do the American. Readers may make an interesting comparison between the moistures of wheats and the flours produced from them; the comparison may also be extended to the glutens.

Indian and Persian wheats have of late been receiving considerable attention from millers, and also bakers who are equally interested in the wheat supply of the country The Indian wheats are characterised as a class by being very low in gluten, and this is accompanied by a low percentage of moisture. The meals, when worked up with water, are almost sandy in their nature; it is only after standing some little time that they begin to acquire the characteristic ductility of wheaten flours. The Persian wheats are decidedly richer in gluten than the Indian: this holds especially with the clean Persian, No. 68.

No. 79 was forwarded by the L.C. Porter Milling Co., of Winona, U.S.A., and is the wheat from which flours Nos. 8 and 9 were made. The higher line of figures represents the results obtained on allowing the dough to lie two hours before extracting the gluten. One very special feature of this wheat, and also the flours produced from it, was the extreme slowness with which they absorbed water and became thoroughly softened and hydrated.

Wheat No. 80 was grown on land 400 to 800 miles west of Winnipeg, Manitoba. The comparatively high moisture, soluble extract, and proteids, are indications of the cold climate in which it has been grown. The comparison between this sample and No. 79 are of interest. The Canadian flours referred to in a subsequent table were made from this wheat.

401. Average Composition of American Wheats.—On page 294 is given the average composition of American wheats, according to Richardson, Chemist to the United States Department of Agriculture. The carbohydrates consist of the starch, dextrin, and sugar. The total quantities of proteids are given, being derived from the percentage of nitrogen found.

402. McDougall Brothers' Report on Indian and other Wheats.—In 1892, these gentlemen, who are millers and bakers of London, were commissioned by the Secretary of State for India to grind some selected samples of wheat, and make baking tests on the resultant flours, and report generally on their milling and baking characteristics. The table on page 295 gives the results of their general milling tests. Reference is made to the baking tests in a subsequent chapter on flour testing.

AVERAGE COMPOSITION OF AMERICAN WHEATS.

No. of Analyses.	District where grown.	Weight of 100 grains.	Water.	Ash.	Oil.	Carbohydrates.	Cellulose.	Proteids.	Nitrogen.	Heaviest 100 grains.	Lightest 100 grains.	Highest Proteids.	Lowest Proteids.
		Grams.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Grams.	Grams.	Per cent.	Per cent.
260	United States and Canada	3·638	10·27	1·84	2·16	71·98	1·80	11·95	1·91	5·924	1·830	17·15	8·05
108	Atlantic and Gulf States ...	3·464	10·42	1·75	2·17	72·61	1·72	11·33	1·81	5·079	1·830	15·58	9·45
47	The Middle West	3·607	10·51	1·70	2·01	71·67	1·90	12·15	1·94	4·902	2·138	16·63	10·15
97	West of the Mississippi ...	3·806	10·04	1·99	2·22	71·12	1·87	12·76	2·04	5·924	2·561	17·15	10·15
8	The Pacific Coast	5·044	9·74	1·84	2·08	76·18	1·56	8·60	1·37	(5·745)	(4·253)	9·47	8·05
6	Canada	3·325	9·74	1·56	2·29	73·87	1·67	10·87	1·74	3·686	2·964	14·70	9·45
32	Pennsylvania	3·373	10·72	1·67	2·05	72·45	1·73	11·38	1·82	4·658	2·035	15·58	9·45
9	Maryland	3·597	10·52	1·75	2·09	72·25	1·74	11·65	1·86	5·079	3·075	14·53	9·80
11	Virginia	3·343	10·34	1·70	2·21	71·87	1·71	12·71	1·95	4·208	1·830	14·00	10·15
7	Georgia	3·597	10·00	1·96	2·30	72·24	1·72	11·78	1·89	4·627	2·834	14·00	9·45
22	North Carolina	3·776	10·03	1·59	2·25	73·94	1·76	10·43	1·67	4·628	2·780	12·43	8·93
17	Alabama	3·314	10·94	2·03	2·21	71·84	1·62	11·36	1·79	4·647	2·011	13·65	9·80
...	Michigan (Kedzie) ...	...	11·28	1·73	...	74·97	...	12·02	1·92	...	...	13·78	9·13
22	Michigan	3·969	10·71	1·64	2·06	72·12	1·80	11·67	1·87	4·902	3·402	15·23	10·50
8	Kentucky	3·454	10·83	1·75	1·87	70·37	2·03	13·15	2·10	3·666	3·146	14·53	11·90
14	Tennessee	3·150	10·19	1·89	2·00	71·33	2·02	12·51	2·00	3·990	2·138	16·63	10·15
12	Missouri	3·502	9·80	1·92	2·19	72·36	2·17	11·56	1·86	3·867	3·098	14·00	10·50
9	Minnesota	3·354	10·60	1·71	2·03	70·96	2·04	12·66	2·03	3·828	3·116	17·15	10·85
10	Kansas	3·201	11·80	1·64	1·98	71·35	2·08	11·15	1·78	3·424	2·881	12·25	13·50
19	Texas	2·847	10·03	1·81	2·11	70·85	2·06	13·14	2·10	3·937	2·561	15·23	10·68
45	Colorado	4·682	9·57	2·21	2·38	70·91	1·62	13·31	2·13	5·924	3·851	15·94	11·19
8	Oregon	5·044	9·74	1·84	2·08	76·18	1·56	8·60	1·37	5·745	4·253	9·47	8·05

MILLING TESTS—McDOUGALL BROTHERS.

WHEAT.	Value in London per 496 pounds net weight on day of valuation.		Weight per bushel	Impurities removed.	Water absorbed to render mellow.	YIELD.				Evaporation and Loss.	Gluten by Water Tests.
						Flour.	Middlings	Pollard.	Bran.		
	s.	d.	Lbs.	Per Cent.	Per Cent.	Per Cent	Per Cent.	Per Cent.	Per Cent.	Per Cent	Per Cent
Indian (Fine Soft White), ...	49	0	64	1·52	2·0	77·46	0·82	8·8	12·0	1·40	6·4
Do.	49	0	64	1·52	2·0	74·10	11·00	8·7	4·0	2·68	6·8
Indian (Superior Soft Red), ...	45	0	62¾	0·72	3·6	78·40	1·68	9·8	9·4	3·6	9·3
Do.	45	0	62¾	0·72	3·6	75·4	7·7	13·5	5·3	0·98	10·5
Indian (Average Hard White), ...	44	0	60	3·7	8·4	80·52	0·78	10·0	8·3	5·1	11·7
Do.	44	0	60	3·7	8·4	73·2	10·3	14·3	3·1	3·8	12·6
Indian (Average Hard Red), ...	43	0	61¼	1·2	7·6	79·88	0·78	13·20	8·50	4·04	13·4
Do.	43	0	61¼	1·2	7·6	74·2	10·3	13·8	3·0	5·1	13·1
English, ...	49	0	60½	1·5	None	65·2	1·1	9·7	17·7	4·8	10·6
Do.	49	0	60½	1·5	None	70·3	7·6	7·2	9·2	4·2	11·4
Australian, ...	50	6	62½	1·0	None	75·8	1·1	7·4	14·4	0·3	11·6
Do.	50	6	62½	1·0	None	75·1	8·0	9·3	5·5	1·1	12·2
New Zealand, ...	48	0	62¾	0·3	None	76·1	0·96	8·8	11·5	2·34	10·2
Do.	48	0	62¾	0·3	None	76·1	7·8	6·6	5·6	3·6	9·0
Californian, ...	48	0	59¼	1·7	None	71·1	0·72	9·2	15·3	1·98	10·5
Do.	48	0	59¼	1·7	None	70·1	14·5	6·3	3·9	3·5	8·7
American (Winter), ...	49	6	61¾	0·5	None	73·8	0·38	7·9	16·4	1·02	11·0
Do.	49	6	61¾	0·5	None	71·5	10·3	11·2	3·1	3.4	11·7
American (Spring), ...	48	0	61	0·9	None	72·2	0·24	7·2	14·7	4·76	15·3
Do.	48	0	61	0·9	None	69·5	12·1	10·4	3·8	3·3	14·6
Russian (Saxonska).	52	0	60½	0·9	None	73·0	1·2	11·6	12·6	0·7	22·1
Do.	52	0	60½	0·9	None	71·4	12·5	11·7	3·3	0·2	23·2
Russian (Hard Taganrog), ...	49	0	61¼	0·8	2·4	76·2	1·2	12·7	8·1	3·4	17·6
Do.	49	0	61¼	0·8	2·4	72·0	9·6	12·1	5·0	2·9	15·6
Egyptian (Buhi), ...	47	0	58	2·7	3·1	72·9	1·0	11·0	10·0	5·5	4·4
Do.	47	0	58	2·7	3·1	72·6	10·4	8·5	3·5	5·4	7·9
Egyptian (Saida), ...	43	6	57½	12·1	2·7	66·9	0·76	11·4	7·5	4·04	7·5
Do.	43	6	57½	12·1	2·7	67·8	7·2	6·5	4·9	4·2	6·6

WHEAT.			QUALITIES OF BREAD.			FLOUR YIELD %
Sort.	Colour.	Structure.	Flavour.	Strength.	Colour.	
English—						
Talavera, Chidham, Rough Chaff, Webb's Challenge, Hallett's Victoria,... ...	White	Soft, ...	Sweet, ...	Medium,	Choice,	68-74
Nursery, Red Lammas, Rivetts, Browick, Golden Drop, April,	Red,	,, ...	,,	,,	Good, ...	66-74
American—						
Duluth, Minnesota, ...	Red,	Hard, ...	Sweet, ...	Full, ...	Good, ...	70-73
Chicago, Milwaukee,... ...	,,	,, ...	,,	Good, ...	,,	68-72
Red Winter, ...	,,	Medium,	,,	,,	,,	70-75
Michigan, ...	White,	,,	,,	Medium,	,,	70-73
Oregon	,,	Soft, ...	Dry, ...	Low, ...	,,	70-73
Californian, Walla Walla, ...	,,	Brittle,	,,	,,	,,	70-75
Chilian, ...	,,	,, ...	,,	,,	Fair, ...	70-74
La Plata, Choice, ...	Red,	Medium,	Sweet and moist eating,	Fair to medium, makes a large and fine-grained loaf,	Good to fine—pale or bluish-white cast,	70-72
,, Secondary, ...	,,	,,	,,	Fair, inclining to softness from growy or sprouted wheat,	Good—tendency to bluish-white cast when loaf is cut,	68-70
Canadian—						
Red, White, ...		Medium,	Sweet, ...	Medium,	Good, ...	70-73
Manitoba, ...	Red,	Hard, ...	,,	Full, ...	,,	70-73
Australian, ...	White,	Medium,	Sweet, ...	Medium,	Choice,	72-76
New Zealand, ...	,,	Soft, ...	Sweet, ...	Low, ...	Good, ...	68-72
Egyptian,...	Mixed,	Medium,	Unpalatable	Low, ...	Fair, ...	68-71
Persian, ...	,,	Brittle,	Dry, ...	Low, ...	Fair, ...	68-72
Indian—						
Bombay, Kurrachee, Delhi,...	White,	Flinty,	Dry, Ricy,	Medium,	Fair, ...	68-75
Calcutta, ...	Mixed,	,, ...	,,	,,	,,	68-74
Baltic—						
Dantzic, Königsberg, Rostock	White,	Soft, ...	Sweet, ...	Good, ...	Good, ...	68-73
,, ,, ,,	Red,	,, ...	,,	,,	,,	68-73
Saxonska, ...	,,	Hard, ...	Dry, Sweet	Full, ...	,,	68-74
Kubanka, ...	Yellow,	Hard, Flinty,	,,	Good, ...	,,	70-72
Russian—						
Odessa, Nicolaieff, Nicopol, Tagaurog, Crimean, Marianople, Azima and Ghirka	Red,	Hard,	Dry and Strong,	Full, ...	Fair, ...	66-73
Berdianski, ...	,,	Medium,	,,	Good, ...	,,	66-73
Polish,...	,,	,,	Sweet, ..	,,	,,	66-73
Turkish—						
Danubian, Salonica, ...	Red,	Medium,	Dry, ...	Low, ...	Fair, ...	66-73
Varna,...	,,	Hard, ...	,,	Good, ...	,,	66-73
Hungarian, ...	Red,	Hard, ...	Dry, ...	Full, ...	Good, ..	70-73

IMPURITIES PRESENT.			GENERAL REMARKS.
Regular.	Occasional.	Per cent.	
Chaff, round seeds,	Smut, wild oats, garlic, barley,	0·5–3·0	Group of fine quality whites; usually clean and reliable in working. Named in order of merit; a group of well-known red sorts.
Cockle and other round seeds, chaff, screenings, fragments of iron, grass seeds,	Smut, garlic, stone, dirt, oats, barley,	2·0–8·0	Spring wheats, usually of great strength; loss in cleaning very variable; grind well. A thoroughly reliable good milling sort. Useful in mixtures for colour & sweetness.
Chaff, straw, barley, oats, seeds,	Smut, stone, ...	1·0–5·0	A variable quality; colour often choice.
	Do., scented seeds,	1·0–4·0	Helps in grinding softer wheats; always dry.
Stone, chaff, seeds, barley, oats,	Smut, ...	1·0–5·0	Care needed in buying; quality very variable.
Barley, oats (chiefly black), smut, dirt, round seeds, and screenings,	Stone, poppy seed, burnt grain, garlic,	3·0–6·0	Flour may be dressed very fine with advantage to appearance of loaf. May replace fine native or soft red foreign sorts. When well cleaned and milled, will yield flour as white as can be obtained from any other No. 1 wheats. Valuable in making straight-grade flours.
”	”	5·0–10·0	The best cheap substitute for native wheat. Useful to replace Red Winter American, Canadian, and soft Russian or Danubian. Grown grains to be expected in all parcels.
Same as spring and winter American,	Same as spring and winter American,	1·0–5·0	Of sweet and reliable quality as a rule. Nearly approaches Duluth in general quality.
Chaff, straw, barley, and oats,	Stones, smut, ...	1·0–3·0	One of the very best colouring wheats; grinds well.
Chaff, round seed, ats, barley,	Dirt, smut, ...	1·0–3·0	Generally softish grown wheats to be expected.
Dirt, stones, seeds, ats. barley,	Smut, garlic, ...	5·0–12·0	Poor lifeless stuff, very little used.
	Smut, ...	3·0–10·0	Quality very indifferent generally.
Weevils, stone, chaff, straw, dirt, pease, ound seed, linseed,	Oats and barley, ...	3·0–12·0	Some of the best whites are useful. Generally costs a lot to clean.
Chaff, round seeds,	Oats, barley, smut, garlic, stone, dirt, rye,	1·0–5·0	A nice clean group; generally produces white sweet bread. Good whites most useful. When really good, a most valuable strong wheat. Characterised by great hardness of grain.
ye, cockle, and ther round seeds, haff, dirt,	Oats, barley, stone, smut,	3·0–12·0	Of these the best usually come from the Crimea (Sebastopol, Eupatoria), and Marianople. Rye and round seeds cause much loss. Useful as strong wheats to replace Spring American. Quality very variable.
ye, cockle, oats, arley, chaff,	Dirt, stone, smut,	5·0–12·0	Low quality sorts, uncertain in working.
ckle, chaff, seeds, oats,	Dirt, stone, smut,	3·0–8·0	Sometimes of excellent quality, and clean.
ckle, chaff, seeds, oats,	Smut, dirt, ...	1·0–3·0	Superior quality strong wheat.

403. Voller on Wheats.—The table on pages 296-7, headed "Dictionary of Wheat, is taken from Voller's excellent work on "Modern Flour Milling." It is particularly valuable as a succinct record of the milling and baking characteristics of the most important wheats and their flours to be found on the British market.

Voller also gives some useful rules as to selection of wheats for different characters, and also a table of mixtures equivalent to certain single wheats, which may be used to replace the latter on their becoming exhausted. Thus—

For largest loaf, *use* good Minnesota or Duluth, run very close by fine Saxonska or Azima.
For whitest flour, *use* good White English, Oregon, and Australian, with choice for the latter.
For sweetest bread, *use* good English and good Dantzic.

The following are examples of replacing mixtures:—

Single Wheats.	May be replaced by
2 Chicago,	1 Duluth. 1 Red Winter.
2 Red Winter,	1 Duluth. 1 Michigan.
3 Spring,	2 Saxonska. 1 Red Winter.
1 Saxonska,	1 Ghirka, Azima, or Polish.
2 Australian,	1 Californian. 1 White English.
2 Californian,	1 Australian. 1 Chilian.
2 Red Winter,	1 Dantzic. 1 Canadian.
2 Californian or Australian,	1 White Bombay. 1 White English.
2 Medium Indian,	1 Californian. 1 Azima.
2 La Plata,	1 Walla. 1 Calcutta, No. 2.

CHAPTER XV.

CHEMICAL COMPOSITION OF FLOUR AND OTHER MILLING PRODUCTS.

404. Physical Properties of Flour.—In addition to its purely chemical composition, flour possesses certain physical properties which are of the highest importance to the baker, and consequently to the miller. These are "Colour" and "Strength." Flavour may also be mentioned, but this is essentially rather a matter of the palate than of chemical analysis, hence a judgment of the flavour of flour is best made by the actual consumer. These three properties of Colour, Strength, and Flavour, together with certain side issues connected with them, largely, if not entirely, determine the commercial value of a sample of flour. For scientific purposes it is necessary to have not only means of judging and comparing these, but also some method of registering for future reference, and for the institution of comparisons between the results obtained by one observer and those of another. In order to do this, these properties must in some way be expressed numerically.

The whole subject of these various measurements is exhaustively discussed in a subsequent chapter on Flour-Testing, but as in this section a number of analyses are quoted, in which estimations of colour, &c., are inserted, a brief mention is here made of the principle of the method by which these have been judged.

405. Colour.—Every miller and baker will be acquainted with the ordinary method, devised by Pékar, of determining the colour of a sample of flour by compressing a small quantity into a thin cake or slab, which is wetted and allowed to dry. The depth and character of the colour are then observed. This test has been in use for some time, and answers admirably the purpose of comparing the relative colour of two or more samples. In some of the earlier tests here quoted the author employed graduated scales of colour prepared by himself: the one of a yellow tint, for comparison with high-class flours; the other grey, for estimations on flours of the lower grades. The nearer the colour approaches white, the less the number assigned to it on the scale. Thus the Grey Scale starts with a very light tint, marked "1," and finishes with a dark tint, marked "16." The whole of the tints have an intensity proportional to their number; thus No. 2 is exactly twice as dark as No. 1, while No. 8 is four times as dark as No. 2.

The Yellow Scale, being intended for patent flours only, is not extended so far as the Grey Scale. It is difficult to compare the two scales with each other, because the colours are dissimilar; but, in intensity, No. 1 yellow is about equal to 1½ grey; No. 10 yellow is three times as dark as 1 yellow, and about equal in intensity to 4½ grey. The colours deepen in intensity by regular intervals from No. 1 to No. 10 yellow.

In using these scales for testing purposes, it was found that in some samples the colour was intermediate in character between the two scales; thus, some flours were grey, with just a tint of yellow; others were very nearly like the Yellow Scale, but rather grey beside it; these properties were indicated by the use of two letters, thus "7·5 G.Y." This means that the flour approached 7·5, on the Grey Scale, in depth of tint, but that it was rather yellower than the scale, but still nearer the grey than the yellow series of tints. On the other hand, 6 Y.G. means that the colour was matched and numbered on the Yellow Scale, but that it was somewhat grey in character.

406. Strength.—This particular term is sometimes employed with different meanings by various handlers of flour. In former works by the author on this subject, he used it as meaning a measure of the water-absorbing power of the flour, and explained that the term "Strength is also sometimes used as the measure of the capacity of the flour for producing a well-risen loaf." In deference to the fact that its employment in this latter sense is the more general, the author also adopts the same definition, especially as the term "water-absorbing power" is very convenient, and in itself explanatory. **Strength, then, is defined as the measure of the capacity of the flour for producing a bold, large-volumed, well-risen loaf.** It is in this sense that the word is throughout used in the present work. Unfortunately at present there is no very satisfactory method of numerically registering strength except through a baking test, when the actual volume or girth of the loaf may be measured. Inferentially, the strength of a flour may be deduced from the character and quality of the gluten.

407. Water-Absorbing Power.—The water-absorbing power of a sample of flour is one of the most important properties it possesses, and its determination is of the utmost importance to both miller and baker. It not only governs the yield in bread of the sample, but also affords evidence of its other qualities, especially its soundness. For if with any particular variety of wheat the water-absorbing power of the flour falls below the average, there is every probability that the wheat is through some cause unsound. Hence, water-absorbing determinations are valuable in several respects. Although not always applied in precisely the same sense, for our present purpose, **Water-absorbing power may be defined as the measure of the water-absorbing and retaining power of the flour, or of the water absorbed by the flour in order to produce a dough of definite consistency:** it always being understood that the dough shall be capable of yielding a well-risen and properly cooked loaf without clamminess.

When in the following analyses the water-absorbing power is quoted, the figures give the number of quarts of water per sack (280 lbs.) of flour required to produce a dough of a standard stiffness. The standard employed is an arbitrary one, based on results obtained with the author's "viscometer" (see Flour Testing, Chapter XXI.), and practically corresponds in stiffness with a very slack "cottage" dough.

408. Composition of Roller Milling Products.—Now that milling has become an art in which the wheat is changed into flour and offal, not by one but by many operations, it is a matter, not only of interest, but of importance, that it should be known where the constituents of the wheat go as each successive step in gradual reduction is taken, and as the resulting products are gradually purified and separated into flours of different qualities and offals.

Early in 1885 the writer personally collected thirty-four samples from a large roller mill recently erected by Mr. J. Harrison Carter, the well-known milling engineer, who has taken much interest in the progress of these experiments, and has rendered the writer great assistance in obtaining the samples and prosecuting his research.

The subjoined table gives the moisture, soluble extract, soluble proteids, wet and dry gluten, fat, cellulose, ash, and phosphoric acid of each sample, and also the colour of the flours, according to the scale already described. The results contained in the table are set out graphically in the two page diagram, Fig. 41, inserted on pages 312-3.

The wheat mixture in use was composed of three parts Winter American, one part Spring American, and two parts of Californian ; it weighed 64 lbs. per bushel.

COMPOSITION OF ROLLER MILLING PRODUCTS.

DESCRIPTION.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Ash.	Phosphoric Acid.	Fat.	Colour.	Cellulose.
				Wet.	Dry.	Ratio.					
Wheat Mixture as it goes on to Grader	12·09	5·18	1·38	17·00	6·04	2·9	1·53	0·78	1·582	...	3·06 3·10
Mixed Tailings from Scalpers, all grades, from First Break	11·69	5·40	1·40	17·00	6·25	2·7	1·60	0·69	1·586	...	3·56
Tailings from Second Break	11·53	4·28	1·34	17·70	6·90	2·6	1·60	0·78	1·800	...	4·44
,, Third ,, ...	11·18	5·20	1·52	19·00	7·12	2·6	1·49	0·77	1·686	...	4·20
,, Fourth ,, ...	11·29	5·38	2·15	18·50	7·19	2·5	2·20	0·60	1·588	...	5·20
,, Fifth ,, ...	11·49	5·96	2·08	16·00	6·00	2·6	3·07	1·03	1·892	...	7·72
,, Sixth ,, ...	11·35	7·54	2·22	None recoverable.			3·98	1·32	2·226	...	10·98
,, Seventh ,, (Bran dusted)	11·39	9·80	2·33	None recoverable.			5·78	2·27	3·320	...	14·60
Middlings from First Break	11·87	4·64	1·00	14·50	5·07	2·8	1·26	0·57	1·552	...	3·50
*Coarse Semolina from Second and Third Breaks ...	12·60	4·00	0·94	15·50	5·72	2·7	1·00	0·22	1·260	...	3·72
*Coarse Middlings from Second and Third Breaks ...	12·52	3·74	1·94	19·50	7·78	2·5	0·78	0·08	1·278	...	1·52
*Coarse Semolina from Fourth and Fifth Breaks ...	12·20	2·96	1·16	17·50	6·37	2·7	1·07	0·37	1·484	...	2·64
*Coarse Middlings from Fourth and Fifth Breaks ...	12·52	3·02	1·06	23·30	8·14	2·8	0·54	0·12	1·072	...	1·26
Flour from First Break, dressed through No. 8 Silk ...	11·94	4·25	1·60	8·20	3·11	2·6	0·73	0·43	1·222	...	1·28
Flour from Second and Third Breaks, mixed, dressed through 11 and 12 Silks	11·64	3·26	1·24	16·50	6·00	2·7	0·43	0·15	1·160	10·0G.	0·74
Flour from Fourth and Fifth Breaks, mixed, dressed through 11 and 12 Silks	11·48	3·32	1·56	19·70	6·87	2·9	0·49	0·27	0·406	4·0G.	0·64
Flour from Sixth Break	12·30	3·60	1·16	23·20	7·85	2·9	0·49	0·22	1·048	5·5G.	0·46

* After being dusted and before going to Grader.

COMPOSITION OF ROLLER MILLING PRODUCTS—*Continued.*

DESCRIPTION.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Ash.	Phosphoric Acid.	Fat.	Colour.	Cellulose.
				Wet.	Dry.	Ratio.					
Bran Flour from Bran duster	12·26	3·70	0·84	23·50	8·60	2·7	0·80	0·35	1·396	16·0G.	0·36
Mixed Yield of Front Spouts of Carters' Wind Purifier, when treating Coarse Semolina	12·49	2·53	1·34	20·00	7·14	2·8	0·49	0·27	0·542	...	0·96
Mixed Yield of Middle Spouts of ditto	12·00	4·24	1·04	14·00	5·48	2·5	1·09	0·54	0·770	...	...
Mixed Yield of Back Spouts of ditto	12·06	8·26	2·22	None	recoverable.		3·42	0·31	2·442	...	...
†Mixed Yield of Front Spouts of Wind Purifier, when treating Coarse Middlings	12·31	2·84	1·12	23·00	7·71	2·9	0·48	0·25	0·124	...	1·28
Mixed Yield of Middle Spouts of ditto	12·20	3·79	0·86	20·50	7·05	2·9	0·21	0·16	0·534	...	2·34
Mixed Yield of Back Spouts of ditto	11·89	6·68	2·00	None	recoverable.		2·08	0·78	1·536	...	11·46
Flour from †	12·33	3·39	0·76	21·00	7·19	2·9	0·20	0·16	0·400	3·4G.	0·52
Straight Grade Flour	12·03	3·88	1·60	23·00	8·54	2·7	0·22	0·12	0·252	4·5G.	0·34
Patent Flour	11·95	2·96	1·36	20·00	6·51	3·0	0·32	0·23	0·034	3·6G.	0·43
Households or Bakers' Flour	12·04	3·96	1·63	25·00	8·89	2·8	0·32	0·17	0·112	5·9G.	0·46
Fine Sharps (Seconds)	11·14	7·38	1·66	19·00	7·00	2·7	1·17	0·30	1·920	...	2·74
Coarse Sharps (Thirds)	11·60	12·14	2·96	5·65	2·64	2·1	3·04	0·47	3·610	...	7·18
Rolled Sharps, after being dusted	11·37	14·95	3·92	None	recoverable.		4·73	2·20	4·944	...	...
Finished Bran	12·11	9·33	1·20	None	recoverable.		6·77	3·89	1·534	...	18·30
Flattened Germ	11·42	33·30	11·76	None	recoverable.		4·17	2·43	9·076	...	3·62
Pocket Stuff from Reduced Middlings in Smith's Purifier	12·30	4.63	1·34	17·00	6·03	2·8	0·48	0·27	1·220	...	0·84

409. Explanation of Diagram.—This diagram, Fig. 41, pages 312 and 313, was arranged and set out by Mr. Zimmer, milling engineer, whom the author supplied with the data contained in the foregoing table; to Mr. Zimmer belongs the credit of setting out in so clear and admirable a manner the tabulated and analytical results: the author takes this opportunity of expressing his thanks to him for the valuable assistance so kindly rendered.

Each substance analysed is therein represented by a large square: this is in its turn divided by fine ruled lines into 100 smaller squares. Each of these small squares may therefore be said to represent 1 per cent. of the whole. The different constituents estimated are each indicated by particular marking; thus, water is shewn by horizontal lines. All soluble matter is ruled diagonally, with lines descending from right to left; these and the other rulings are explained on the diagram itself. In making the analyses, soluble ash was not estimated; but as that body is present in the extract it had to be allowed for; this was done by assuming that 0·6 per cent. of wheat ash is soluble in water: that proportion of the ash is in every case calculated as soluble; then the soluble extract, less the soluble ash and proteids, is assumed to consist of dextrin and sugar. It would have been preferable to have made direct estimations of the ash in the soluble extract, but this idea did not occur until after the completion of the whole series of analyses. The spaces left blank represent the difference between the total of directly estimated constituents and 100, the difference being made up by starch, indeterminate proteids, &c.

In each square the constituents are arranged in the following order:—

Water.
Soluble Proteids (or Albuminoids). Gluten.
Dextrin and Sugar.
Soluble Ash. Insoluble Ash.
Fat.
Cellulose.

The general arrangement of the squares will be easily understood by all who are familiar with a milling engineer's "*modus operandi.*" The clean wheat is placed in the top left hand corner; this goes to the first break, and is there split up into middlings, tailings, and flour. The similar products of each break are arranged in three vertical columns. The middlings and semolinas are dressed over Carter's wind purifiers: the products of the various spouts being shown. No attempt is made to illustrate the further reduction and purification of these compounds; the flours resulting therefrom, in common with the break flours, produce straight grade flour, which again splits up into patent and bakers' flours. The composition of the germ and other offals is also illustrated.

410. Tailings.—Studying first the tailings from each break, the moisture contained is somewhat less than that of the wheat; this is doubtless the result of the heat evolved during the milling. The soluble extract, soluble proteids, ash, phosphoric acid, fat, and cellulose gradually increase; this follows from the fact that more and more of the endosperm is being removed at each break, the tailings being gradually reduced to simple bran. The gluten at first somewhat increases; this is due to the semolina and flour of the earlier breaks being made chiefly from the heart of the grain. The portion of endosperm nearest the bran contains the most gluten, and so that constituent rises, until at the fifth break there is a slight fall; but from the tailings of the sixth and seventh break no gluten is recoverable. That, in the sixth break tailings, gluten is nevertheless present is shown by the quantity which is obtained from the bran flour.

411. Break Flours.—Glancing at the break flours, that from the first break contains very little gluten, but high quantities of cellulose and ash. The second and third break flour is somewhat richer in gluten, but is very low in colour. The fourth and fifth break flour is low in gluten, but much better in colour. The sixth break flour falls off in colour, but is higher in gluten. The seventh break or bran flour is high in gluten and fat, low in soluble extract, and specially so in colour.

412. Middlings and Semolinas.—The middlings from the first break contain a fair amount of gluten, but the fat and cellulose are very high. The first break middlings and flour are treated as offal, and are at this stage finally separated from the other products of reduction. The granular products of the second and third breaks are separated into "coarse semolina" and coarse middlings, the latter being the finer of the two. These consist of fragments of the endosperm mixed with small pieces of offal, composed principally of broken bran. The products of the fourth and fifth breaks are also similarly divided. The coarse semolinas from the whole four breaks then go together to a set of Carter's wind or gravity purifiers, and are separated into three products according to their density. The densest of these three is the nearly pure broken endosperm; the middle is a mixture of endosperm and branny matter; while the back spouts yield only very fine branny offal. The coarse middlings from the whole four breaks are likewise similarly treated over another set of purifiers.

Considering first the coarse semolinas, that from the second and third breaks is lower in gluten than that from the fourth and fifth. It is also higher in fat, but lower in cellulose. The bran fragments are found more plentifully in the second and third break semolina, while the germ finds its way into that of the fourth and fifth breaks. The coarse middlings, in each case, are richer in flour-forming constituents, consisting of more nearly pure fragments of endosperm; those from the latter pair of breaks being the richer of the two. The next point is the nature of the respective products of the separation effected by the gravity purifiers on the coarse semolinas. Passing reference has already been made to those bodies. The densest bodies, which consequently find their way into the front spouts, contain a good proportion of gluten, the fat and cellulose being high. The material of the middle spouts also contains a considerable quantity of flour forming compounds, but no gluten was recoverable from the yield of the back spouts. The series of purifiers treating coarse middlings yields from the front spouts purified middlings, containing very little matter foreign to flour—the gluten is high, while ash and fat are low—the cellulose is somewhat high. The arrangements of the mill permitted of the taking of a sample of flour that was being made from these purified middlings only; its analysis is given in the table, but is not shown on the diagram. This flour is lower in gluten than the straight grade, but is better coloured than even the patent. The middle spouts give a material low in ash, but higher in cellulose, than the corresponding yield of the purifiers treating coarse semolinas. The back spouts product yields no gluten, but a high proportion of fat, and particularly of cellulose.

413. Flours.—The whole of the flour from the various breaks, and the reductions of the semolinas (excepting those of the first break), go to form the straight grade flour: this constitutes the whole of the marketable flour produced by the grain. The water of the straight grade flour is almost identical with that of the clean wheat: the soluble extract is lower, but the soluble proteids run slightly higher. The gluten is much higher, amounting to 8·54 against 6·04 per cent. The ash and phosphoric acid, 2·05, have decreased considerably; falling from 1·53 and 0·78 to 0·22 and 0·12. The fat and cellulose follow suit, falling from 1·582 and $\left\{ \begin{array}{l} 3{\cdot}06 \\ 3{\cdot}10 \end{array} \right.$ (duplicates) to 0·252 and 0·34. The colour is 4·5 G., being exceedingly good for a straight grade flour. This straight grade was divided into a small percentage of "Patent," and a "Households" or "Bakers'" flour. The patent flour contains rather less water than the straight grade; also less gluten and fat. The cellulose of the patent flour is slightly higher than that of the straight grade. The households flour is considerably richer in gluten, but in other chemical constituents closely resembles the patent. The quantities of fat, ash, phosphoric acid, and cellulose, are in each exceedingly small, so that but little difference is observed between either of the three flours. The cellulose of flour is in so finely divided a condition that the difference in texture of two filter papers might make a perceptible difference in two cellulose estimations in the same sample. There is not the marked difference in quality between the patent and households flours observable sometimes: the households has, in fact, not been impoverished in order to produce a quantity of a very high-class patent flour. In colour the patent stands at 3·6 G., the straight grade at 4·5 G., and the households at 5·9 G.

414. Offals: Fine Sharps.—This material, also sometimes termed "seconds," looks as good as what one sometimes sees sold as flour. It contains a considerable quantity of gluten, 7·0, more in fact than some of the flours: but as might be expected, the fat, ash, and cellulose are high. The soluble extract is also very high.

415. Coarse Sharps, or Thirds.—These also contain gluten, but only a very small amount, 2·64. The soluble extract and proteids are very high, so also are the fat and cellulose.

416. Rolled Sharps.—These are not included in the diagram. The soluble extract and proteids are even higher than in the preceding; ash, phosphoric acid, and fat are also high.

417. Bran.—The bran presents several very interesting matters for observation: as might be expected, gluten is absent, and cellulose is very high, amounting to over 18·30 of the whole substance. The bran also yields more ash and phosphoric acid than any other portion of the grain. In the diagram the ash is divided, as in the other analyses, into a soluble and insoluble portion, calculated on the assumption that 0·6 per cent. of ash is soluble. With regard to bran, it was thought worth while to make an additional estimation of the amount of ash actually present in the soluble extract; the result of this analysis gave 2·61 per cent., being considerably lower than the estimate contained in the diagram. It does not follow that if the burned ash were treated with water that a larger percentage would not be dissolved. The explanation is that the physical condition of the bran, in broad flakes, is such that, whatever soluble matters are locked up within it, they do not yield themselves to treatment with water. This is exemplified in the case of the soluble extract and proteids: compared with the rolled sharps the bran yields but 9·33 and 1·20 respectively, against 14·95 and 3·92 in the sharps. Another sample of the bran was treated with water for 24 hours, and then the soluble extract and proteids determined—the results were 13·1 and 2·2 per cent., still being less than in the sharps. These figures afford additional proof of the fact that whatever soluble constituents the bran may possess, they do not readily yield themselves to water as a solvent: that this is due to the physical condition is shown by the sharps, which also consist of the integument of the grain, yielding so much more soluble matter, the principal difference simply being that the latter is much more finely broken. The albuminous matter of the bran consists largely of cerealin, with which the large cuboidal cells of the inner bran are filled. This body is actively diastasic, but is altogether devoid of gluten-like properties.

418. Fluff.—A sample of this was collected from the pockets in Smith's purifiers; the cellulose is higher than that of flour, to which the fluff is somewhat similar in appearance. It contains a fair amount of gluten, and also of fat. In appearance this substance looks as though it contained a good deal of the parenchymatous cellulose of the endosperm of the grain. On consulting figure 30 it will be seen that the starch granules are held together in larger cells by walls of cellulose; these walls most probably find their way into the fluff and stive dust.

419. The Germ.—This most interesting body differs remarkably in composition from the other parts of the grain. The percentage of contained water is somewhat low, but the soluble extract is remarkably high, amounting to just one third of the whole of the body as removed in the modern processes of roller milling. Of the soluble extract, 11·76 per cent. consists of soluble proteids as estimated by the "albuminoid" ammonia process. There is no gluten recoverable. The ash and phosphoric acid are high; the fat also is much higher than in any other part of the grain, amounting to 9·076 per cent. Even this amount is less than that yielded by some samples examined by the author, from which as much as 12 per cent. of fat has been obtained. The cellulose is moderately high.

Detailed analyses of germ have been made from time to time; there follow results of such analyses made respectively by Tatlock of Glasgow, Richardson, and the author:—

ANALYSES OF GERM.

	RICHARDSON.		TATLOCK.		JAGO.	
	Per cent.	Per cent.		Per cent.		Per cent.
Water,	...	8·75	...	11·52	...	13·23
Ash,	...	5·45	...	3·96	...	4·94
Oil,	...	15·61	..	5·40	...	12·03
Soluble in 80 per cent. alcohol,	26·45	...	...	...	...	...
Insoluble in water,	...	1·98	...	...	Dextrin,	1·24
Soluble in water,	25·47	...	Gum & Sugar,	9·72	Maltose,	5·54
Sugar or Dextrin,	...	18·85	...	...	...	...
Non-reducing substance,	...	2·94	...	...	...	...
Proteids,	...	3·65	...	...	...	...
Soluble in water,	4·44	...	...	...	...	...
Dextrin,	...	1·44	...	...	...	...
Proteids,	...	3·00	...	...	...	...
Starch, &c., undetermined,	...	9·95	..	40·76	...	33·78
Cellulose,	...	1·75	...	5·96		
Insoluble Proteids,	...	26·60	Total protds.,	22·68	Sol. protds.,	15·51
					Insol. protds.,	13·73
		100·00		100·00		100·00

The sample of germ examined by Tatlock was an impure one, the analysis having been made in the earlier days of roller milling. That examined by the author was from a fine sample of Minnesota wheat. The water, ash, and oil were determined by the usual methods. The dextrin and maltose were determined by making an estimation of the copper oxide reduced from Fehling's solution by the aqueous extract, and also taking a polarimetric reading of the solution. The angular rotation due to maltose was calculated from the copper oxide precipitate, and then the rotation over that amount was calculated as being due to dextrin. These quantities are very low, compared with the high soluble extract obtained on making a direct estimation of the portion of the germ dissolved by water. It is probable that a large portion of the sugar of the germ does not reduce Fehling's solution, and so would not be estimated in the way just described. A 10 per cent. solution of the germ in cold water had an angular rotation of + 2·0° in a 20 centimetre tube, with sodium light. The starch and cellulose were undetermined, the results given being obtained by difference. The total proteids were determined by a nitrogen combustion; in order to estimate the soluble proteids, 600 c.c. of 1 per cent. aqueous infusion were evaporated to dryness, and a combustion made on the residue. The difference between the total and the soluble proteids is reckoned as insoluble proteids.

As one of the objects of modern milling is to thoroughly remove the germ from flour, the actual effect produced by germ, when present, is a subject of great importance. An account of some experiments on mixtures of germ and flour is given later in this chapter.

420. Richardson's Analyses of Products of Roller Milling.—Clifford Richardson, Chemist to the Department of Agriculture of the United States Government, has made a most important and exhaustive series of analyses of products of roller milling. Richardson selected samples from three mills; the first being from Messrs. Pillsbury's mill at Minneapolis, where a straight run of spring American wheat is used; the second, Messrs. Herr and Cissel's mill, who employ soft winter wheat; and the third from the mill of Messrs. Warder & Barnett, of Ohio, who use all red winter wheat. These analyses, the results of which are tabulated on pages 314-315, 316-317, are of such great value as to warrant their quotation, together with the remarks thereon, in full.

421. "Interpretation of the Analyses.—The wheat as it enters the mill is subjected to a series of operations which removes dirt, foreign seed, the fuzz (beard) at end of the berry, and a certain portion of the outer coats, through the agency of a run of stones and brushes. The result of this operation is to lower the amount of inorganic matter or ash, and to increase or decrease the other constituents but slightly, the proteids being a few tenths of a per cent. greater in amount. The point from which a convenient start may be made is at the first break.

"The chop from the first rolls is very marked in its difference in composition from the original wheat. It, of course, has less fibre (cellulose), and also it is seen, less ash, oil, and proteids; in fact, it is starchy. It contains more water, owing to the fact that its comminution has allowed it to absorb the moisture from the air, and in general it will be observed that the coarser or more fibrous a specimen is, the less water it contains, while the finer material holds more. For example, the percentage of water in several portions of grain are as follows:—

	Per cent.
Original grain, ...	9·66
Ready for the break, ...	8·23
Chop from first break, ...	12·52
Fifth break, ...	7·62
Bran, ...	10·91

"The heat caused by the friction of the process, of course, is an active agent; as may be seen on comparing the original grain and that ready for the break. The question of the relation of the various products to humidity is, however, considered in greater detail in another portion of these remarks.

"The starchy chop from the first break is carried off to the various purifying and grading machines, but for the present it will be left, as it is desirable to follow the breaks to the end.

"The tailings from the first scalper, consisting of the wheat grain split open along the crease, which serve to feed the second break after the cleaning which they undergo, vary but little from the wheat which goes to the first break. There are slight differences which must be attributed to the difficulty of selecting and preparing for analyses samples of the product of the different breaks, the finer chop having a tendency to sift out from the lighter bran; but they are not great enough to vitiate the conclusions. In the first break so little is done, except to crack open the wheat and clean it for the following rolls, that only a small change should be expected.

"The chop from the second break is more from the centre of the wheat grain. It contains less ash, fat, and proteids than any of the break products, and includes, as was shown by our preliminary investigation, the greater portion of the endosperm.

"The tailings supplying the third break already show, owing to the greater amount of chop produced on the second break, a marked increase in those constituents which are peculiar to the outer portions of the grain, that is to say, there has been a marked increase in ash, fibre, and proteids. This increase becomes still more apparent from break to break, until the bran alone is left, which contains more ash and fibre than any other product of the wheat. The several chops increase in a like manner, the last or sixth break chop holding more proteids than the bran, and even any other of the resulting material. This is probably due to the comminution of the bran in the last break, and consequently, as will be seen, the middlings from this chop are richer in nitrogen than any other, although not the richest in gluten, owing to the proportion of bran and germ which they contain.

"Having followed the grain through the breaks to the bran, the products of the purification of the chop remain to be studied.

"The shorts or branny particles removed from the chop, or from the middlings, by aspirators, contain much less fibre and ash than the bran, although they are of similar origin, that is to say, from the outer coats of the grain. The analyses point to their origin from those portions of the coat which contain less ash and fibre.

"The middlings are graded into five classes, and in their original uncleaned state they differ chemically in the fact that from No. 1 to No. 5 there is a regular decrease in ash, fibre, and fat, while No. 5 is richer in proteids than any other. This would be expected from our preliminary examination, which showed a decrease in bran from beginning to end, and that No. 5 was the purest endosperm.

"After cleaning, the same relations hold good, but owing to the removal of the branny particles there is in all cases a loss of ash constituents and fibre. The effect of cleaning is more apparent in Nos. 1 and 2 where more bran is removed.

"The reduction of the middlings on smooth rolls changes the composition but slightly, and the flours which originate from this process are very similar to the middlings from which they were produced. That from the fourth reduction is richer in nitrogen, as would also be the case with the fifth, although want of a specimen prevented analysis.

"The tailings from the middlings purifiers present the usual characteristics of bye products, which owe their existence to the outer part of the grain, with its high percentages of ash and fibre, and, in this case, also of nitrogen. It is remarkable, however, that the tailings marked No. 6 contain only one-third as much ash as the others; but this is explained by the fact that they are largely composed of endosperm.

"The tailings from the different reductions are nearly alike in composition, with two exceptions. Those from the fourth contain little of ash fibre and nitrogen. Like No. 6 of the purifier tailings they consist largely of endosperm. Those from the second reduction contain much germ, and are, therefore, richer in nitrogen than the rest.

"The repurified middlings, as might be expected, contain much more ash, oil, and fibre, than the original, and there is also an increase in nitrogen, but not in gluten, owing to the large amount of bran they contain.

"Analyses of three grades of flour as furnished to the market follow. From a cursory glance it might be said that the low-grade flour was the best, as it contains the most proteids, but its weakness is discovered in the fact that it has only 4 per cent. of gluten. The bakers' flour contains more ash, oil, fibre, proteids, and gluten, than the patent; but owing to the increased amount of the first three constituents mentioned, it is proportionately lacking in whiteness and lightness. The two flours each have their advantageous points.

"Several other grades of flour, break flour, stone flour, and flours from the first, second, and third tailings, are all very similar, and, as far as chemical analyses is concerned, good. The preliminary examination has, however, shown certain defects in each. The break flour is richer in proteids and gluten than any other, and if it were pure, and its physical condition were good, it would be of value.

"The roller process is distinguished for the completeness with which it removes the germ of the grain during the manufacture of flour by flattening and sifting it out. This furnishes the three bye-products which are known as first, second, and third germ. They consist of the germ of the wheat, mixed with varying proportions of branny and starchy matter, the second being the purest. They all contain much ash, oil, and nitrogen; and if allowed to be ground with the flour, blacken it by the presence of the oil, and render it very liable to fermentation, owing to the peculiar nitrogenous bodies which it carries.

"The flour from the bran dusters is much like that from the tailings, and like the stone stock, from a chemical point of view. This merely shows that chemical evidence should not alone be taken into consideration, for the bran-duster flour is a dirty, lumpy bye-product, while the stone stocks are valuable middlings. Analyses of various tailings are next in the series, and need no comment. Those of the dust from middlings and dust-catchers are rather surprising, in that they both contain much gluten, and the first one much fibre; but this is due to their containing both bran and endosperm.

"To follow the gluten through the process it is necessary to go back to the breaks. The amount in the various chops does not vary greatly. There is an apparent anomaly, however, in the fifth and sixth breaks, where no gluten was found in the feed, but much in the chop. This is owing to the fact that the feed has become at this point in the process so branny that by the usual method of washing to obtain the gluten it does not allow of its uniting in a coherent mass, and separating from the bran.

"Among the middlings, both uncleaned and clean, the fourth is the richest in gluten, and the result of the process of cleaning is to increase the amount, although slightly diminishing the nitrogen, which is due to the removal of the branny matter, which, though rich in nitrogen, is poor in gluten.

"In the products of the reduction on smooth rolls, the chops from the

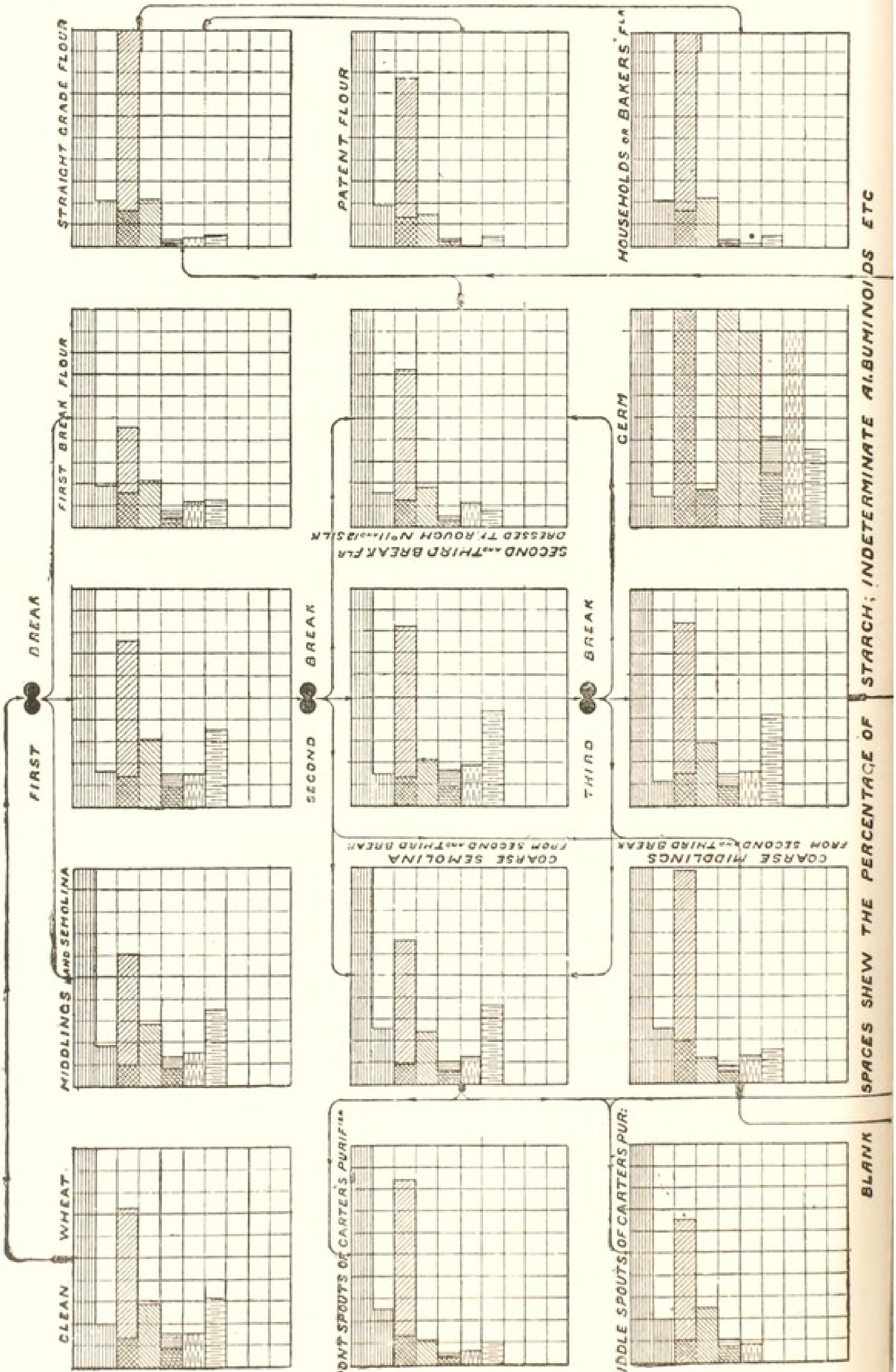

FIG. 41.—COMPOSITION OF ROLLER MILLING PRODUCTS.

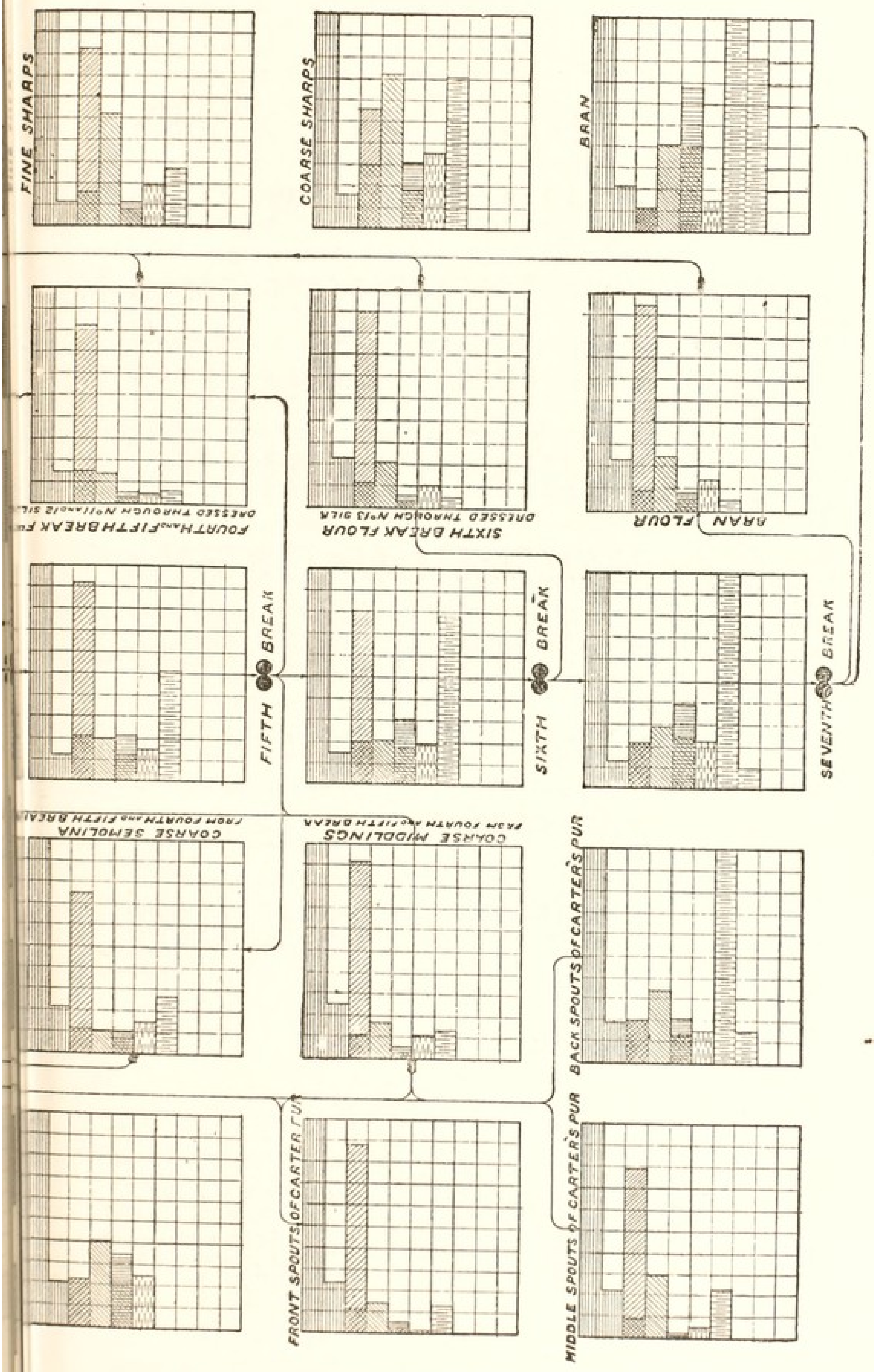

FIG. 41.—COMPOSITION OF ROLLER MILLING PRODUCTS.

ANALYSES OF THE PRODUCTS OF ROLLER MILLING, BY RICHARDSON.

NAMES.	Water.	Ash.	Oil.	Carbo-hydrates.	Fibre.	Proteids.	Nitrogen.	Phos-phoric Acid.	Ratio Nitrogen to Phos-phoric Acid.	Gluten.	
										Moist,	Dry.
C. A. Pillsbury & Co., Minneapolis, Minn.	%	%	%	%	%	%	%	%	%	%	%
Wheat as it enters the mill ...	9·66	1·91	2·61	69·64	1·70	14·18	2·27	·82	2·77	...	...
Wheat prepared for the rolls ...	9·07	1·79	2·74	70·37	1·68	14·35	2·30	·82	2·80	32·31	11·88
Cockle and screenings	9·03	2·65	4·32	66·12	4·23	13·65	2·18	·78	2·80	...	...
Scourings removed by cleaners ...	9·27	3·68	3·73	70·19	1·58	11·55	1·85	·76	2·43	...	...
First break	8·23	1·73	2·68	71·56	1·62	14·18	2·27	·91	2·49	31·92	11·69
Chop from first break	12·52	·88	2·08	70·44	1·13	12·95	2·07	·46	4·50	34·10	12·27
Second break	8·37	2·04	2·47	71·47	1·65	14·00	2·24	·98	2·29	32·78	11·80
Chop from second break	12·78	·57	1·68	71·82	·55	12·60	2·04	·34	5·94	36·88	12·56
Third break	9·92	2·55	5·25	65·10	2·13	15·05	2·41	1·33	1·81	32·09	12·40
Chop from third break	12·70	·78	1·86	71·10	·78	12·78	2·04	·42	4·86	37·19	13·00
Fourth break	8·18	3·30	4·09	66·20	3·00	15·23	2·44	1·44	1·07	27·88	10·54
Chop from fourth break	12·35	1·47	2·87	67·90	1·23	14·18	2·27	·75	5·05	30·52	11·64
Fifth break	7·62	5·16	4·91	61·76	4·80	15·75	2·52	2·58	·98	...	...
Chop from fifth break	11·91	1·99	4·16	64·46	1·73	15·75	2·52	1·01	2·49	27·97	11·82
Sixth break	7·66	5·68	5·34	59·42	5·60	16·28	2·60	2·95	·81	...	...
Chop from sixth break	11·84	3·29	4·92	59·09	3·18	17·68	2·83	1·66	1·70	24·04	10·69
Bran	10·91	5·59	5·03	56·21	5·98	16·28	2·60	2·78	·94	...	...
Shorts	10·94	3·41	4·67	60·28	3·90	16·80	2·69	1·62	1·66	...	...
Middlings uncleaned :											
No. 1	12·71	1·27	2·73	68·78	1·03	12·48	2·16	·64	3·39	29·68	10·57
No. 2	12·18	1·04	2·16	70·49	·83	13·30	2·13	·54	3·94	32·99	11·49
No. 3	12·27	·70	1·80	71·52	·58	13·13	2·10	·36	5·83	35·52	12·21
No. 4	12·47	·68	1·75	70·69	·58	13·83	2·21	·40	5·52	45·62	15·69
No. 5	12·34	·61	1·75	70·24	·53	14·53	2·32	·33	7·03	43·82	14·86
Middlings cleaned :											
No. 1	12·67	1·07	2·12	70·16	·85	13·13	2·10	·59	3·56	34·03	11·16
No. 2	9·93	·65	1·90	74·09	·65	12·78	2·04	·33	6·18	...	...

ANALYSES OF THE PRODUCTS OF ROLLER MILLING, BY RICHARDSON—*Continued.*

NAMES.	Water.	Ash.	Oil.	Carbo-hydrates.	Fibre.	Proteids.	Nitrogen.	Phos-phoric Acid.	Ratio Nitrogen to Phos-phoric Acid.	Gluten.	
										Moist.	Dry.
Middlings cleaned—*continued.*	%	%	%	%	%	%	%	%	%	%	%
No. 3	12·36	·59	1·70	71·67	·55	13·13	2·10	·24	8·75	44·43	14·99
No. 4	12·51	·52	1·77	71·57	·33	13·30	2·14	·29	7·34	51·93	17·85
No. 5	12·35	·51	1·62	70·74	·43	14·35	2·30	·23	10·00	46·15	14·87
Middlings, reduction on smooth rolls:											
First middling	12·64	·82	2·56	70·80	·58	12·60	2·02	·46	4·39	34·20	11·57
Chop from first middling ...	12·74	·72	1·99	71·72	·58	12·25	1·96	·40	4·90	32·16	10·91
Second middling	...	...	...	...	...	...	...	...	...	...	...
Chop from second middling ...	12·48	·57	1·68	71·24	·38	13·65	2·18	·34	6·41	41·36	13·65
Third middling	12·29	·61	1·86	71·91	·55	12·78	2·04	·34	6·00	36·70	11·81
Chop from third middling ...	12·73	·79	2·01	71·29	·58	12·60	2·02	·34	4·70	34·58	11·68
Fourth middling	11·43	·56	1·86	73·12	·43	12·60	2·02	·34	5·94	37·00	12·23
Chop from fourth middling ...	11·72	·50	1·76	72·56	·33	13·13	2·10	·27	7·78	42·06	12·32
Fifth middling	12·21	·65	2·08	71·85	·43	12·78	2·04	·40	5·10	36·25	11·97
Chop from fifth middling ...	11·47	·56	2·03	72·66	·50	12·78	2·04	·37	5·57	40·84	13·11
Flour from reduction of middlings:											
First	12·03	·39	1·58	73·70	·25	12·05	1·93	·24	8·04	31·51	10·97
Second	12·42	·44	1·66	72·55	·33	12·60	2·02	·24	8·42	37·04	12·07
Third	11·54	·38	1·36	75·24	·28	11·20	1·79	·19	9·42	32·54	10·99
Fourth	11·58	·40	1·42	72·92	·38	13·30	2·13	·20	10·65	37·90	12·52
Fifth	...	...	...	...	...	...	...	...	...	...	..
Tailings from middlings purifiers:											
No. 1	12·33	3·30	4·96	60·06	3·25	16·10	2·55	1·61	1·60	...	...
Nos. 2, 3, and 4	11·59	3·09	3·92	...	...	14·53	2·32	1·39	1·67	12·28	7·62
No. 6	12·0	·90	2·37	69·10	1·10	14·53	2·32	·49	4·73	39·88	14·37
Tailings from reduction:											
First	11·78	3·26	5·03	60·82	2·63	16·98	2·72	1·82	1·47	13·04	5·47
Second	10·35	3·38	4·37	59·87	2·08	19·95	3·19	1·68	1·90	...	...
Third	11·72	2·35	4·37	63·27	1·66	16·63	2·66	1·34	1·98	..	...

ANALYSES OF THE PRODUCTS OF ROLLER MILLING, BY RICHARDSON—*Continued.*

NAMES.	Water.	Ash.	Oil.	Carbo-hydrates.	Fibre.	Proteids.	Nitrogen.	Phos-phoric Acid.	Ratio Nitrogen to Phos-phoric Acid.	Gluten.	
										Moist.	Dry.
Tailings from reduction—*continued.*	%	%	%	%	%	%	%	%	%	%	%
Fourth	12·09	·88	4·16	68·47	·40	14·00	2·24	·48	4·67	35·73	13·34
Fifth	12·12	2·29	3·85	63·93	1·18	16·63	2·66	1·35	1·97	1·89	·67
Re-purified middlings	11·72	2·11	3·67	65·99	1·63	14·88	2·38	1·21	1·98	28·17	10·74
Finished flour :											
Bakers'	12·18	·62	2·00	69·99	·33	14·88	2·38	·31	7·68	51·21	16·97
Patent	11·48	·39	1·45	73·55	·18	12·95	2·07	·18	11·50	36·14	10·85
Low grade	12·01	1·99	3·86	63·26	·93	17·95	2·74	1·16	2·36	10·01	4·26
Break flour	12·48	·58	1·87	69·44	·23	15·40	2·46	·31	7·94	51·38	15·87
Stone flour	12·04	·49	1·61	72·85	·23	12·78	2·04	·27	7·55	38·21	11·74
Flour from tailings :											
First	12·55	·62	2·93	70·25	·35	13·30	2·13	·30	7·10	39·13	12·85
Second	12·50	·85	2·79	70·20	·53	13·13	2·10	·45	4·67	37·78	12·68
Third	11·20	·76	2·63	72·28	·48	13·65	2·18	·39	5·59	43·25	13·87
Cockle chop	12·45	2·79	4·34	61·01	3·63	12·78	2·04	·86	2·37	..	...
Cockle bran	7·71	3·46	3·84	65·46	9·03	10·50	1·68	·83	2·02	...	...
First germ	8·69	3·42	9·35	53·28	1·23	24·13	3·86	1·83	2·11	...	...
Second germ	8·75	5·45	15·61	35·19	1·75	33·25	5·32	2·57	1·98	...	...
Third germ	7·68	4·94	13·75	39·25	1·50	32·88	5·26	2·56	2·05	...	...
Bran duster flour	11·78	1·17	2·71	70·20	·50	13·65	2·18	·66	3·30	58·59	13·72
Stone stock :											
No. 2	12·15	·40	1·64	72·91	·25	13·65	2·18	·19	11·58	47·55	15·32
No. 3	12·01	·55	2·12	71·76	·43	13·13	2·10	·28	7·50	46·39	15·15
Tailings :											
From sixth break	11·64	2·29	4·06	64·31	1·95	15·75	2·52	1·23	2·05	16·45	6·17
From first centrifugal reel ...	11·42	2·15	3·44	66·56	1·20	15·23	2·44	·98	2·49	6·58	2·39
From second centrifugal reel ..	11·07	2·85	4·73	61·82	2·20	17·33	2·79	1·47	1·88	...	...
Tail end of the tailings	11·36	3·87	5·23	...	...	15·75	2·52	1·75	1·44	10·74	4·41
Dust from No. 1 middlings ...	11·03	1·83	2·73	64·86	5·20	14·35	2·30	·55	4·18	25·78	10·31

ANALYSES OF THE PRODUCTS OF ROLLER MILLING, BY RICHARDSON—*Continued.*

NAMES.	Water.	Ash.	Oil.	Carbo-hydrates.	Fibre.	Proteids.	Nitrogen.	Phosphoric Acid.	Ratio Nitrogen to Phosphoric Acid.	Gluten.	
										Moist.	Dry.
	%	%	%	%	%	%	%	%	%	%	%
Dust from dust catcher	11·53	1·17	2·04	69·01	1·65	14·00	2·24	·55	4·07	35·05	13·00
Herr & Cissel, Georgetown, D.C.											
Mixed wheat, clean	9·62	1·93	2·29	71·83	1·55	12·78	2·04	·98	2·08	30·00	11·03
First break	8·13	2·03	2·46	72·30	1·60	13·48	2·16	1·05	2·05	29·17	10·42
Second break	9·47	2·00	2·01	71·81	1·58	13·13	2·10	·91	2·30	34·02	11·87
Third break	8·79	2·03	2·37	71·98	1·70	13·13	2·10	1·10	1·90	29·24	10·32
Fourth break	9·91	2·39	2·33	70·97	1·75	13·65	2·18	1·14	1·91	34·08	12·23
Fifth break	7·18	3·46	...	...	..	15·40	2·46	1·35	1·82	26·75	10·09
Sixth break	9·38	4·76	...	..	...	16·10	2·58	2·46	1·04	...	...
First middlings	11·96	·49	1·22	75·30	·35	10·68	1·71	·25	6·84	32·99	9·92
Second middlings	11·89	·51	1·21	75·56	·33	10·50	1·68	·25	6·72	35·49	10·55
Third middlings	10·88	·50	1·19	75·45	·25	11·73	1·88	·24	7·83	42·10	13·32
First middlings through smooth rolls	9·87	1·84	2·00	71·98	1·18	11·13	2·10	·87	2·42	28·97	10·59
Patent flour	12·98	·32	·92	75·60	·20	9·98	1·60	·16	10·00	29·55	9·08
Bakers' flour	13·29	·47	1·26	72·45	1·50	11·03	1·76	·28	6·28	35·04	11·30
Low grade flour	12·59	1·05	2·33	69·10	·75	14·18	2·27	·58	3·91	35·96	12·81
Germ middlings	11·10	2·41	3·74	60·59	1·63	14·53	2·32	1·19	1·94	...	...
Feed middlings or tailings ...	8·53	3·75	4·96	62·21	4·10	16·45	2·63	1·98	1·32	...	...
Bran middlings	8·24	6·89	5·52	56·77	6·13	16·45	2·63	·98	2·68	...	..
Warder & Barnett, Springfield, Ohio.											
Wheat	9·05	2·06	2·46	71·67	2·33	12·43	1·99	1·03	1·93	20·93	10·34
Patent flour	12·32	·34	1·05	78·28	·33	10·18	1·71	·19	9·00	35·52	10·76
Bakers' flour	11·98	·60	1·77	71·52	1·00	13·13	2·10	·33	6·36	38·29	12·30
Low grade flour	12·36	·69	1·00	75·04	·93	9·98	1·60	·30	5·33	28·37	9·96
Middlings	8·49	4·28	5·94	66·64	3·15	17·50	2·80	1·12	1·50	...	..
Bran	7·74	6·99	4·99	...	...	15·40	2·46	1·04	2·36	...	...
Patent flour, second sample ...	13·59	·36	1·08	73·94	·35	10·68	1·71	...	...	...	...

higher middlings are the richest, and if the analyses of the flours were complete, No. 4 would probably contain more than the lower numbers.

"The tailings are, as has been already said, remarkable, not so much that No. 1 has no gluten, but that Nos. 2, 3, 4, have 7·62 per cent., and No. 6 as much as 14·37 per cent. The regular increase shows that the highest number must contain a large portion of endosperm.

"That this is the case the microscopic examination of the different tailings has shown. No. 1 is found to consist almost entirely of the outer coating of the grain; Nos. 2, 3, and 4, of the same, mixed with a large proportion of endosperm, which is attached thereto, while in No. 6 it is difficult to dicover any large amount of anything but flouring material, and the small percentage of ash shows also that it cannot contain much bran.

"In a like manner No. 4 tailings from the reductions has 13·34 per cent. of gluten, which is owing to the large proportion of endosperm which it contains, and in this case, too, the fact of the presence of so much of the interior of the berry is presaged by the low percentage of ash. The remaining tailings of this class have little or no gluten, with the exception of No. 1, as they contain very little endosperm.

"In connection with the remaining specimens, the gluten has been already mentioned, and the results as a whole warrant the conclusion that less of it is wasted in the bye-products than would be imagined. For a complete discussion of this point, data, which are not at hand in regard to the per cent. of each material produced, are necessary.

"The products from Virginia wheat, similar to those which have just been described, present the same but not as wide variations in the breaks and in the flours; the low grade, instead of containing less gluten, has more than the bakers' or patent. This may be due to the greater softness of the wheat, in consequence of which it is less suited to the process, a fact which is confirmed to a certain degree by the specimens of flour from Ohio wheat, among which the low grade, although not exceeding the other brands in the amount of gluten, approaches very nearly to them, and it is therefore only reasonable to conclude that the spring wheats are particularly suited for roller milling.

"One of the characteristic features of the roller milling process, as has been mentioned, is the removal of the germ of the grain, thus preventing its injuring the quality of the flour. Among the bye-products of the Pillsbury mill are included three separations of germs, known as first, second, and third. They are all rich in oil and proteids, which together form one-half of the substance. The second germ seems to be freer from contamination, and was selected for a more detailed examination [of which the results are given, together with those of other analyses, in a preceding paragraph].

"It has been found that the water extract, if left in contact with the residue of the germ, would soon be the cause of a peculiar fermentation. This shows the bad effect the presence of this soluble proteid would have in flour, causing a fermentation or putrefaction which would injure and discolour it. The oil in the germ is also an additional source of trouble, in that it is readily oxidized under certain circumstances and tends to blacken the flour."

422. Further Examination of Flours Produced during Gradual Reduction.—The great importance which attaches to these led the author to make a further series of examinations of the flours produced at the various breaks and during the reductions of the middlings, together with the finished flours, straight grade, bakers', and patent. For the series of samples in illustration of this point, the author has to thank an important firm of Liverpool millers, whose mill is arranged on Simon's system. As being of more immediate importance to the miller and baker, the tests have been confined to estimations of moisture, gluten, water-absorbing power, and colour. The wheat mixture consisted of—

2	Parts	Australian.
2	,,	Californian.
1	,,	White Kurrachee.
2	,,	Canadian White.
2	,,	Chicago Spring.
2	,,	Saxonska.
1	,,	Hard Duluth.
1	,,	Polish Red.
4	,,	Oregon.
1	,,	English.
18		

In addition to these the author was kindly supplied by Messrs. Ure & Sons, of Glasgow, with samples of flour from American Spring and Winter Wheats respectively. Descriptions of these, together with results of analyses, are also included.

FLOURS YIELDED BY GRADUAL REDUCTION.

No in Fig. 42	Description.	Moisture.	Crude Gluten.			Colour.	Water-Absorbing Power.	
			Wet.	Dry.	Ratio.		Quarts per Sack.	Lbs. per 100 lbs. flour.
	Wheat	13·50	25·0	9·15	2·7	...	...	...
1	I. Break Flour ...	13·18	21·0	8·57	2·4	20G.	60	53·58
2	II. III. IV. } Breaks Flour ...	13·40	27·0	9·80	2·7	2G.	61	54·47
3	V. Break Flour ...	12·80	43·0	14·6	2·9	16G.Y.	77	68·76
4	I. Reduction ...	13·24	22·0	7·7	2·8	3G.	60	53·58
5	II. Reduction ...	12·45	25·0	9·2	2·6	7Y.	71	63·40
6	III. IV. } Reduction ...	13·52	26·0	9·3	2·7	2Y.	66	58·94
7	IV. V. } Reduction ...	13·04	29·0	10·1	2·8	10Y.	70	62·51
8	VI. Reduction ...	13·40	27·0	9·5	2·8	9Y.	71	63·40
9	VII. Reduction ...	12·30	32·0	10·5	3·0	12Y.	75	66·97
10	Straight Grade Flour ...	12·94	25·0	9·5	2·6	6G.	67	59·83
11	Patent Flour	12·94	22·0	8·1	2·7	5Y.	65·5	58·49
12	Bakers' Flour	13·30	26·0	9·7	2·6	6G.Y.	67	59·83
13	III. Flour	12·94	32·0	12·1	2·6	20G.	81·5	72·78
	SPRING AMERICAN:							
37	Weakest Break Flour	13·50	34·0	12·0	2·8	8G.	71·0	63·40
38	Strongest Break Flour	13·40	40·0	13·9	2·8	16G.Y.	72·0	64·29
39	Strong Flour from last Reduction of Middlings	11·61	33·0	11·3	2·9	18G.Y.	98·0	87·51
	WINTER AMERICAN:							
21	Weakest Break Flour	12·75	15·0	5·3	2·8	1·5G.	64·0	57·15
22	Strongest Break Flour	12·51	30·0	10·4	2·8	10·0Y.	67·5	60·27
23	Strong Flour from last Reduction of Middlings	11·30	29·0	10·2	2·8	15·0Y.	91·0	81·26

In Fig. 42 the results of the analyses of these flours, together with those of several others which have been deemed of special interest, are set out diagrammatically. The corresponding numbers, 1-49, across the top and bottom of the diagram refer to the particular flours; the following is an index of these figures:—

Nos. 1-13. First thirteen flours given in preceding table of those yielded by gradual reduction; arranged in the same order.

No. 14. Stannards' Crown, see No. 64 in flour tables.

,, 15. Flour from Old White English Wheat, see No. 14 in flour tables.

,, 16. Flour from Kiln Dried Scotch Wheat, see No. 13 in flour tables.

Nos. 17-19. Taylor's Supers, Whites, and Households.

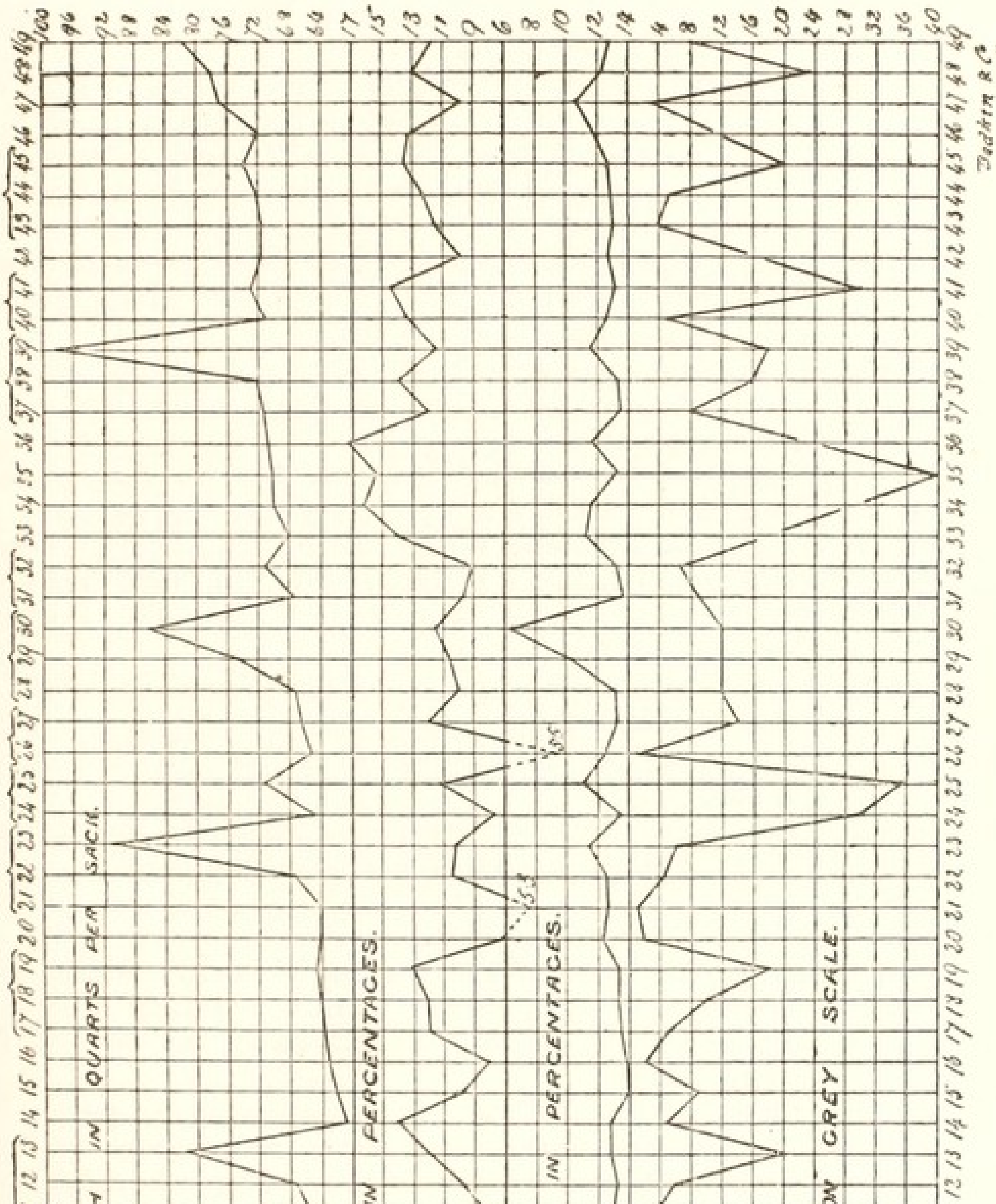

FIG. 42.—DIAGRAM OF FLOUR-TESTING RESULTS.

No. 20. Straight Grade from very choice Californian Wheat, see No. 27 in flour tables.

Nos. 21-23. Flours from Winter American Wheat, see gradual reduction table, 17-19.

,, 24-25. Flours from Varna Wheat, the former slightly heated in hold of vessel, see Nos. 29-30 in flour tables.

,, 26-27. Flours forwarded from North of Ireland as types of flours, respectively fitted and unfitted for bread-making by soda process.

,, 28-30. Sample of English Seconds, tested immediately on being received, and after 2 and 16 days respectively, gentle kiln drying, see paragraph 424.

,, 31-32. Flours from Bombay Wheat, milled respectively dry and damped, see Nos. 31-32 in flour tables, and also paragraph 423.

No. 33. Flour from Australian Wheat, see No. 4 in flour tables.

,, 34. Flour from Odessa Wheat, see No. 2 in flour tables.

,, 35. Flour from Taganrog Wheat, see No. 28 in flour tables.

,, 36. Flour from Saxonska Wheat, see No. 3 in flour tables.

Nos. 37-39. Flours from Spring American Wheat, see gradual reduction table, Nos. 14-16.

,, 40-41. L. C. Porter's Patent and Bakers' Flours, see Nos. 8 and 9 in flour tables.

No. 42. Flour from No. 2 Calcutta Wheat, see No. 1 in flour tables.

Nos. 43-45. Best Patent, Second Patent, and Remaining Flour, from No. 1, Duluth Spring Wheat, see Nos. 23-25 in flour tables.

No. 46. London Town Households.

,, 47. Hungarian Patent Flour, see No. 52 in flour tables.

,, 48. Pillsbury's Straight, see No. 74 in flour tables.

,, 49. Canadian "Hungarian" Patent Flour, see No. 35 in flour tables.

In the upper part of the diagram the water-absorbing power in quarts per sack is set out, the lowest observed water absorbed, 60, being taken as the limit in the direction of weakness; the higher the line in the case of each particular flour, the greater is its water-absorbing power. These estimations were in each case those made with the viscometer in the manner already referred to.

Note that in the diagram the word "strength" is used, instead of the phrase "water-absorbing power": it is the latter which is intended.

Gluten in percentages occupies the next position; the diagram provides for variations from 7 to 17; in two instances of abnormally low glutens the gluten curve is carried as a dotted line into the next division of the diagram. Again, the higher the curve, the greater is the percentage of gluten.

Moisture is also set off in percentages, but with this important difference: the lowest degree of moisture is placed at the top, and the readings go downwards; therefore, the drier the flour, the higher does the moisture line reach.

The colour is set out on the Grey Scale; where the flours are really of a yellow tint, or bloom, their hue has been translated into the equivalent grey tint. Consequently, the readings of colour must only be viewed as showing the degree of intensity of tint, and not its character or quality. The colours represented by the lowest numbers are placed highest, so that the lower the colour curve, the darker is the flour. In some few cases colour has not been determined; this is shown by gaps in the colour lines.

The arrangement of the figures in the moisture and colour divisions is reversed, in order that in each instance a rise of the curve shall correspond with improvement in quality of the flour, in so far as it is affected by that particular constituent or property.

Considering at this stage those flours taken as illustrations of milling by gradual reduction, No. 1, the 1st Break flour, is low in water-absorbing power (60 quarts), contains about the average gluten of the series, and is low in colour. No. 2 consists of the flour from the 2nd, 3rd, and 4th breaks; this shows but little improvement in water-absorbing power, rather more in gluten, but a decided improvement in colour. No. 3, the 5th Break flour, absorbs much more water, while the gluten is the highest of the series: this is accompanied by a considerable falling off in colour. We have next the flours produced by the reduction of the semolinas; that of the 1st reduction is low in water-absorbing power and gluten, but of good colour. The 2nd reduction produces a flour of improved water-absorbing power and gluten, with but little variation in colour. The joint product of the 3rd, and part of the 4th reduction, yields a flour which shows a falling off in water-absorbing power, with a slight increase in gluten. The remainder of the flour from the 4th reduction, together with that of the 5th, shows an increase in both water-absorbing power and gluten, while the colour somewhat falls off. The 6th reduction flour absorbs rather more water, while the gluten is once more rather less in quantity. The flour from the 7th reduction, No. 9, shows an increase in both water-absorbing power and gluten, while the colour becomes slightly darker. We next come to the Straight Grade flour, No. 10; comparing this with the Patent, No. 11, and Bakers' flour, No. 12, the Straight Grade runs intermediate between the other two in water-absorbing power, gluten, and colour. No 13, termed "Thirds flour," is obtained by again rolling the tailings from the last reduction of middlings; this flour, it will be noticed, is highest in water-absorbing power, and next to the highest in gluten, while the colour is very low.

Turning next to the series of flours obtained from American winter wheats, Nos. 21-23 in diagram, and 17-19 in gradual reduction table, the gluten in the weakest Break flour, No. 21, is only 5·3 per cent., while the colour is very good, and the water-absorbing power low. No. 22, which was the strongest Break flour, shows a slight increase in water-absorbing power, and a considerable increase in gluten: as might be expected the colour is slightly lower. Taking next the flour from the last reduction of middlings, the water-absorbing power in this reaches the remarkably high figure of 91 quarts per sack; the gluten, however, is absolutely less than that in No. 22; the colour has slightly fallen off. In these three flours the moisture diminishes slightly with the increase in quantity of water absorbed. Somewhat similar lessons may be learned from the series of flours from American spring wheats, No. 37-39 in diagram, and 14-17 in gradual reduction table. Again, the weakest Break flour absorbs comparatively little water, 71 quarts, while the gluten amounts to 12·0 per cent.; the colour is high. The strongest Break flour shows an increase in gluten, and a very slight increase in water absorbed; the colour has fallen off. The flour from the last reduction of middlings registers the enormous water-absorbing power of 98 quarts per sack. A dough test, with 88 quarts per sack, was mixed with the greatest difficulty, and took 257 seconds to run through the viscometer; the 98 quarts test ran through in 64 seconds. The gluten of this flour was only 11·3 per cent., being less than in the weakest Break flour; the colour again descends. In this series, as in those from winter wheats, the moisture diminishes with the increase of strength.

423. Damping Wheats.—It is the custom of certain millers to add to some of the harder and more flinty wheats, particularly those of India, more or less water as a preliminary to milling. The addition of such water is popularly supposed to have two effects, the first being a softening of the bran, and the second an increased yield of flour. The softening of the bran renders it less brittle, and so less is supposed to get broken up, and thus into the flour.

It is essentially a question for the miller, rather than the chemist, to decide whether the damping of Indian wheats renders them more workable and amenable to milling processes generally. It is quite conceivable that a "mellow" wheat is more easily converted into flour than one which is hard and brittle; but, against any consideration of ease in milling must be set the effect, if any, of damping on the after quality of the flour produced.

In connection with this subject the author has analysed a number of samples of Indian and other hard wheats, dry and damped, and also the flours produced therefrom. The following are the general conclusions derived from an extended and exhaustive series of experiments:—

In artificially damping wheats, but a small proportion of the water finds its way into the flour. The actual amount varied from 3·8 to 17·1 per cent. of the total quantity added.

The addition of water to wheats already containing an average quantity of water (in experiment cited, 13·2 per cent.) is decidedly deleterious; strength and colour are both injuriously affected.

With wheats in a dry state (11·0 to 11·5 per cent. of water) damping in a slight degree does not seriously affect the colour or strength of the flour.

On making baking tests with the flours from such slightly damped wheats compared with those of the wheats milled dry; the damped wheat flours fall off less during fermentation, yield bread of better colour and flavour, and in practically the same quantity.

The slight damping of the very dry wheats enables the miller to produce a better quality of flour.

424. Artificial Drying of Wheats and Flours.—By means of a series of experiments on flour, Graham very clearly showed the advantages derived from gently kiln drying excessively damp wheats. An inferior flour was taken, and one portion heated for some six hours to a temperature of 140° F. The dried and undried flours were then shaken up with water in the manner previously described for the purpose of obtaining the soluble extract, except that separate portions of the flour and water were allowed to stand for four and eight hours respectively before filtration. At the end of four hours the percentage of soluble extract, yielded by the undried flour, amounted to 10·49 per cent., while the dried sample gave only 8·7. The difference between the two at the end of eight hours is still greater; the undried flour gave 16·11 per cent. of extract, while the dried sample yielded only 10·64 per cent. Evidently, then, this treatment, by partly destroying the diastasic power of the proteids degraded by moisture, prevents excessive diastasis of the starch, on the flour being treated with water. The soluble proteids, maltose, and dextrin all show a decrease, as may readily be seen on consulting the following table :—

	ARTIFICIAL DRYING OF FLOUR (GRAHAM).			
	UNDRIED FLOUR, ON STANDING.		DRIED FLOUR, ON STANDING.	
	4 hours.	8 hours.	4 hours.	8 hours.
Maltose	6·82	11·14	4·44	4·44
Dextrin	0·43	1·23	1·78	2·91
Soluble Proteids ...	3·19	3·74	2·48	3·29
Total Soluble Extract	10·44	16·11	8·70	10·64

As a result of these experiments, Graham recommended the kiln-drying of damp wheat, suggesting that the initial temperature might be 100° F., increasing slowly to 140° F., at the same time submitting it to a current of air, and taking care that the thickness on the kiln floor is not too great. (Cantor Lectures, Jour. Soc. Arts, pp. 116-7, Jan. 9, 1880.) Unfortunately, Graham seems not to have made any gluten determinations in these flours. The temperature he recommends (140° F. = 60° C.), is identical with that at which flour, on being heated for several hours, according to Weyl and Bischoff, appears to lose the faculty of forming gluten. (Jour. Chem. Soc., 1882, p. 537, Abstracts.) The author can confirm this statement, having repeated their experiment with the same results. If the kiln-drying should destroy, or even materially impair, the gluten-forming powers of the flour, this would tend to seriously counterbalance the great benefit derived from the retardation of diastasis as the result of the application of heat.

The author recently made a series of experiments on a sample of

Seconds flour of low quality, stonemilled from English wheats. Immediately on receiving the sample, its strength, moisture, and colour were estimated in the usual manner. A strength determination was also made on the dough after standing 24 hours (stability test). The weather was intensely cold at the time of making these experiments; the doughs were probably very little above the freezing point during the time they were standing. This is mentioned, because the amount of falling off in strength was so much less than that in some other samples, the results of which are recorded in paragraph 570, and which were tested during a hot July. The flour was next placed above a heating furnace, and allowed to remain there for some days; the temperature was taken from time to time, by plunging a thermometer in the flour, and was found to range between 27° and 30° C. (80·6°-86° F.) After two days' drying a fresh series of determinations were made in the flour, and again after sixteen days. The results of the various tests are given in the following table:—

ARTIFICIAL DRYING OF FLOUR.

DESCRIPTION.	Moisture.	Crude Gluten.			Colour.	Water-Absorbing Power.			
		Wet.	Dry.	Ratio.		Quarts per Sack.	Lbs. per 100 lbs. flour.	Same after 24 hours.	
								Quarts per Sack.	Lbs. per 100 lbs. flour.
Undried Flour (No. 28, Fig. 42)	13·4	29·0	10·3	2·8	12·0G.	67·0	59·8	65·0	58·0
Flour after 2 days drying (No. 29, Fig. 42) ...	10·3	31·0	10·7	2·9	12·0G.	74·5	66·5	...	...
Flour after 16 days drying (No. 30, Fig. 42) ...	6·5	32·0	11·6	2·8	12·0G.	86·0	76·7	82·0	73·2

These flours are set out in Figure 42, being bracketed together as Nos. 28-30.

As might be expected, the natural result of drying is to lessen the moisture; this falls in two days from 13·4 to 10·3 per cent.; simultaneously the water-absorbing power rises 7·5 quarts. A diminution of moisture of 2·1 per cent. corresponds to an evaporation of 2·3 quarts per sack; but the flour shows, as the result of actual trial, that its water absorbing power had increased to a far greater extent. During the sixteen days the furnace was not kept continually alight, so that proportionately the moisture has not so much diminished as during the first two days. With a total diminution of moisture of from 13·4 to 6·5 per cent., which equals 6·9, the water-absorbing power had increased by 19 quarts. A diminution in moisture of 6·9 per cent. is equivalent to loss by evaporation of 7·6 quarts per sack, but, as before, the water-absorbing power of the flour has increased by a much greater quantity. The next point for consideration was whether this increase in power of absorbing water might not be apparent rather than real; and that while the flour would require more water to first convert it into dough, it would fall off to a correspondingly greater extent during fermentation. In order to obtain information on this point the 24 hours absorption tests were made; they show that the original flour fell off during that time 2 quarts, while the dried flour lost 4 quarts in water-absorbing power. Compared with the undried flour, that which had been dried until 6·9 per cent., or 7·6 quarts per sack of water had been evaporated, maintained, after being 24 hours in dough, the advantage in water-absorbing power to the extent of 17 quarts. In gluten the flours show a slight increase as the result of being dried. The three samples were exactly alike in colour. These experiments probably afford the explanation of that improvement effected in flour by keeping for some time. The author was some time ago informed by a baker that he found, as a result of storing Hungarian flour, that its water-absorbing power materially increased without any sensible diminution in weight. The author was, on being told, somewhat sceptical on the point, but his subsequent experiments confirm the baker's observations. These experiments show that **gentle artificial drying of flour increases its water-absorbing capacity to a considerably greater extent than that of the water lost by evaporation. In all probability, similar drying of damp wheats would have a like effect.**

425. General Relationship existing between Water-Absorbing Power, Gluten, Moisture, and Colour of Flours.—Under this heading may be considered such flours included in the diagram, Figure 42, as have not as yet received specific mention.

No. 14 is a sample of Stannard's Crown Flour; this is rather a biscuit than a bread flour; it may be noticed that while the water-absorbing power is very low, the gluten is high. This flour is easily hydrated, and forms a very ductile dough, specially suited for some varieties of biscuit work. The next flour, No. 15, is milled entirely from English wheat: the water absorbed and gluten were low, and moisture high; the colour is fairly good. The flour from kiln-dried Scotch wheat is also low in absorptive power and gluten, together with high moisture; the colour was very good. It would have been interesting to have been able to compare this flour with that made from the same wheat undried. Nos. 17-19 are examples of three grades of flour from the same miller; as is usually the case, as the water absorption and gluten increase, the colour decreases. Nos. 24-25 are of interest as showing the effect on the quality of the flour of heating in a vessel's hold; the water-absorbing power and gluten are both diminished thereby. The flours 33-36 are marked by their very high percentage of gluten; notwithstanding this, their absorptive capacity does not rank so high as that of other flours whose percentage of gluten is less: they are respectively, flours from Australian, Odessa, Taganrog, and Saxonska wheats. Nos. 40 and 41 are high in gluten, but still not quite so high as the group just referred to; their water-absorbing power is however somewhat more. The series 43-45 are obtained from No. 1 Duluth spring wheat, and serve as an additional illustration of different grades of flour, produced during roller milling. No. 47 is a Hungarian Patent; the water absorption is high; the gluten, medium; moisture, low; and colour, good. Pillsbury's Straight runs high in water-absorbing power, rather less gluten than the preceding; moisture, medium. The last flour, No. 49, is of special interest as possessing the greatest water-absorbing power of all the flours which are representative of those that are sold as finished products. Nos. 23 and 39 are of course simply intermediate products of milling. This No. 49 is a Canadian Patent, its gluten is medium and its moisture somewhat high; the colour is fair.

Reviewing the whole series, the highest water-absorbing powers are not associated with highest glutens, neither are they with lowest moistures; while the low strengths are in some instances found with low, and in others with high glutens. Comparing water absorption with moisture, the dryness of a flour does not necessarily correspond with its water-absorbing power, although in many instances a connection may be observed between them. With one and the same flour, increase or decrease of moisture influences the water-absorbing capacity to a very marked degree. The colour does not bear a very close relationship to the other properties referred to, because it is so largely governed by the methods employed in milling. With flours produced at different stages of the same milling process from one wheat or wheat mixture, the colour almost always falls off with increase in water-absorbing power and gluten.

In judging the value of a flour from the analytic data given in this diagram, the water-absorbing capacity may in the first place be taken as the measure of the water required by the flour to produce dough; it also is the principal factor in determining the bread-yielding capacity of the flour. Water-absorption tests after standing, or their equivalents, as briefly referred to in another part of this work, indicate the degree which the dough will fall off during fermentation. The gluten is in the first place a measure of the flesh-forming constituents of the flour, and thus partly of its nutritive value. The quantity and quality of gluten will determine the capacity of the flour for retaining the water used in doughing; and also, whether or not the loaf will be well risen and of good pile. For instance, although flour No. 39 will greedily absorb water, yet it would not produce so well risen a loaf as No. 38: this is partly due to its containing less gluten, but also to its gluten being of inferior quality. The dryness of the flour shows the actual percentage of solid food-stuffs which it contains; and also, as has previously been explained, affords indications of its soundness. The colour of the flour, when wetted, is an approximate measure of the colour of the bread made therefrom; but discrepancies between the colours of the flour and that of the bread are frequently observed, which in some instances are probably due to irregularities in the bread-making process. The same flour will produce bread of many shades of difference in colour, according to whether it be properly or improperly manipulated.

426. Effect of the Germ on Flour.—One of the questions which for a considerable time has occupied the attention of the milling world, is whether or not the removal of the germ affects the flour injuriously or otherwise. Among the various authorities on this point, Graham, Richardson, and others, are unanimous in expressing a strong opinion in favour of its removal. Briefly stated, the reasons that render this course advisable are that the presence of the germ discolours the flour, and also gives it a decided tendency to become rancid. In addition, the germ exerts a marked diastasic action on the imperfectly matured starch of slightly unsound flours. On the other hand, the advocates for the retention of the germ assert that it renders the flour sweeter, and also causes the bread to have a pleasant moistness on the palate. Under any circumstances these results are not likely to be attained except by using the flour immediately it is milled; this is frequently impossible, and even then the baker must be prepared to face all those difficulties caused by the presence of active diastasic agents in the sponge and dough. Milling experiments on a large scale have been made on the germy semolina produced during gradual reduction. Such semolina, on being reduced on stones, yields a dark coloured unsatisfactory flour, which produces a low quality bread. On rolling and repurifying these semolinas, the resulting flour is of good colour, and yields bread of high quality. So far, these experiments afford evidence directly in favour of the removal of the germ. The steady demand for roller-made flour demonstrates that the opinion of the public, as consumers, is also in favour of its removal. An extensive series of experiments made by the author, and previously published, prove most conclusively the ill effects resulting from the admixture of germ with flour.

427. Wheat Blending.—Some of our readers may have expected ere this a description of the principles which should govern the miller in his selections of wheat for blending purposes; but, as the end of wheat grinding is to produce flour having certain definite characters, it has been thought well to postpone the treatment of this question until after that of the behaviour of different kinds of flour during panary fermentation has been fully considered.

428. Distribution of Gluten in Wheat.—Considerable interest attaches to the relative proportions of gluten in the flours produced during the different operations of gradual reduction. Closely connected with this question is that of the distribution of gluten in the wheat grain. A number of writers on wheat make the statement that gluten is found almost, if not quite, exclusively in the inner layer of the bran; and that it constitutes the contents of those cuboidal cells seen so prominently in the inner layer of bran when microscopically examined. These cells are even now frequently termed "gluten cells" from this supposed property. The bran of wheat contains, however, no gluten whatever, the whole of that body being derived from the contents of the endosperm. Hence it follows that flour contains more gluten than does whole wheat meal. The following methods, suggested by Randolph of Philadelphia, may be adopted in order to prove the presence of gluten in the endosperm of wheat.

If whole wheat grains be allowed to soak in water, to which a few drops of ether have been added to prevent germination, they will in a few days become thoroughly softened, and the contents of such a grain may then be squeezed out as a white tenacious mass. Examination of the remaining bran shows the "gluten cells" undisturbed, closely adhering to the cortical protective layers. By now carefully washing the white extruded mass, the major part of its starch may be removed; and upon the addition of a drop of iodine solution microscopic examination shows numerous networks of fine yellow fibrils, still holding entangled in their meshes many starch granules, coloured blue by the iodine. In carefully washed specimens these spongelike networks are seen to retain the outline of the central starch-filled cells, and evidently constitute the protoplasmic matrix in which the starch granules lay. Upon gently tearing such a specimen under a moderate amplification, the fibrils will be seen to become longer and thinner, in a manner possible only to viscid and tenacious substances—a class represented in wheat by gluten alone.

An eminently satisfactory proof of the proteid nature of these central networks may be obtained by heating the specimen in the solution of acid nitrate of mercury (Millon's reagent), when the fibrils will assume the bright pink tint characteristic of proteids under this treatment.

Another most satisfactory method of studying the distribution of gluten in sections of wheat, is that of removing the starch by diastasis effected by malt infusion. If a thin section of a wheat grain be momentarily placed in water at 100° C., so as to gelantinise the starch, then transferred when cool to filtered malt infusion, and maintained from half-an-hour to an hour at a temperature of about 60° C., all the starch will be digested away, while the insoluble proteid and other constituents will remain entirely unaltered. A section of wheat grain thus treated will exhibit throughout its entire central portion close-meshed gluten networks, which become slightly denser towards the cortex of the grain. The proteid character of these reticuli is here, as in the first method, susceptible of micro-chemical demonstration by Millon's reagent. A relatively very faint colouration, indicating the presence of proteids, is noticeable in the "gluten cells," while the gradual condensation of the gluten of the endosperm as the cortex is approached is evidenced by a vivid colouration of the fibrils.

429. Tabulated Results of Flour Analyses.—The following tables contain analyses of flour selected from among those made by the author during 1885-6. Flours have been selected which are of interest for one of the following reasons—1st, their having been produced from single wheats; 2nd, their being well-known brands; 3rd, their representing the flour supply of certain large towns.

On page 333 are given the results of analysis of a number of single wheat flours. Flours Nos. 12-16 were milled purely for the ordinary purposes of sale, as were also Nos. 19-27, and 35-36. The others were specially ground on stones as experimental tests on the respective wheats. Nos. 19-22 were milled in Glasgow, and Nos. 23-27 in Liverpool. Nos. 28-33 were all prepared in precisely the same manner as No. 28, hence the comparison between them is very instructive. Nos. 29 and 30 show strikingly the ill effects on a flour of "heating" in the wheat; the moisture increases, while the water-absorbing power rapidly falls off. In Nos. 14-16, and 19-22, the glutens were estimated immediately on doughing the flours: in the other analyses, unless specially stated otherwise, the doughs were first allowed to stand one hour. Among the whole of the flours examined, No 35, from Canadian Hard Fyfe wheat, stands pre-eminent in the matter of water-absorbing power. The wheat from which this sample was made grew in Manitoba, to the north-west of Winnipeg, and was forwarded by the Canadian Pacific Railway Company, whose efforts to supply the millers and bakers of this country with such a magnificent wheat and flour will, as time goes on, amply reward their enterprise. The writer personally visited this district in 1893, and collected samples of flour which are among those included in Chapter XXI. on Flour Testing.

The results of examination of a number of well-known brands and varieties of flour are given on pages 334 and 335. The Hungarian flour, No. 37, is of the same brand as is No. 10. In the first five flours the glutens were estimated immediately, while in those following, the doughs were first allowed to stand an hour. Many of the earlier analyses were made before the devising of the apparatus for testing water absorption, and so do not give that most important factor in determining the value of a flour. The flours Nos. 42-44 were made from Hard Fyfe wheat, No. 79 in the preceding chapter. Nos. 39-50 are a number of well-known brands of American flour. Nos. 52-62 are various Hungarian samples; Nos. 52-56 are different grades of flour supplied by the one merchant; so are Nos. 57-59; and again, Nos. 60-62. No. 64 is registered as a weak flour; it is, however, scarcely a bread flour, being used chiefly as a high-class biscuit flour.

Nos. 65-67 are flours supplied by one of the largest and best known London millers.

Nos. 68-70 were milled at the same time as Nos. 28-33.

Nos. 71-73 were obtained from Glasgow, and are representative samples of home-milled flours from American wheats: they rival, and in some qualities beat, the flours produced from the same class of wheats by American millers, and imported into England.

No. 74 is a sample of Pillsbury's well-known flour, imported into London by Messrs. Klein & Sons.

The flour supplies of large towns, pages 336 and 337, call for no very special remarks: in addition to the samples here quoted, many of those given in the previous tables find their way also into the places included in this list.

FLOURS USED IN VISCOMETER EXPERIMENTS, CHAPTER XXI.

No.	Name and Description.	Moisture.	Soluble Extract.	Soluble Proteids	Crude Gluten.			Ash.	Fat.	Water-Absorbing Power.	
					Wet.	Dry.	Ratio of Wet to Dry.			Quarts per Sack.	Lbs. per 100 lbs. flour.
1	No. 2, Calcutta (No. 42, Fig. 42) ...	12·60	5·40	0·90	28·1 21·5	9·68 8·15	2·9 2·6	1·2	1·50	71·5	63·45
2	Odessa (No. 34, Fig. 42)	11·60	4·90	0·60	49·5	16·18	3·0	0·76	1·04	70·0	62·51
3	Saxonska (No. 36, Fig. 42)	11·80	5·00	1·20	53·0	17·20	3·1	0·75	0·92	70·5	62·95
4	Australian (No. 33, Fig. 42)	11·30	4·50	1·20	42·0	14·20	3·0	0·54	1·00	68·0	60·72
5	Town Whites	11·76	6·60	1·06	35·0	13·10	2·6	...	...	70·0	62·51
6	Town Households	11·80	5·20	1·14	39·5	13·09	3·1	...	...	72·0	64·29
8	Patent Flour from American Hard Fyfe Wheat (No. 40, Fig. 42)	12·60	...	...	40·0	13·42	2·9	...	...	71·0	63·40
9	Bakers' Flour from American Hard Fyfe Wheat (No. 41, Fig. 42)	13·16	...	...	42·0	14·54	2·8	...	...	73·0	65·19
10	AAAAA Hungarian Flour	11·22	...	...	33·0	11·35	3·0	...	...	78·0	69·65
11	English Wheat Flour	14·02	...	...	22·0	7·8	2·9	...	...	63·0	56·26

The wheats in Nos. 1-4 were specially ground on stones, and the flour produced dressed through No. 9 silks.

The upper gluten figures in No. 1 were obtained by allowing the flour to remain in dough for two hours before washing out the gluten.

FLOURS FROM SINGLE WHEATS.

No.	Name and Description.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Colour.	Water-Absorbing Power.	
					Wet.	Dry.	Ratio of Wet to Dry.		Quarts per Sack.	Lbs. per 100 lbs. flour.
12	Flour from Red Wheat, grown in Midlothian, Scotch Milled ...	14·04	4·16	1·13	24·5	7·97	3·0	...	...	...
13	Flour from Kiln-dried Scotch Wheat (No. 16, Fig. 42)	13·80	...	...	22·0	7·94	2·7	2·5 G.	63·0	56·26
14	Flour from Old White English Wheat (No. 15, Fig. 42)	14·00	...	...	29·0	9·82	3·0	9·0 G.	62·0	55·36
15	Flour from Hard Minnesota Wheat, Scotch Milled	13·64	5·06	1·56	28·5	9·85	2·9	...	...	...
16	Flour from Dantzic Wheat, Irish Milled	12·24	5·30	2.05	28·16	8·86	3·1	...	...	...
17	Flour from Oremburka Wheat	16·50	6·30	1·70	29·0	10·60	3·0	...	...	...
18	Flour from Kubanka Wheat	10·90	7·30	1·40	48·0 44·0	15·8 16·3	3·0 2·7	...	...	...
19	Straight Grade from Winter American Wheat	11·88	3·37	1·52	30·00	9·76	3·0	7·0 G.	...	...
20	Patent from ditto	11·96	3·04	1·08	24·00	8·20	2·9	3·0 G.Y.	...	...
21	Straight Grade from Minnesota Wheat	12·29	4·57	0·98	31·00	10·68	2·9	14·0 G.	...	...
22	Patent from ditto	12·10	4·49	1·46	29·00	9·76	3·0	7·5 G.Y.	...	...
23	Best Patent from No. 1 Duluth Spring Wheat, Roller Milled (No. 43, Fig. 42)	13·02	...	...	34·0	11·35	3·0	8·0 Y.	71·5	63·85
24	Second Patent from the same Wheat (No. 44, Fig. 42)	13·00	...	...	36·0	12·4	2·9	12·0 Y.G.	72·0	64·29
25	Remaining Flour from same Wheat (No. 45, Fig. 42)	12·76	...	...	39·0	13·4	2·9	20·0 G.	74·0	66·08
26	Straight Grade from Azima Wheat	12·36	...	...	39·0	12·7	3·0	14·0 G.Y.	71·5	63·85
27	Straight Grade from very choice Californian Wheat (No. 20, Fig. 42)	12·10	...	...	21·0	7·13	2·9	2·0 G.	64·0	57·15
28	Flour from Taganrog Wheat, ground on French Stones, dressed on Silk Reel, Cloth, Nos. 9, 10, 11, and 12, Swiss (No. 35, Fig. 42)	13·24	...	...	48·0	15·43	3·1	say 40 G.	70·0	62·51
29	Flour from Varna Wheat (No. 25, Fig. 42)	11·22	...	...	35·0	11·17	3·1	say 35 G.	71·0	63·40
30	Flour from Varna Wheat, slightly heated in hold of vessel (No. 24, Fig. 42)	13·60	...	...	22·0	7·65	3·0	say 30 G.	65·0	58·04
31	Flour from No. 1 White Bombay Wheat, 12 per cent. of water added 24 hours before grinding (No. 31, Fig. 42)	13·74	...	...	27·0	9·6	2·9	9·0 G.	67·5	60·27
32	Flour from No. 1 White Bombay Wheat, milled dry (No. 32, Fig. 42)	13·20	...	...	26·0	9·05	2·9	6·5 G.	71·0	63·40
33	Flour from Middlings of No. 1 White Bombay Wheat, rolled and dressed through No. 10 Silk	12·52	...	...	22·0	8·13	2·7	5·0 G.Y.	70·0	62·51
34	Flour from Red Californian Wheat, (No. 2, Fig. 42)	10·70	...	...	29·0	10·0	2·9	12 G.Y.	73·5	65·63
35	Patent Flour from Manitoba Hard Fyfe Wheat (No. 49, Fig. 42)	12·90	...	...	30·0	10·8	2·7	9·0 G.	82·0	73·23
36	Bakers' Flour from ditto	13.50	...	...	31·0	11·7	2·6	16·0 G.	77·0	68·76

WELL-KNOWN BRANDS AND VARIETIES OF FLOUR.

No.	Name and Description.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Colour.	Water-absorbing Power.	
					Wet.	Dry.	Ratio of Wet to Dry.		Quarts per Sack.	Lbs. per 100 lbs. flour.
37	Hungarian, Economo Mills, Trieste, AAAAA	12·62	4·66	0·93	29·0	9·83	2·9	...	...	...
38	Hungarian, Vienna Lions, O	11·64	6·3	2·43	25·5	8·44	3·0	...	...	...
39	Minneapolis, Pillsbury's Best	13·0	4·66	1·5	31·66	11·61	2·72	...	...	...
40	"Amazon," Pillsbury's Bran Flour	13·1	7·26	1·85	24·5	9·59	2·55	...	...	...
41	Minneapolis, "White and Gold," by Cahill and Fletcher, Galaxy Roller Mills	12·9	6·00	2·35	29·5	10·22	2·8	...	...	...
42	Porter's Strong Bakers' Flour	11·44	4·00	1·24	39·00	14·45	2·7	...	...	...
43	Porter's Standard Flour	11·15	3·60	1·06	37·00	13·10	2·8	...	...	...
44	Porter's "OOOO Boss" Flour	11·36	3·77	0·82	36·50	12·20	2·9	...	...	...
45	Washburn's "OO" Flour	12·37	3·57	1·06	29·20	11·70	2·6	11·0 G.	...	...
46	Washburn's "OOO" Flour	11·92	...	0·98	29·75	9·77	3·0	...	...	...
47	"Royal Patent," St. Louis	11·66	2·80	1·20	18·00	6·42	2·8	14·0 G.	...	...
48	Crosby's "AAA" Flour	13·51	3·46	1·06	25·00	8·73	2·9	...	...	...
49	American "Long John"	12·51	...	...	30·00	11·40	2·6	7·0 G.	68	60·72
50	"May Flower" Flour	11·06	4·98	1·60	31·50	11·40	2·8	...	...	...
51	Russian Flour...	12·16	4·10	1·12	32·00	12·70	2·5	...	...	...
52	Hungarian, Vienna Lions, O (No. 47, Fig. 42)	10·86	...	...	30·3	9·86	3·0	7·0 Y.	77·0	68·76
53	,, ,, 1.	10·76	...	...	26·0	8·97	2·9	7·0 Y.	77·0	68·76
54	,, ,, 2.	11·18	...	...	28·0	9·20	3·0	6·0 Y.	71·5	63·85
55	,, ,, 4.	11·06	...	...	26·0	8·74	2·9	10·0 Y.	73·0	65·19
56	,, ,, 5.	10·68	...	...	30·0	10·25	2·9	12·0 Y.	74·5	66·53

WELL-KNOWN BRANDS AND VARIETIES OF FLOUR—*Continued.*

No.	NAME AND DESCRIPTION.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Colour.	Water-absorbing Power.	
					Wet.	Dry.	Ratio of Wet to Dry.		Quarts per Sack.	Lbs. per 100 lbs. flour.
57	Hungarian Victoria Empress	10·82	...	...	30·4	10·48	2·9	7·0 Y.	76·0	67·87
58	" Victoria Diamonds	10·54	...	...	27·0	9·75	2·8	7·5 Y.	75·0	66·97
59	" Victoria Pyramids	10·98	...	...	25·0	9·23	2·7	11·0 Y.	74·5	66·53
60	" Five Tulips, price 43/6	12·40	4·80	0·99	32·0	10·05	3·0	11·0 Y.	73·0	65·19
61	" Three Stars, price 43/6	12·87	3·92	0·77	30·0	9·43	3·0	8·0 Y.	73·5	65·63
62	" Victoria Diamonds, 42/6	12·82	4·00	0·70	30·5	9·30	3·0	6·0 Y.G.	72·0	64·29
63	Pillsbury's Crown	12·84	...	...	41·3	16·46	2·5	20·0 G.	73·0	65·19
64	Stannard's Crown (No. 14, Fig. 42)	12·80	...	...	37·0	14·20	2·6	5·0 G.	61·0	54·47
65	Supers, Taylor's, London	13·54	...	...	35·0	11·83	2·9	5·5 G.Y.	63·5	56·70
66	Whites, "	13·40	...	..	37·0	12·07	3·0	10·0 G.Y.	64·0	57·15
67	Households, "	13·50	...	...	40·0	13·00	3·0	18·0 G.	64·5	57·60
68	Flour from following mixture—one-fifth each of choice Californian, Australian, Canadian White, Duluth Spring, Ghirka, roller-milled in Liverpool	12·60	...	...	31·0	10·6	2·9	6·5 G.	67·5	60·27
69	Flour from rolled middlings of Varna and Taganrog Wheats ...	13·46	...	...	34·0	11·55	2·9	18·0 G.Y.	67·5	60·27
70	Flour from following mixture—20, No. 1 White Bombay, damped; 30, New English; 10, Old English; 20, Taganrog; 20, Varna	13·32	...	...	30·0	10·25	2·9	16·0 G.	68·0	60·72
71	Ure & Son's Minnesota Straight	12·70	...	...	34·0	12·0	2·8	15·0 G.	78·0	69·65
72	Glasgow Milled "Spring" Straight	12·71	...	...	33·0	11·7	2·8	17·0 G.	72·5	64·74
73	Glasgow Milled Minnesota Patent	12·60	...	...	33·0	11·3	2·9	14·0 Y.	73·5	65·63
74	Pillsbury's Straight (No. 48, Fig. 42)	12·30	...	..	35·0	13·0	2·7	23·0 G.	78·0	69·65

FLOURS, ILLUSTRATING SUPPLIES OF LARGE TOWNS.

No.	Name and Description.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Ash.	Colour.	Water-absorbing Power.	
					Wet.	Dry.	Ratio of Wet to Dry.			Quarts per Sack.	Lbs. per 100 lbs. flour.
	London.										
75	Households, RR, Red on White Diamond; J. & H. Robinson, Deptford Bridge Mills	11·04	6·20	1·68	32·4	10·3	3·1	...	...	...	...
76	Town Households, supplied in London	12·88	6·42	1·60	28·6	9·4	3·0	...	...	...	...
77	Whites	13·50	4·20	0·98	25·5	8·37	3·0	...	...	...	...
78	Whites made from 4 Fine English White, 1 Old Red English, 1 Red English, and Kubanka	13·34	5·00	0·93	27·83	8·88	3·1	...	...	...	...
79	Best Whites, Country, supplied in London, stone ground	13·09	4·83	0·91	23·83	8·43	2·8	...	...	...	...
80	Town Whites, RRR, Black on Red Diamond, J. & H. Robinson, Deptford Bridge Mills	11·10	5·53	1·40	29·0	9·37	3·1	...	...	...	...
81	Country Whites	12·70	5·32	1·02	25·3	8·44	3·0	...	...	..	...
	Manchester.										
82	Flours from one Milling firm. price 36/6 per sack of 280 lbs.	12·54	3·40	0·52	24·4	8·50	2·7	0·54	8·5 Y.G.	69·0	61·62
83	,, 32/6 ,, ,, ...	12·90	3·44	0·69	27·8	9·20	3·0	0·44	9·0 Y.G.	66·0	58·94
84	,, 30/6 ,, ,, ...	12·68	3·80	0·55	25·5	8·89	2·7	0·52	4·5 G.Y.	68·0	60·72
85	,, 28/6 ,, ,, ...	12·66	4·01	0·64	26·3	9·24	2·7	0·64	5·0 G.Y.	68·0	60·72
86	,, 26/6 ,, ,, ...	13·04	4·04	0·75	30·2	10·25	3·0	0·64	10·0 G.Y.	67·0	59·83
87	Flours from one Milling firm. ,, 36/6 ,, ,, ...	12·78	3·64	0·76	25·0	8·31	3·0	0·46	1·5 G.	62·0	55·36
88	,, 32/6 ,, ,, ...	13·20	4·01	0·72	24·9	8·73	2·8	0·44	2·0 G.	65·0	58·04
89	,, 30/6 ,, ,, ...	12·84	3·76	0·72	25·4	8·82	2·9	0·42	4·5 G.	62·0	55·36
90	,, 28/6 ,, ,, ...	12·98	3·20	0·65	28·0	8·72	3·2	0·50	7·5 G.	63·5	56·70
91	From one firm. ,, 36/6 ,, ,, ...	13·20	3·76	0·48	28·0	9·38	3·0	0·40	2·0 G.Y.	62·5	55·81
92	,, 30/6 ,, ,, ...	12·52	3·40	0·79	29·1	10·20	2·9	0·50	4·0 G.Y.	64·0	57·15
93	From one firm. ,, 32/6 ,, ,, ...	11·58	3·68	0·44	25·0	9·53	2·6	0·52	4·25 G.Y.	70·0	62·51
94	,, 28/6 ,, ,, ...	12·06	4·12	1·04	27·0	9·10	3·0	0·46	6·0 G.Y.	66·0	58·94
95	High Grade, ,, 36/6 ,, ,, ...	12·84	3·32	0·61	30·3	9·30	3·2	0·50	4·5 G.Y.	65·0	58·04

FLOURS, ILLUSTRATING SUPPLIES OF LARGE TOWNS—*Continued.*

No.	NAME AND DESCRIPTION.	Moisture.	Soluble Extract.	Soluble Proteids.	Crude Gluten.			Ash.	Colour.	Water-absorbing Power.	
					Wet.	Dry.	Ratio of Wet to Dry.			Quarts per Sack.	Lbs. per 100 lbs. flour.
96	Medium, price 32/6	13·32	4·04	0·68	29·0	9·30	3·1	0·46	9·0 Y.G.	65·5	58·49
97	Stoned Milled, ,, 32/6	12·72	4·48	1·20	29·2	9·52	3·0	0·46	8·0 G.Y.	61·0	54·47
	Birmingham.										
98	Extras	12·66	...	...	29·0	9·34	3·1	...	5·0 G.	71·0	63·40
99	Flours from one firm	13·01	...	...	28·0	9·40	2·9	...	5·0 G.	70·0	62·51
100		13·08	...	...	30·0	11·10	2·7	...	16·0 G.	74·0	66·08
101		13·25	...	...	31·0	11·20	2·8	...	12·0 G.	73·5	65·63
102	From one Superfines	13·00	...	...	27·0	9·50	2·7	...	5·0 G.	70·0	62·51
103	firm. Fines	12·60	...	...	30·0	10·60	2·8	...	8·0 G.	73·0	65·19
104	Superfines	12·96	...	...	28·0	10·20	2·7	...	10·0 G.	73·5	65·63
105	From one Superfines	12·70	...	...	30·0	11·10	2·7	...	14·0 G.	74·0	66·08
106	firm. Plain Tie	13·47	...	...	29·0	10·35	2·8	...	6·5 G.	70·0	62·51
107	Superlative, Minnesota	13·55	...	...	33·0	11·50	2·8	...	6·0 G.Y.	70·5	62·95
108	From one Seconds	12·62	...	...	25·0	9·50	2·6	...	14·0 G.	69·0	61·62
109	firm. Pink Tie	12·92	...	...	27·0	9·95	2·7	...	14·0 G.	71·0	63·40
110	Plain Tie	13·41	...	...	31·0	11·36	2·7	...	18·0 G.	70·0	62·51
111	Standard	13·40	...	...	24·0	8·60	2·8	...	4·0 G.	70·0	62·51
112	From one Whites	12·36	...	...	31·0	11·30	2·8	...	14·0 G.	72·5	64·74
113	firm. Seconds	12·57	...	...	31·0	10·80	2·9	...	17·0 G.	71·5	63·85
114	Seconds	13·45	...	...	32·0	10·60	3·0	...	15·0 G.	68·0	60·72
115	Seconds	13·07	...	...	29·0	10·00	2·9	...	13·5 G.	68·0	60·72
116	Seconds	13·20	...	...	30·0	10·50	2·9	...	...	68·0	60·72
117	From one Seconds	13·42	...	...	30·0	10·90	2·8	...	18·0 G.	75·5	67·42
118	firm. Pink Tie	13·15	...	...	29·0	10·50	2·8	...	15·0 Y.	77·5	69·20
119	Seconds	13·52	...	...	31·0	11·00	2·8	...	15·0 G.	72·0	64·29

430. Baking Characteristics of Typical Flours.—The table on this and following pages records not only the gluten and other determinations in certain typical flours, but also contains a statement of their general baking characteristics :—

TYPICAL FLOURS AND THEIR CHARACTERS.

NAME.	Moisture.	Dry Gluten.	Water absorbed. Quarts per sack	GENERAL CHARACTERISTICS.
Spring American patent.	12·60	13·42	71·0	Hard dry flours, containing a high proportion of very elastic gluten, which only slowly softens during fermentation. Water-absorbing power high ; colour good, but white, with comparatively little yellow or bloom in the bread. Loaf very bold and of good texture ; crust yellow without foxiness ; will bear very hot oven. Bread tends somewhat rapidly to become hard and dry, and is comparatively flavourless. A doughing flour, but it may be used in rapid sponges, or one-third in long sponges.
Spring American bakers'.	13·16	14·54	73·0	Also hard and dry, higher proportion of gluten, but usually somewhat less elastic ; softens very slowly. Water absorbed rather higher than with the patent ; colour dark and greyish, varies with different brands. Loaf bold but textureless, crust very foxy, catches readily in the oven. Bread harsh and dry ; has, with samples of specially low grade, a strong beany flavour. Straights and bakers' grades are good sponging flours, not good doughing flours.
Canadian hard Fyfe wheat patent.	12·90	10·8	82·0	Very much the same characteristics as the spring American patent, but has remarkably high water-absorbing capacity. A sponging and doughing flour, but neither straights nor bakers' grades from this wheat are good doughing flours.
Winter American patent.	11·66	8·26	65·0	Comparatively soft flours, containing a moderate proportion of gluten, which softens more rapidly during fermentation than the preceding, but still is fairly tough and elastic. Absorb medium quantity of water. Colour is very good, white and more bloomy than the spring American. Makes a very good loaf by itself, quite of medium size, and fair texture. Good yellow crust without foxiness. Bread fairly moist and pleasant in flavour. Doughing flours all grades, but may be used for rapid sponges taken on the first turn.
Winter American bakers'.	11·73	10·1	69·0	Similar on the whole to the patents in general properties. Some brands make doughs with little elasticity, but which hold up well and do not give during fermentation. Loaf not up to medium size, low, and with rather a tendency to run. Much less foxy crust than spring American of about same grade, also better colour in crumb. Flavour moderate, and usually devoid of any harshness. Bread sometimes clammy.
Kansas hard winter patent.	12·45	13·5	73·0	The hard winter wheat flours of Kansas are very similar in character to the spring American flours of Minnesota. The gluten runs fully as high, but is rather softer, and softens more rapidly during fermentation than the spring Americans. The colour is generally good, in many samples being marked by a much fuller yellowness than is the spring American patent. Flavour is usually good, and bread fairly moist. May be used for sponging, and also answer well as doughing flours for mixing with very weak, flavoury varieties.
Californian straight grade.	12·1	7·13	64·0	These are usually weak, dry flours, with comparatively little gluten. They are of good colour, full yellow, and sweet in flavour.

TYPICAL FLOURS AND THEIR CHARACTERS.—*Continued.*

NAME.	Moisture.	Dry Gluten.	Water absorbed, Quarts per sack.	GENERAL CHARACTERISTICS.
Kubanka (Russian), ...	10·90	16·06	...	Hard, dry flour, with unusually high percentage of gluten; makes a big loaf. Colour very yellow, almost pea shade; bakes very foxy. Bread very harsh and coarse in flavour. Sponging—long sponges—not good doughing flour.
Azima (Russian) straight grade,	12·36	12·70	71·5	Hard flours, with good percentage of gluten, but soften more readily during fermentation than spring American grades, for which these flours make useful substitutes. Colour of patents good; rather more tendency to foxiness than the American. Loaf bold, but if the dough is permitted to lie, frequently shows tendency to run. Bread comparatively flavourless; in lower grades coarse in flavour. Sponging flours; the patent grade may be used, one-third in sponge and one-third in dough.
Hungarian best patent, ...	10·82	10·48	76·0	Dry and comparatively soft flours; only medium percentage of gluten, which is very soft but elastic. Water-absorbing power remarkably high; colour white, with a most delicate shade of bloomy yellow. Loaf not very large, but of peculiar silky texture; crust yellow, without foxiness. Bread moist and of exquisitely delicate flavour. Doughing flours, but may be used in rapid sponges taken on the first turn.
Hungarian lower class patents,	10·98	9·23	74·5	Flours with less gluten and lower water-absorbing power than the higher-class patents. Colour very good, but usually full yellow. Bread moist, and somewhat liable to be clammy.
No. 2 Calcutta flour, ...	12·60	9·68	71·5	Indian flours generally are hard flours of a ricy character. Their gluten is low in amount, and usually very deficient in elasticity. The quantity of water absorbed is high. Colour is low, except with very great milling precautions. Loaf is small and runny, devoid of texture, and foxy. Bread is harsh and beany in flavour.
Old white English wheat flour,	14·00	9·82	62·0	Flours from English wheats are usually soft and damp. Vary considerably with change of climate and locality. Proportion of gluten low and devoid of much elasticity. Water-absorbing power low. Patent flours are of very good colour and bloomy; bakers' grades dark and grey. Loaf small and compact; crust of better class of flours free from foxiness. Bread is moist, and has a very sweet, nutty flavour. Doughing flours all grades; may be used alone, doughing direct.
Flour from kiln-dried Scotch wheat,	13·80	7·94	63·0	Scotch flours are even moister and softer than those from English wheats. Like them, they are low in gluten and water-absorbing capacity. Loaf is small, bread moist, and flavour pleasant. Doughing flours all grades; may be used alone, doughing direct.
French flour, ...	...	10·31	61·0	French flours have recently (1894) been again placed on the English markets. They are below the average of English milled flours, of the same price, in strength and water-absorbing power, but in most cases possess good colour and flavour.

CHAPTER XVI.

BREAD-MAKING.

431. Having fully dealt with flour and yeast, there now remain only salt and water as essential constituents of bread; some brief reference must be made to these compounds.

432. Salt, Sodium Chloride, NaCl.—Salt is a white crystalline body, about equally soluble in either hot or cold water, and having a characteristic saline taste. Salt is used in the making of bread for two reasons—first, to give the necessary flavour, without which bread would be tasteless and insipid. In addition to its own saline flavour, recent experiments have shown that the presence of salt stimulates the capacity of the palate for recognising flavours of other substances. Thus, minute quantities of sugar are recognised in the presence of salt which in its absence would be unnoticed. This doubtless accounts for the importance of salt as a flavouring agent.

In the second place, salt actively controls some of the chemical changes which proceed during fermentation; thus, salt exerts a solvent influence on some of the insoluble proteids of flour; but in the quantities employed in bread-making it produces a decidedly binding effect on the gluten of the dough. It further checks diastasis, and so retards the conversion of the starch of the flour into dextrin and maltose. Salt also checks alcoholic fermentation; the results of careful measurement of this action are given in Chapter XI., paragraph 339. The retarding influence of salt also extends to the other ferments, as lactic, viscous or ropy ferments, and so tends to prevent injurious fermentation going on in the dough.

433. Water.—In considering the quality of water for dietetic purposes, the chemist, first and foremost, addresses himself to the task of determining whether or not the water shows evidences of previous sewage contamination. He next ascertains the hardness and also the amount of saline matters present. The methods he adopts for this purpose vary, but the conclusion at which he seeks to arrive is practically the same. It may be safely laid down as a rule for the baker that a water which would be rejected, on analysis, as unfit for drinking purposes, should also without hesitation be rejected by him. Water containing living organisms should in particular be carefully avoided, as these might very possibly set up putrefactive fermentation during panification.

Among the waters which would be passed by the chemist for drinking purposes, there exist, however, considerable differences. Thus, some are hard, others are extremely soft; salt may be present in certain waters, while in others it may be almost absent. The difference between hard and soft waters is that the former contain carbonates and sulphates of lime or magnesia in solution; the act of boiling precipitates the carbonates as a fur on the vessel used, and so hardness due to the carbonates is termed temporary hardness, in distinction from that of the sulphates which, not being removed by boiling, constitutes permanent hardness.

Much speculation exists as to whether or not the hardness or otherwise of a water exerts any practical influence on bread-making. In brewing it is recognised that a soft water obtains more extract from the malt than a hard one, but the comparison with the case of bread is scarcely fair, because in the wort the liquid is filtered off from the "grains," while in bread the whole mass, whether soluble or insoluble, goes into the oven together. The general tendencies of hard water would be to dissolve less of the proteids than would a soft water, and consequently the dough in the former case would be, to the extent of the action of the hard water, tighter and tougher than that produced when the water is soft. (It will be remembered that gliadin is soluble in distilled water, but that the salts of the flour itself are sufficient to prevent its going into solution.) The use of very soft water is very nearly equivalent to the result produced by using softer flours. Thus, hard water will tend to make whiter bread, because, not only is the quantity of proteids dissolved smaller, but with the same quantity in solution their action would be checked by the presence of the soluble lime salts. At the same time the bread would eat somewhat harsher and drier than that made with soft water. Speaking generally the changes which go on during panification proceed more rapidly with soft than with hard water. Working in a similar manner, *i.e.*, with the same times and temperatures, hard water is not likely to produce as good results as soft water at its best. In order to obtain the same results, the various steps in the process of fermentation should be somewhat modified; thus, the bread would probably require to lie somewhat longer in the sponge and dough stages, or the temperature employed might be somewhat higher. Both colour and flavour of bread depend on fermentation being allowed to proceed to exactly the right point and no further—hence hard water, by altering the length of the fermenting process, will affect both these when fermentation is carried out under precisely the same conditions with hard water as with soft. Further, as the keeping moist of bread depends largely on the degree of change produced in the gluten and other constituents, it is quite possible that the rate of drying may be effected by the use of hard water. Some years ago the writer made a series of experiments on the manufacturing scale on the comparative advantages of hard and soft water for bread-making purposes. The use of a water-softening plant was afforded him by the inventors, and over some weeks the character of bread made with the very hard water of the district compared with that made from the softened water. The general conclusion was that no very great difference was caused, or at least no difference that could not be produced by other modifications under the control of the baker, such as slight alterations of the blend of the flour, or mode of fermentation. So far as it went the action of soft water was considered, everything else being equal, an improvement on the hard.

434. Objects of Bread-making.—The miller's art is directed to the task of separating that part of wheat most suitable for human food from the bran and other substances whose presence is deemed undesirable. The flour thus produced requires to be submitted to some cooking operation before it is fitted for ordinary consumption. Given the flour, it is the baker's object to cook it so that the result may be an article pleasing to the sight, agreeable to the taste, nutritious, and easy of digestion. It is universally admitted that these ends are best accomplished by mixing the flour with water, so as to form a dough; which dough is charged, in some way, with gas, so as to distend it, and then baked. The result is a loaf whose interior has a delicate, spongy structure, which causes good bread to be, of all wheat foods, the one most readily and easily digested when eaten. This charging with gas is most commonly effected by fermentation, but other methods are also to a limited extent adopted: these will be described in turn. Fermentation has one great advantage over other bread-making processes, in that it not only produces gas, but also effects other important changes in certain of the constituents of flour.

435. Definitions of various Stages of Bread-making.—The methods employed in the manufacture of bread differ in various parts of the country: it will be well to first give a few definitions, and then proceed to describe and discuss the principal methods and their underlying principles.

436. The Ferment.—Among many bakers the first step in bread-making is the preparation of a "ferment." This most commonly consists of potatoes, boiled and mashed with water into a moderately thin liquor, to which a little raw flour is generally added. The yeast is next introduced, and fermentation allowed to proceed until the whole of the fermentable matter is exhausted, and a quiescent stage reached. The essential point about a ferment is that it shall contain saccharine matters and yeast stimulants in such a form as to favour growth and reproduction of yeast, and growth and reproduction in a particularly vigorous condition. For this purpose it is necessary that the ferment be not too concentrated, because no yeast reproduction occurs with too great a degree of concentration. On Briant's authority the following table is given in the Quarterly Trade Review *(Bakers' Q.T.R.)*:—

Concentration of the Medium in which Yeast was grown.		Extent of Yeast Reproduction.
6 per cent. of solid matter.	...	6·60 times.
10 ,, ,, ,,	...	7·37 ,,
14 ,, ,, ,,	...	14·20 ,,
19 ,, ,, ,,	...	10·10 ,,
25 ,, ,, ,,	...	12·50 ,,
36 ,, ,, ,,	...	No reproduction.

A medium containing about 14 per cent. of solid matter is here indicated as being most favourable for reproduction.

Independently of this, too, the actual quantity of ferment, as compared with quantity of yeast, is of importance; for on referring to Adrian Brown on fermentation (Chapter IX.), it is seen that too great a crowding of yeast cells, independently of the composition of the liquid, may permit fermentation, while absolutely inhibiting reproduction.

Various substitutes for potatoes may be used in the ferment; among these are raw and scalded flour, malt, malt extracts, and other preparations.

437. The Sponge.—This consists of a portion only of the flour that it is intended to convert into bread, taken and made into a comparatively slack dough, with a portion or the whole of the water to be used in making all the flour into bread. The yeast or the "ferment" (together with usually a small proportion of salt) is incorporated into the sponge. Sponges containing the whole of the water are termed "batter" or "flying" sponges. Because of its greater slackness, compared with dough, fermentative changes proceed more rapidly in the sponge. The writer recently made a series of observations on small fermenting sponges made in the laboratory with distillers' yeast; these were very slack, and the number of yeast cells was counted by means of the hæmatimeter immediately on mixing, and again subsequently at intervals of about two hours. Not only was there no reproduction, but the cells present gradually lessened in number, doubtless as a result of disintegration of those deficient in life and vigour. From this, and the reproduction table given under the heading of Ferment, the conclusion is drawn that **no reproduction whatever of yeast** *(Saccharomyces cerevisiæ)* **occurs in the sponge.**

438. The Dough.—This consists of the whole of the flour to be used, together with the whole of the water and other constituents of the bread, whether mixed straight off or with intermediate stages of ferment and sponge.

439. Various Methods of Bread-Making.—Among these may be included the following:—

Dough made right off—Off-hand Doughs.
Ferment and Dough.
Sponge and Dough.
Ferment, Sponge, and Dough.
Flour Barm, Sponge, and Dough—Scotch System.

A useful classification of bread-making processes on this principle is given in an essay on "The Best System of Bread-Making," contributed to the National Association Review (late Q.T.R.), by W. T. Callard. The following arrangement has been suggested by Callard's paper:—

440. Off-hand Doughs.—In this system the dough is made direct, without any preceding stages of ferment or sponge.

Types of Bread made by Method.—Sometimes employed in making tin-bread (*i.e.*, bread baked in tins), but also at times for making crusty bread.

Flours Used.—Strong patent flours, mixed very slack for tin bread. Strong London households for crusty cottage bread.

Dough-Making.—Generally from 1¼ lbs. to 2 lbs. of distillers' yeast taken to the sack (280 lbs.), with sometimes a little brewers' yeast in addition. Formerly from 10 to 14 lbs. of boiled potatoes were also added, but this appears to be no longer the rule. Salt from 3 to 3½ lbs. per sack. The slack tin-bread doughs, containing 70 quarts water per sack, are frequently made by hand, and fermented at a temperature of about 76—80° F. when mixed: they lie for about ten hours, and yield about 104 loaves per sack.

For cottage bread the dough is made much stiffer, about 60 quarts of water per sack, and usually allowed to ferment at a higher temperature, so as to be ready in about six hours. These tight doughs are generally made by machinery, or else the dough is made at first somewhat slack, and then "cut back" and dusted up at intervals.

Economic Advantages and Disadvantages.—All labour of sponging and extra manipulation saved, bread produced in less time, only one blend of flour and one doughing operation. An increased cost results from the large quantity of yeast required; also number of troughs and consequent space necessary is considerable.

Character of Bread—Appearance.—Very red and fiery in crust, not clear in the partings of the crust, volume fair. When used for cottage bread, a small and rough-looking loaf is the result.

Yield.—Large, the high proportion of yeast enabling the flour to carry considerable quantities of water.

Flavour.—Sweet, but somewhat neutral at times, and even harsh, when fermentation has been pressed to the utmost extent. In cottage bread when forced, to get a big loaf, there is often a tendency to sourness.

Texture.—Poor, loaf devoid of silkiness or pile, holes of æration unequal, and cottages small and close.

Colour.—Dull, and devoid of sheen.

Moisture.—High, even to clamminess in some loaves.

Summary.—A system in which colour and appearance are sacrificed to moisture and convenience of working.

441. Ferment and Dough.—As the term implies, this bread-making system is one in which a ferment and dough are employed.

Types of Bread made by Method.—Used very largely in London and the South of England in the manufacture of crusty bread, and also well adapted for tin bread.

Flours Used.—These should be fairly soft, and spring Americans should not exceed 40 per cent. of the whole mixture. Of hard wheat flours, Russians seem to suit this method of bread-making better than the spring American, owing to their glutens mellowing down more rapidly. Some bakers who work by this method claim to use English wheat flours to the exclusion of all other varieties. Winter American patents and also Hungarian flours answer well in this type of bread.

The Ferment.—This most frequently consists of from 10 to 14 lbs. of potatoes to the sack, boiled or steamed, and then mashed with water so as to yield about 3 gallons of liquor. Brewers' yeast is frequently used in ferments, although recently distillers' yeasts have been similarly worked. The ferment is "ready" in about six hours. Various substances are employed as substitutes of potatoes in ferments.

Dough-Making.—The ferment is taken, together with about 2½ to 3 lbs. salt to the sack, water over all to the extent of about 56 quarts to the sack, and allowed to work fairly warm, say 80—84° F. The dough is allowed to lie for various times, from two to about five hours. This will depend on the working temperature, character of flour, and strength or quantity of ferment used.

Economic Advantages and Disadvantages.—After the labour of preparing the ferment, all that of making and breaking down the sponge is avoided; there is but one blend of flour required; and altogether the cost of manipulation is very little more than that of off-hand doughs subsequent to the ferment. It has the advantage that comparatively few troughs are necessary, because in most cases each can be used several times over during the day's work. The yeast required is not high in amount, but the potatoes used sensibly increase the cost of production, and from their dirty character are a nuisance in the bakery.

Character of Bread—Appearance.—Loaf is usually well risen, bearing in mind the class of flours employed. The crust is rough, inclined to break, and usually "short" and crisp in texture. Is bright and clear, except when too strong dark flours are used.

Yield.—Small, because soft flours are generally employed, say about 90 loaves to the sack.

Flavour.—Good, and particularly suited to the London palate, there being considerable sweetness. As in all cases where ferments are used, there is danger of "yeastiness," unless care is taken that the ferment is not allowed to stand sufficiently long for lactic or other foreign fermentation to proceed unduly at the close of the alcoholic fermentation.

Texture.—Close and even (*i.e.*, holes of æration regular), but not silky.

Colour.—Good, with nice bloom; crust tendency to brownness, but should be free from any foxy tint, the result of absence of very hard flours. Crumb clear and bright, but comparatively devoid of sheen.

Moisture.—Fair, when bread is first made; but all bread of this kind has seen its best twelve hours after leaving the oven.

Summary.—A very useful system of bread-making, well adapted to districts where bread is eaten very fresh.

442. Sponge and Dough.—This is probably the most widely used of all bread-making methods, and evidently therefore adapts itself well to diversified requirements.

Types of Bread made by Method.—Almost every kind of bread, from the tightest crusty bread dough to that for the slackest tin bread, may be made in this manner.

Flours Used.—Practically every variety of bread-flour offered to the baker can be utilised in this method; the great advantage is that hard flours can be used in the sponge, thus giving them the advantage of long fermentation, while softer flours are appropriately worked in at the dough stage.

Sponge Making or "Setting."—A blend of hard flour is used for this purpose, and a quantity taken equal to from a quarter to a half the whole of the flour to be used. A frequent plan is to take a bag (140 lbs.) of spring American patents for the sponge, and a sack of home-milled softer flour for the dough. Sufficient water must be taken to make the sponge-dough very slack, say from 6½ to 8 gallons of water to the 100 lbs. of flour. Distillers' yeast is now most frequently employed, and a quantity may be taken of from 6 to 10 ounces to the sack of flour (over sponge and dough); if wished, brewers' yeast may be employed instead, but the quantity must considerably vary according to the strength of the yeast. A little salt is usually added to the sponge, say about ½ lb. to the sack. Formerly potatoes were occasionally added direct to the sponge: this custom seems now, however, almost obsolete. On being set, the sponge is allowed to ferment for from six to ten hours, according to the temperature, quantity of yeast, character of flour, and other considerations. In machine-bakeries sponges are usually set somewhat stiffer than where sponges and doughs are made by hand.

The Dough.—The sponge, when ready, is taken, mixed with the remainder of the flour, the water, and the salt. Soft, flavoury flours are introduced at this stage, and the dough allowed to lie about two hours. The temperature both of sponges and doughs is governed by how soon either may be wanted, the atmospheric temperature, and other considerations.

Economic Advantages and Disadvantages.—The adaptability of this method is one of its great advantages, and also the readiness with which it lends itself to the selection and use of any variety of flour. There is somewhat greater expense in working, because of the double handling involved in working the sponge as well as the dough. It is doubtful, however, whether this is appreciable in the hand-made bread bakery, as it amounts simply to making the dough in two instalments in the same trough—there is, in fact, an advantage, as the sponge flour will have had time to soften, and get to work more kindly before the full quantity is worked in in the dough.

Character of Bread—Appearance.—Almost any shape of loaf is well made in this manner, the bread is bold, and, generally speaking, of good appearance.

Yield.—With the great elasticity of the system, as a whole, the yield varies considerably according to the character of flours used. Taking a general average, 93 to 96 loaves per sack is a good proportion. If an excess of hard, strong flour is used in order to get more bread than this, the flavour is likely to suffer.

Flavour.—One of the essential characters of this type of bread is that, if well made, it embodies to perfection the natural flavour of the flours, without any adventitious characters introduced with foreign flavouring ingredients. If the flours are well selected, both for sponge and dough, there should be, on the one hand, an absence of that "rawness" characteristic of under fermentation, and of any harshness resulting from destruction of all moisture and sweetness-conferring constituents by over fermentation.

Texture.—The bread should have a good pile, crumb even, white, and silky, with full sheen on the fibre of the bread.

Colour.—The crust should be golden brown, without foxiness or abnormal paleness. In the crumb the colour advantage of the class of flour used should be fully developed.

Moisture.—Bread made in this manner is free from any clamminess, and may easily pass over the line into harsh dryness—this, however, is a fault that should not occur, rather than a necessity of the method. From the very even sponginess of the bread, although when fresh cut it may be very moist, yet it tends to rapidly dry out when cut slices are allowed to lie about. But when properly made, this bread retains its moisture in the uncut loaf remarkably well.

Summary.—An interesting point about the sponge and dough method is its comparison with that of ferment and dough; both have their advantages, but that just described for most purposes has the preference. Comparing breads made by the two methods, ferment and dough made bread is at its best when quite fresh; while suitably made sponge and dough bread retains its eating properties considerably longer.

443. Ferment, Sponge, and Dough.—This is essentially a combination of the two immediately preceding methods, and is frequently chosen where brewers' yeast is used, as the ferment exerts a specific and valuable action on yeast of that description. A ferment being employed, instead of adding yeast to the sponge direct, a description of the sponge and dough method applies also to this process. One of its advantages is that it permits more individuality in character of the bread than where a compressed yeast is used, which can be freely purchased by any baker. When by means of a "ferment" the baker practically makes his own yeast, he becomes liable to the risks as well as the advantages accruing from being his own yeast manufacturer. This method is frequently associated with the manufacture of patent yeast by the baker himself. The whole of the various methods previously described are susceptible of the same modifications, except perhaps tight, off-hand, crusty bread doughs, which would rise with difficulty under the action of this usually comparatively weak yeast.

444. Flour Barm, Sponge, and Dough—Scotch System.—The flour barm is practically a combination of the making a baker's malt and hop yeast with a slow, scalded flour ferment. The preparation of the flour barm has been fully described in the earlier part of this work, Chapter XII., paragraph 367.

Type of Bread made by Method.—This is the well-known close-packed "Scotch brick," being a high and comparatively narrow loaf, prepared from tough, hard flour of the highest class.

Flours Used.—In sponges, strong patents or straight grades from Duluth or Russian wheats. In doughs, winter Americans and softer, but still tough, home-milled flours.

Sponges.—These are known as "half" or "quarter" sponges, and consist of either the half or quarter of the whole liquor employed to the sack of flour. The requisite quantity of flour barm is taken, for which, however, distillers' yeast may be substituted without materially altering the character of the bread. About 6 lbs. of salt are used to the sack, one-sixth of which goes into the sponge.

Doughs.—These are made in the usual way, but it is customary to give the dough a very thorough working after it has laid some time. One of the most suitable ways of doing this is by passing the dough repeatedly through a dough-brake.

Economic Advantages and Disadvantages.—The cost of production is, according to the views of the Scotch baker, very low, as he views the yeast as costing him very little, the flour used coming back into the bread. This is not quite correct, because a certain portion must have been changed into alcohol and carbon dioxide during fermentation; and, again, the labour of preparation must cost something.

Character of Bread—Appearance.—The appearance is attractive, the loaves are high, and the sides, where they have been separated from each other, have a very smooth, silky appearance.

Yield.—Large, the character of the flours used permitting this, and also the fact of most of the bread being close packed. An average yield in a large factory has for some months been as much as 101 quarterns per sack.

Flavour.—Characteristic, and marked by the presence of a decided acidity of pure and pleasant taste, due largely, if not entirely, to the presence of lactic acid. The large quantity of salt used gives a saline character to the taste, immediately recognised by the English palate, which also usually misses the sweetness generally found in the best qualities of bread made in the south.

Texture.—Scotch bread has the perfection of texture, being silky, with large bulk and pile, and small regular holes of æration.

Colour.—The long system of baking employed gives the crust a dark brown colour, and hence the bloom of crust is not such an important characteristic as in south country crusty bread. The crumb is exceedingly white, but has comparatively rarely the creamy, yellow bloom seen in some of the bread made in other localities. The sheen of the bread is remarkably distinct, the holes having a rich, full glaze.

Moisture.—Good, and the bread keeps remarkably well.

445. Detailed Examples of Preceding Methods.—Following are accounts of different processes of bread-making, culled from various sources as representing the details of methods that have been or are actually in use. The first account is somewhat historical, being given in a Report to the Secretary of State, in 1862, by Bennett, as representing "London Practice" at that time. It will be readily understood that no single account, or even a number of accounts, can cover all the varieties of bread made in so vast a city as London. The whole of the following quantities are calculated to a sack of flour.

446. Bennett's Account.—The ferment is made about twelve o'clock in the day in the following manner—nine pounds of potatoes are boiled and mashed in a tub; this is cooled down with water until at a temperature of 80° F. One quart of brewer's yeast is then added, together with about two pounds of flour. Fermentation sets in, and completes itself in about six hours. At the end of that time the sponge is made by adding the ferment to about the quarter of the total flour, and about eight gallons of water: this is kneaded and allowed to ferment; this sponge is allowed to rise once, and then fall and rise again: on the top of the second rise the dough is made. The sponge takes about six or seven hours to undergo the changes mentioned. To the finished sponge, the remainder of the flour, about three pounds of salt, and another seven or eight gallons of water are added, making altogether about sixteen gallons, or 64 quarts to the sack of flour. The dough is kneaded, and allowed to stand from one to two hours. It is then scaled and moulded, 4 lbs. 6 oz. of dough being taken for the 4 lb. loaf: the loaves are then baked from two to three hours. The yield of bread is about ninety-one 4 lb. loaves to the sack of flour.

Bennett's estimate of the time the bread is in the oven is enormous, and, so far as the author is aware, is far in excess of that now adopted, even in London, where bread is generally kept in the oven longer than elsewhere.

447. Methods with Distillers' Compressed Yeasts.—These are now largely used, and the following represent successful London methods of working:—

Method without Ferment.—Sponge, 7 lbs. best potatoes, boiled, mashed with about 30 quarts of water, and strained into trough. This should have a temperature of about 85° F. In a bowl of this strained liquor ½ lb. of compressed yeast is "dissolved," this is then added to the rest of the liquor. From a quarter to a third of the flour is next added, and thoroughly mixed. In warm weather, ¾ lb. of salt is to be added to sponge. This sponge breaks in about six hours, and again rises in another hour. Dough is made by adding another 30 quarts of water at 85°, in which either the 3 lbs. of salt, or what remains of that quantity after what has been used in the sponge, is dissolved. The rest of the flour is added and the dough kneaded. The dough is allowed to stand from half-an-hour to an hour, then scaled and moulded.

Method with Ferment.—For the ferment, 7 to 12 lbs. of best potatoes are taken, boiled, mashed in a tub with from 2 to 4 quarts of water; when cooled down to 85° F. 2 lbs. of raw flour are added and 1 pint of brewers' yeast. The ferment is allowed to work for about five or six hours, and in about seven hours the sponge is set. The sponge and dough are made in the same manner as before described.

448. Birmingham Practice.—In Birmingham, bread is commonly made in the following manner—no ferment is employed; the sponge is made with about 3 pints of brewers' yeast to the sack of flour, and is allowed to stand for about ten hours. The yeast is mostly obtained from small public breweries. Salt is used in the proportion of about 2½ lbs. to the sack; but the quantity is increased or diminished according to the strength of the flour. In hot weather French and German (compressed) yeasts are used either in whole or in part as substitutes for brewers' yeast. When compressed yeast alone is used the sponge is allowed to stand for about eight hours. The use of potatoes is almost discontinued in Birmingham, as the bakers there are of opinion that they give much trouble without any corresponding advantage.

449. Manchester Practice.—Some of the Manchester bakers still use a potato ferment, but the practice is fast dying out. Compressed yeast is employed almost entirely to the exclusion of other kinds. Dutch yeast is most commonly preferred, of which 1 lb. is used per sack. One third of the entire water is used in the sponge, which is made very light. The water is used either hotter or colder according to the temperature of the atmosphere, but no attempt is made to fix the temperature other than by the judgment of the workman. In two hours the sponge begins to drop: 3 lbs. of salt are then dissolved in the remainder of the water, and this, together with the remainder of the flour, is mixed in with the sponge in order to prepare the dough. In all, about 75 quarts of water are on the average used to the sack of flour. The dough after standing one hour is weighed off, and is usually baked in tins. The time in the oven is one hour.

450. Scotch Practice.—This in its turn differs considerably from English modes of making bread. For the earlier portion of the following description the author is indebted to an article on Scotch Sponging in the "American Miller," by Thoms of Alyth. The author applied to Mr. Thoms for permission to use his article, and also for data as to Scotch methods of doughing and baking. That gentleman in reply sent a letter which is so valuable that the author thinks it the best plan to quote it *in extenso.*

In Scotland, flour barms are largely used, almost to the exclusion of other forms of yeast: the preparation of these barms has already been described. The barm constitutes the ferment, and is mixed direct into the sponge. Scotch bakers work on either the half or quarter sponge system. The following directions for sponging are quoted from Thoms' article.

451. "Half Sponge.—Sponging with either Virgin or Parisian barms is identical, whether the sponges are half or quarter. A 280lbs. sack of flour requires over all stages of fermentation from 16 to 18 gallons of liquor. I assume here that the reader knows all about stirring a sponge. Half sponge means half of the total liquor in sponge. For every five or six parts, whether pints or gallons of liquor in half sponge, we give one part of either of these barms. The temperature of the sponge liquor, of course, varies with the seasons, ranging from, in summer, 76° F. to 84° F.; in winter, from 90° F. to 98° F.; the sponge to rise twice, and be on the second turn within 12 hours. Also, to every gallon of liquor in sponge, when using water of ordinary softness, two oz. of salt, and the rest of the salt considered necessary at doughing stage. The best flour we find for sponging with these barms is American North-west 'Spring' and Russian 'Straight' grades. Observe, not 'Bakers,' which means 'straight,' or one-run flour, with the cream, in the shape of patent, taken out. The less winter wheat flour used in these sponges the better; it should be used at the dough stage. Few varieties of winter wheat flour will rise twice in the sponge and produce good bread. Many of them, when sponged without admixture, particularly 'patents,' will not rise twice with the purest barm or pressed yeast. Limited to winter wheat flour and half-sponging with these barms, I would sponge stiff almost half the total flour, and take the sponge on the first turn. Sponging with strong glutinous flours, such as Hard Spring and Russian, I would use only about one-third of the total flour required in all stages; that is, the half-sponge here referred to is only a fair working stiffness.

452. "Quarter Sponge.—This system is found most convenient where machinery is used (the half sponging where hand labour is employed for sponging and doughing), and means $\frac{1}{4}$ of the total liquor for a known quantity of flour in the first stage, instead of $\frac{1}{2}$ as in half-sponging. Quarter-sponging is done in tubs. Sponge for one sack of flour requires a tub of 50 gallons capacity. Say we wish quarter-sponge ready for doughing at 4 a.m. to-morrow, then at 2 p.m. to-day we take —for making about one sack of flour into bread—3 gallons water, $1\frac{1}{2}$ or $1\frac{1}{4}$ gallons barm, and six oz. salt, and mix these with the necessary flour into a sponge as stiff as batch dough. In 12 hours, or 2 a.m. to-morrow, the sponge will be turned, the first time $\frac{1}{2}$ an inch, then we break in or up with machine or hands the quarter with 12 gallons more water, $1\frac{1}{2}$ lbs. or $1\frac{1}{4}$ lbs. more salt, and add enough flour to form a very weak sponge. This will rise again in the tub and be on the turn in about 2 hours, or 4 a.m., when the remainder of the salt necessary is dissolved in $\frac{1}{2}$ gallon water, and dough made. Many, and especially in cold weather, do not dissolve the salt in water, but simply sprinkle the salt over the sponge in the machine or trough. It will be observed that in neither the half nor quarter sponges is there ferment or potatoes used. The barm is the ferment, and is added direct to the sponge. For regulating fermentation in warm weather, in addition to colder water, it is advisable to reduce the quantity of barm or yeast, and in cold weather to increase it."

453. Doughing and Baking.—Here follows Mr. Thoms' letter—"My article in the 'American Miller' on 'Flour Barms and Sponging' leaves off with the sponges ready at 4.0 A.M. Let us suppose the sponges 'broken in'—the technical term—with the necessary salt and water, we then mix in the flour. Yes! but what flour? Spring American is supposed to be used in sponges, and what we will use in dough will depend on the price for the flour, the price for bread, and whether our bread is to be crusty as in England, or close packed, high volumed, and silky skinned as in Scotland. In England I might use all Winter American flour in dough, here not more than half Winter—sound *red*. What home grist we have goes into the dough, together with part Spring flour. Indian wheat is going largely into English grist, but I would prefer the Indian in sponge. I doubt the dough stage being long enough to allow the hard gluten of Indian wheat time to sufficiently hydrate and soften [peptonise]; without which the bread would be harsh, low, dry soon, &c., &c.

"The doughs, of whatever flours composed, will be made by 4.30 or 4.40 A.M., and are allowed to lie for $\frac{3}{4}$ hour, then turned, dry dusted, and kneaded from one end of the trough to the other and back again; and in another $\frac{3}{4}$ hour or so, or about 6.0 A.M. they are thrown out and scaled off. Where kneading machines are employed the dough should have more mixing, in order to knock out proof before throwing or turning out. How do you know when it is ready to throw out and scale off? We judge only by feel and smell. The dough should feel tight, lively, and resistant, tear easily; and the rent, on the head being held down and a deep inspiration taken through the nose, should show carbon dioxide in volume nearly suffocating, accompanied by a slightly vinous odour.

"If scaling off begins at 6.0 A.M., moulding the loaves may begin at about 6.30 or 6.45. This refers to medium slack doughs for close packed bread; stiff doughs require longer. After moulding, the medium slack loaves are allowed from 15 to 30 minutes to prove in the boxes, and then run into the oven. Stiff dough, again, requires longer proof; and, except in summer, the boxes holding the moulded loaves are slightly heated.

"The time in oven for 4 lb. close-packed, square loaves is two hours, and the best baking temperature 400° F., while the bread is baking. For 2 lb. square loaves, the same temperature, time, $1\frac{1}{2}$ hours; these data refer to both steam and Glasgow ovens coke heated inside. A higher temperature and shorter time we find carbonises the top and bottom crusts, while the crumb in the heart of the loaf is more or less raw. Crusty loaves, 4 lbs., slightly packed, temperature about the same or a little less, 380° to 400° F., and time, $1\frac{1}{2}$ hours; 2 lb. crusty loaves, same temperature, time, 1 hour. These are not the shortest times in which the various breads can be baked, only what experience has shown me to be the best. The baking heats refer to the time while the breads are in the oven. If the fires are lighted at 4.0 A.M., it will, of course, be necessary to heat the ovens higher than that; how much higher will depend on the heat of the ovens before lighting the fires. On Mondays we go higher than on other days; the steam ovens we heat up to 480° F.; the ovens heated with coke or coal inside we heat up to 550° F. By the time the batches are ready to go in they well have cooled down to 420—30° F., and by the time the batches are actually in they will show a temperature of 410—15° F."

454. Wilding's Bread-making Directions.—The following particulars as to bread-making by different processes are quoted from the First Prize Examination Paper written by William John Wilding, for the Bakers' National Association annual examination in 1894. They are introduced here for two reasons: one, their value as being one of the most recent practical baker's contributions on this subject; and secondly, as an illustration of the good work being done by the Association in disseminating useful knowledge among members of the baking trade. The prices given may be taken as those ruling at Midsummer, 1894.

A.—Ferment and Dough.
B.—Sponge and Dough.
C.—Off-hand Dough.

A. Set ferment for one sack flour, 280 lbs., with 2 gallons water, 1 lb. yeast (distillers'), 2 lbs. flour, 2 oz. sugar. When stirred, the temperature should be about 76° F., let stand one hour, or till it has settled down in tub. Make dough with 12 galls. water, or sufficient water to make a nice dough, 2¼ lbs. salt, ½ lb. "diastase," and sack of flour; temperature of dough to be 78 to 80° F. When made, should stand three hours or so, or till ready to throw out; or it may be cut back, but this class of dough need not be cut back if it is properly made; although it will improve it by doing so. When ready, throw out, scale, and mould on bench, prove for five minutes, then mould into boxes. When all moulded, put tops on, and place on plate.

B. Set sponge for one sack of flour, with 7 galls. water, ½ lb. yeast, ¼ lb. salt in summer, stir with about 80 to 90 lbs. flour, temperature when stirred 76° in summer, little warmer in winter; ready in about eight hours. Make dough with seven more galls. water, ½ lb. diastase or malt extract, and 3¾ lbs. salt (this quantity is higher than is usually used in England, but I give this as, say, you use 3 lbs., well the flavour of the loaf will be rather insipid, having no flavour of salt nor of sugar). This dough should be cut back, and will be ready to throw out in 1½ or 2 hours. Temperature of dough when made 76 to 80° summer. Scale and mould clear, using a little more labour in the moulding than the preceding one.

C. For one sack, using all the liquor of course, about 14 galls., 2 lbs. yeast (distillers'), 2¼ salt, or 2½ in summer, ¾ lb. malt extract. Make into dough, which should be about 78° F. Cut back every two hours until it has been made eight hours, when it should be ready to throw out. Mould, and let it prove before going into oven.

No. A. Cost of flour blended so as not to contain very much hard flour, say one part English, one Spring American, patent the other part, half and half of Hungarian and Californian, cost, say	£1	4	0
1 lb. yeast	0	0	6
Sugar and malt extract and salt	0	0	6
Fuel	0	0	4
Labour	0	2	6
Cost of sack of flour made into bread ...	£1	7	10

B. Cost of flour, namely, two parts Spring American patent (part of this would be used in the sponge, or as much as would be required for it), one part English and Hungarian. This would all be used in the dough, cost 25s. This mixture should yield more loaves to the sack than A.

Flour	£1	5	0
Labour	0	2	9
Yeast	0	0	3
Diastase	0	0	3
Salt	0	0	1½
Fuel	0	0	4
	£1	8	8½

C. Flour, one part Spring American patent and Winter American patent, two parts English, one part Hungarian, cost 24s.

	£	s	d
Flour	£1	4	0
Labour	0	2	9
Yeast	0	1	0
Diastase	0	0	4½
Salt	0	0	1
Fuel	0	0	4
	£1	8	6½

A costs	£1	7	10	Materials, labour, &c.
B ,,	1	8	8½	,, ,,
C ,,	1	8	6½	,, ,,

A. The bread would be fairly small, with a sweet flavour, more pleasant to the taste than the eye. The cost of production is low; I average it 2s 6d for labour, that is, reckoning a man at 30s per week to do two sacks a day. Of course this is heavy work, but more as a comparison.

B. The bread would be larger, better "pile," the flavour more acid and salty. The loaf should look well, liable to be slightly foxy if not properly treated. Labour hire, 2s 9d; also flour, 25s.

C. The bread will be rather small but sweet, with a very small quantity of salt. In labour, higher than "A"; also more yeast and yeast food or diastase.

B would produce more loaves to the sack than A or C, therefore making up for higher price flour. C would produce less than A, so therefore the value of the three will not vary very much."

REVIEW OF PANARY FERMENTATION.

455. It is proposed in the succeeding paragraphs to consider the nature of the chemical changes which occur during bread or panary (from *panis*, bread) fermentation. Suggestions will also be made as to possible improvements in methods of carrying out the various processes, with the hope that they may lead to the avoidance of those causes which result in the production of bad or inferior bread.

456. The Ferment.—Potatoes, termed by the baker "fruit," constitute the principal ingredient of the ferment; their composition is indicated in the following analyses. No. 1 was grown with mineral manure, No. 2 with a rich nitrogenous manure :—

	No. 1.	No. 2.
Water, ...	76·40	75·20
Starch, ...	14·91	15·58
Proteids, ...	2·17	3·60
Dextrin, ...	2·34	1·29
Sugar, ...	0·15	1·11
Fat, ...	0·29	0·31
Extractive Matter, ...	1·70	1·99
Cellulose, ...	0·99	1·03
Ash, ...	1·00	0·90

Roughly speaking, a potato contains three quarters of its weight of water and about 15 per cent of starch; the remainder being made up of small percentages of proteids, dextrin, sugar, and other substances. On being boiled, the starch is gelatinised, and on mashing the potatoes, together with the liquor in which they have been boiled, a starch paste is formed, containing also considerable quantities of dextrin and sugar, and what is of great importance, soluble nitrogenous compounds. Yeast on being sown in this medium sets up an active fermentation, largely due to the sugar already present, together with the strong nitrogenous stimulant. In Chapter XI. it has been demonstrated that the fermentation is almost as active in the filtered potato water as in the mash. It must also not be forgotten that yeast alone is incapable of inducing diastasis in starch paste. Consequently, any unaltered starch suffers little change in a ferment containing only boiled potatoes and yeast. But raw flour being also commonly added, the yeast induces a change in the flour proteids, in virtue of which they become somewhat active hydrolysing agents, and so the potato-starch is indirectly converted in part into sugar. The yeast, when sown in a ferment, multiplies by growth, and thus a relatively smaller quantity of yeast is enabled to do the after work. A large proportion of the starch of the potato still remains unchanged at the close of the fermentation of the ferment; so also, the nitrogenous matter of the potato in great part remains. When the ferment is added to the sponge, the smaller quantity of yeast not only does more work because of its having had the opportunity of growth and reproduction in the ferment, but also because the nitrogenous matter of the potato still acts as a yeast stimulant in the sponge. The active effect of potato water alone shows that this stimulating action of the ferment on yeast must not be entirely ascribed to the starch present. From the active stimulating nature of the nitrogenous matter of potatoes on yeast, it seems probable that that matter consists of nitrogen in some other form than albuminous compounds. Summing up these changes into one sentence, **in the ferment the yeast acts on the soluble proteids of the flour and enables them to effect, to a limited extent, diastasis of the starch: this results in the production of a saccharine medium in which the yeast grows and reproduces; further, the soluble nitrogenous matter of the potato acts as an energetic yeast stimulant.**

It is essential that the potatoes used in the ferment be sound: they should first of all be washed absolutely clean. A common practice is to place them in a pail or tub, with water, and scrub them with an ordinary bass broom; this treatment is inefficient, as potatoes served in this way still retain a considerable amount of dirt. The potatoes are then boiled in their jackets, and afterwards rubbed through a sieve in order to separate the skins. By far the best plan to clean potatoes is by means of a machine, of which the following type answers well for all practical purposes. The machine consists essentially of an outer tub, in which is fixed a vertical revolving brush: the potatoes are put in, and about two minutes turning the brush cleans them most effectually. The dirt is removed and also a good deal of the outer skin, while the interior of the potato remains intact. Treated in this manner the potatoes have only just the slightest film of skin to be removed, after boiling, by means of the sieve. In the next place, the pan, or other vessel used for boiling the potatoes, should be kept clean; this is only done by its being washed, drained, and wiped dry every day. Not only the potatoes, but the water in which they are boiled, should be quite clean enough, if need be, to go into the bread. At present, many bakers steam their potatoes in preference to boiling: this modification is cleanly and convenient. The potatoes are placed in a metal work cage, which in its turn is placed in a box arrangement, through which steam is conducted from a boiler: when sufficiently cooked, the cage, together with the potatoes, is lifted out, and its contents poured on to a sieve. The ferment should be rapidly cooled to the pitching temperature of about 80° F in summer, and 85° in winter: in summer it is very important that the baker should throughout conduct his fermentation at as low a temperature as possible. During the time that a ferment is working the temperature should be kept even: for this purpose select a place in the bakehouse free from draughts or excessive heats.

At present, flour, together with malt extract and a number of other materials, are being used as substitutes for potatoes in ferments.

457. Panary Fermentation.—The consideration of the division of this process into sponging and doughing may be postponed until after a study of the nature of the changes occurring during panification as a whole. Yeast, flour, and water, at a suitable temperature, on being mixed so as to form a dough, immediately begin to react on each other. The flour, it must be remembered, contains sugar, starch, and both soluble and insoluble proteids. The yeast consists essentially of *saccharomyces;* but bacterial life is also present in greater or less quantity, not only in the yeast but also in the flour. The yeast rapidly sets up alcoholic fermentation, thus causing the decomposition of the sugar into alcohol and carbon dioxide gas; the latter is retained within the dough and causes its distension. Functioning in dough, no reproduction of the yeast occurs; after a time the yeast cells disappear through the degradation and rupture of their walls. In addition, the yeast attacks the proteids present, effecting changes in them which are similar to, if not identical with, the earlier processes of digestion. Albumin and its congeners are, in fact, more or less peptonised. The gluten, from being hard and india-rubber like, becomes softer, and within certain limits more elastic; but if fermentation be allowed to proceed too far, the gluten softens still further, and its peculiar elasticity in great part disappears. It is uncertain to what extent these changes in the gluten are due to the specific action of yeast, as they also occur, although more slowly, in flour which has simply been mixed with water. It has been already explained that under the action of yeast the albuminous bodies of flour acquire the power of effecting the diastasis of starch; this compound is consequently to some extent converted into dextrin and maltose during panification. The amount of starch so hydrolysed depends largely on the soundness of the flour. In addition, the diastase of the flour itself will probably have some action in inducing starch conversion. The lower the grade of the flour, the more raw grain diastase it usually contains. When potatoes are used, whether as a ferment or as a direct addition to the flour, they furnish soluble starch, and also act as a nitrogenous yeast stimulant. While the yeast effects important changes in the albuminous compounds of flour, experiments made and described in Chapter XI. show that little or no gas is evolved as a consequence of such changes. The gas produced in dough during bread-making is the result of normal alcoholic fermentation of sugar by the yeast. **Summing up the changes produced in panification—they are alcoholic fermentation of the sugar, softening and partial peptonising of the proteids, and a limited diastasis of the starch by the proteids so changed.**

So much for the action of yeast on dough. The next point of importance is the effect produced by such other organisms as may be present. The principal one of these is the lactic *bacillus*; under its influence the sugar of the dough is converted into lactic acid. Either the organism itself, or the acid produced by its action on sugar, has a softening and dissolving effect upon gluten. Opinions differ as to the desirability, or otherwise, of the presence of lactic ferments in yeasts used for bread-making. It has already been explained that their being found in any but the smallest quantity in brewers' or compressed yeasts is an unfavourable sign, as they show that due care has not been taken in the manufacture of the yeast; for that reason their presence is deemed unfavourable. In Scotch flour barms the presence of lactic ferments in not too great amount is deliberately encouraged: experience having shown that if the barms be brewed so as to exclude these organisms such good bread is not produced. In Scotch bread-making very hard and stable flours are used; the lactic ferment does good service in softening the gluten. It is possible also that during the long period of sponging and doughing, the changes induced by the lactic ferment may cause slight evolution of gas; but so far as actual æration of the dough is concerned this may be viewed as a negligeable quantity. It must be remembered that the *soupçon* of slight buttermilk flavour is a valued characteristic of Scotch bread. In bread-making, as conducted by most English processes, particularly with soft flours having but little stability, there seems no useful function which the lactic ferment can perform; its absence is therefore rather to be desired than its presence. A yeast may contain other organisms in addition to those just mentioned; these are capable of inducing changes of a far more serious nature than does the lactic ferment. Among these there are the organisms which cause butyric and putrefactive fermentation. That bane of the baker, sour bread, is commonly ascribed to the action of either lactic or acetic fermentation; it is, however, far more probable that this unwelcome change is due to incipient putrefactive and butyric fermentation; since the odour of a sour loaf is very different from that of either the vinegar-like smell of acetic acid or the buttermilk odour accompanying lactic acid. The souring takes place more usually in the bread rather than in the dough.

In order to produce a healthy fermentation in dough, healthy yeast is of vital importance: purity from foreign organisms is desirable (saving, perhaps, a small proportion of lactic ferment in flour barms), but above all the yeast itself must be active and in good condition. Given a yeast, which contains a certain percentage of foreign ferments, those ferments will be held in abeyance while the yeast itself is energetic and healthy. Bakers are often puzzled by microscopic observations of yeast; they find that, of two yeasts, one produces sour and the other a good bread, and yet that the two contain about the same quantities of disease ferments. They are consequently very apt to despise any conclusions they may have drawn from microscopic observations; but the difference in such cases lies in the yeast itself: the one will be healthy the other weak and languid. Quoting again from previously described experiments, in the same sample of wort, divided into two portions, the one only of which was sown with yeast, and both equally exposed to the air, it was found that in the presence of yeast life, *bacteria* refused to develop, while in its absence they reproduced with enormous rapidity. In the same way the healthy yeast suspends the developments of *bacteria* in dough, while the yeast being weak and almost inactive, bacterial life flourishes apace. Examination would reveal that in most cases of unhealthy panary fermentation the fault is as much due to the yeast itself as to the abnormal presence of foreign ferments.

458. Sponging and Doughing.—This division of the process of panary fermentation into two distinct steps is of extreme interest. The origin, and reasons which led to the adoption, of this mode of procedure are probably due to the exigencies of dough-kneading by hand. For even when using flour from the lot which has been placed in his trough, the baker usually elects to work a part of it into a sponge first. The reason, or at least one reason, is that the dough softens on standing, and therefore there is less work involved in mixing in the flour in two instalments than in one, as the first lot will have got considerably softer. Further, very little experimental work in this direction will have shown the baker that he required to use less yeast, and got better results when working in this way. Hence, doubtless, for original reasons such as these, the division of bread-making into sponge and dough. Independently of this, they have for other reasons a most important scientific justification. The reader will by this time be familiar with the division of flours into strong and weak varieties. The various tests given in a preceding chapter show, not merely that one flour absorbs more water than another to form a dough of standard stiffness, but also that some flours fall off far more rapidly in stiffness than do others when kept in the condition of dough. There are therefore two distinct properties here to be considered in relation to flour, the absolute quantity of water it absorbs, and also the rate at which slackening goes on during panification. Remembering the previous definition of water-absorbing power, **the relative capacity of resistance of flours, to a falling off in water-retaining power during fermentation, may appropriately be termed their "Stability."** As a rule, the strong flours are also the more stable, but this does not necessarily hold good in all cases. It has been already explained that, for the production of the best bread, fermentation should be allowed to proceed sufficiently far to soften and mellow the gluten, but no further. At stages either earlier or later than this, the bread will lack both in appearance and flavour. It is therefore necessary to so regulate fermentation as to stop at precisely this point: unfortunately no exact means are at present known whereby it can be determined with precision. The more stable a flour is, the longer it requires to be fermented before this point is reached, hence where flours of different qualities are being used, the more stable should be set fermenting earlier than the others. In this lies the reason for using some flours at the sponge and others at the dough stage. Flours from hard wheats, such as Spring American or Russian, should be used in the sponge; and American Winter or English wheaten flours in the dough. Working with stable flours in the sponge, experience has shown, according at least to the London practice, that the best results are obtained by allowing the sponge to rise and fall once, and then to rise again. The time taken for this rising and falling is found to agree with that necessary for the sufficient mellowing of the gluten. This empirical test, which is the result of careful watching and experience, is at present the baker's principal guide in determining the progress of fermentation. It affords evidence of the degree of rapidity with which gas is being evolved, and indirectly of the extent to which the other chemical changes have proceeded.

459. Variety and Quantity of Yeast used.—The variety of yeast employed produces a marked effect on the character of the resultant bread. Good brewers' yeast is almost universally admitted to induce a characteristic sweet or "nutty" flavour, hence it is largely used in the manufacture of so-called farmhouse bread. Colour in this variety of bread is secondary to sweetness of flavour. While brewers' yeast has a somewhat energetic diastasic action on the proteids and starch of dough, its fermentative power is comparatively low in that medium. Undoubtedly, one of the reasons which has led to the comparatively extensive use of potatoes in bread-making is their stimulant action on the gas-producing power of brewers' yeast in dough.

Continental compressed yeasts, on the other hand, are marked by their rapid power of inducing alcoholic fermentation in dough: experience indicates that neither potato nor flour ferments are necessary, at least as stimulants, when working with these yeasts; although those bakers who have been in the habit of using potatoes, because of the specific flavour and character they impart to bread, will probably by preference, for some time at least, continue the practice.

Motives of economy on the part of the bakers, and competition on the side of the yeast merchants, both lead to a certain rivalry among the latter as to whose yeast is able, weight for weight, to adequately ferment the greatest quantity of flour. Now, while it is important that the baker should know with accuracy the relative strengths of different brands of yeast, it is nevertheless not wise to be too sparing in the quantity employed to a sack of flour. Although four ounces of yeast may be sufficient to ferment a sack of flour, yet half-a-pound will do it much better, and probably with greater economy in the long run.

First, select the strongest and purest yeast you can get for the money, and then don't be afraid to use sufficient of it. This advice should have especial weight in the south of England, where soft, weak flours, having comparatively little stability, are so largely employed. Flours of this kind will not bear being kept so long in the sponge and dough stage as is necessary to ferment them with a very small quantity of yeast; they, if so treated, produce sodden, heavy, and sometimes sour loaves; when any saving in yeast is more than compensated by a less yield of bread.

460. Management of Sponging and Doughing.—In order to insure success in the manufacture of bread, sound materials are the first requisite: after that the most important in this, like all other operations in which fermentation employs an important part, is the proper regulation of temperature. The yeast should always be stored where it will get neither too hot nor too cold; for extremes of temperature in either direction weaken the action of yeast. Brewers' yeast in particular suffers from this in summer weather; and so, many bakers who use it in the winter change over to compressed yeast in the summer. In summer time the compressed yeasts are when fresh more active than in winter: in proof of this, compare the results of tests made and given in Chapter XII. In winter the strength of the yeast may be increased by allowing it to stand for a time in water at 85° F. before being used. A still better plan is to stir a handful of raw flour and a small quantity of sugar or malt extract into a bowl of water and then add the yeast; let this stand for about an hour, gently stirring now and then in order to ærate the liquour. Such treatment refreshes and invigorates the yeast, and so enables it to afterwards work more actively. Both sponge and dough should be so managed as to keep the temperature as nearly constant as possible during the whole of the fermentation. Any considerable rise in temperature accelerates the action of the yeast, but at the same time, and to a greater degree, stimulates lactic and other foreign fermentation. Good yeast works well at from 80° to 85° F., and at that temperature lactic and butyric fermentation proceed but slowly, even in the presence of the special organisms which induce these types of fermentation. Sudden cold should also be avoided, as a chill to working yeast is most detrimental, causing fermentation to entirely cease, or at the best to proceed most sluggishly. Such a sudden lowering of temperature may indirectly be the means of producing a sour loaf.

461. Use of Salt.—A great deal has been written as to the use of salt as a guiding agent in fermentation; so far as the yeast is concerned, salt is generally viewed as having a retarding influence; although the opinion has been expressed that quantities of salt under 3 per cent. of the water used stimulates the action of yeast. This opinion is based on certain observations of Liebig. The author's own experiments (*vide* Chapter XI., paragraph 339) lead him to conclude that salt, in all proportions from 1·4 per cent. upwards, retards alcoholic fermentation, and diminishes the speed of gas evolution. Salt acts still more powerfully as a retarding agent on lactic and other foreign ferments, and so aids in the prevention of unhealthy fermentation. In addition, salt also checks diastasis, and thereby prevents undue hydrolysis of the starch of the flour. In summer time, or when any suspicion of instability attaches to the flour, it is well to add some portion of the salt to the sponge; but when the flour is good, and the yeast pure and healthy, the whole of the salt may be deferred to the dough stage.

In the Scotch methods of bread-making, flours of a very strong and stable character are used in the sponge, which altogether is allowed to stand about twelve hours. A slight amount of lactic acidity is developed in this, and is viewed as normal; it has an important function in softening and mellowing the gluten. It will be noticed that a small proportion of salt is, in the Scotch process, added to the sponge.

462. Loss during Fermentation.—This has been variously estimated, among the highest figures being that of Dauglish, who expressed the opinion that this loss amounted to from 3 to 6 per cent. In order to determine the maximum amount of loss possible, the author made a direct experiment—100 parts by weight of soft flour from English wheats were made into a dough with distilled water, two parts of pressed yeast being added; no salt being used. This dough was allowed to stand for from eight to nine hours at a temperature of about 85° to 90° F.; fermentation proceeded violently, but towards the end of the time had apparently ceased. The dough was then placed in a hot-water oven, and maintained at a constant temperature of 212° F. for 10 days; the same weight of flour and yeast, but no water, was also placed in the oven. At the end of that time the fermented dough was found to have lost 2·5 per cent. compared with the flour. Now in this extreme case a soft flour was used with distilled water and no salt, and about six times the normal amount of yeast; the temperature was purposely maintained at a high point, and the fermentation carried on so long as any decided evolution of gas occurred. Yet, under these conditions, which far and away exceed in severity any such as are met with in practice, the loss was less than Dauglish's minimum estimate. It will be of interest to notice that the percentage of loss closely corresponds with that of sugar in flour, according to the analysis given in paragraph 338, Chapter XI. "Tablier Blanc," in the "British and Foreign Confectioner," states, as the result of experiments of his own, that the loss of solid constituents of flour during fermentation, as practically conducted in bakeries, amounts to 1·37 per cent. Turning next to the loss in weight of the dough during fermentation—Thoms gives, as the result of direct tests on the dough from a sack of flour, the loss during working as from 10 to 12 lbs., or from 3·5 to 4·2 per cent. Dauglish's estimate was probably based on somewhat similar data; but a moment's consideration shows that this loss must consist largely of water which escapes by evaporation from the dough during fermentation.

463. Baking.—For baking, the oven should be at a temperature of 450-500° F. Many modern ovens are now fitted with a pyrometer, by means of which the temperature may be read off. If depending on this instrument, care must be taken that it is in efficient working order. In the oven the dough rapidly swells from the expansion of the gases within the loaf by the heat. Its outside is converted into a crust; the starch being changed into gum and sugar: these are at the high temperature slightly caramelised, and so give the crust its characteristic colour. The effect of the heat on the interior of each loaf is to evaporate a portion of the water present in the dough: the carbon dioxide, and a portion of the alcohol produced by fermentation, escape with the steam, and may be recovered from the gases within the oven. While any water is present in the bread, the temperature of its interior can never rise above the boiling point of that liquid. Owing to the pressure caused by the confining action of the crust, that boiling point may, however, be somewhat higher than under normal atmospheric pressure. The increase due from this cause is probably not more than some two or three degrees. As baked bread still contains some 35 to 40 per cent. of moisture, it may be safely stated that the inside of the loaf never rises to a higher temperature than 215° F. It is commonly stated that, in the act of baking, the starch of flour is gelatinised. This, however, is only partly the case. The temperature of a baked loaf rises considerably above that requisite for gelatinisation, but there is also another condition necessary. Gelatinisation is essentially an act of union with water, and a loaf does not contain sufficient moisture to anything like gelatinise the whole of the starch. At the moment of writing, a fragment of bread has just been examined microscopically, and field after field is seen of unbroken and apparently unaltered starch corpuscles. One of the largest present was measured and found to be 0·057 m.m. in diameter, showing that the starch had not even materially swollen. Doubtless under the influence of heat the starch has become softened, but the larger proportion of the granules still remain intact. (Compare paragraph 151, page 78.) At the temperature of the interior of the loaf, the coagulable proteids will have been coagulated, and their diastasic power entirely destroyed. The composition of bread, compared with that of flour, is dealt with subsequently.

464. Time necessary for Baking.—The time during which bread is kept in the oven varies considerably in different parts of the country: much must depend on the temperature—whether the oven be quick or slack. For 4 lb. crusty loaves an hour to an hour and a quarter seems to be an average time. The half-quartern or 2 lb. loaf is a much commoner size in the south of England, and loaves of this description can readily be baked in from forty to fifty minutes in any well constructed oven.

465. Glazing.—The admission of steam to an oven, when properly managed, has the effect of producing a glazed surface on the outside of the crust: this operation is familiar to bakers as that by which Vienna rolls are glazed. In order that the operation shall be effective, the bread or rolls should be as cool as possible. The steam should be simply at atmospheric pressure, and saturated with moisture. At the instant of the cool loaf entering the steam atmosphere of the oven, a momentary condensation of steam occurs over the whole surface, which is thus covered with a film of water at the boiling point. This renders the starch of the outside surface soluble, and as the water dries off leaves a glaze of soluble starch, part of which possibly has been converted into dextrin. The injection of steam into the oven not only helps to dextrinise and glaze the crust, but also serves the purpose of keeping the interior of the loaf moist by preventing too rapid evaporation.

466. "Solid" and "Flash" Heats.—These terms are frequently used by the baker in speaking of the character of the heat of different ovens. The former is applied to heat which is continuous, the latter to heat which is very temporary, but frequently for the moment intense. It will be found that the so-called "solid" heat is usually evolved from the walls of a well-heated oven. A good oven should have plenty of material about it; this gets hot through, and afterwards radiates heat slowly but continuously. If the oven walls be too thin they cool too quickly; in consequence they have to be heated very intensely at the start; the result is that the oven at first burns the bread, and towards the end has not heat enough to complete the baking of the batch. With thicker walls the initial temperature of the oven need not be so high; the fall in temperature taking place more slowly, the oven still retains a good heat at the close of the baking. The heat which reaches the bread from the walls of the oven is largely in the form known as "radiant" heat; it is continuous, and need not be of abnormally high temperature in order to thoroughly and efficiently bake bread. The consequence is that the interior of the bread is well baked, while the crust is not burned.

A "flash" heat, on the other hand, is produced by the contact of highly heated gases with the bread. Certain varieties of ovens are fired by the introduction of flame into the oven itself. Such introduction of flame should be employed to previously raise the temperature of the oven, not, if used at all, to bake the bread itself. The reason is obvious; it is exceedingly difficult to regulate the temperature of a current of hot air from a flame with great exactitude. The temperature is sufficiently high at one time to burn the crust; at another so low as to prevent, during the time the bread is in the oven, its inside being sufficiently cooked. Further, if the bread is to be heated by the hot air resulting from the direct admission of flame into the oven, there must necessarily be also some means of exit for the gases from the flame. The hot air from a furnace cannot, in fact, be drawn into the oven without some means for their after escape. The result is that these gases carry with them the steam evolved from the baking loaves, and so subject the bread to a dry, instead of a steam saturated, atmosphere.

467. Cooling of Bread.—The loaves on being taken from the oven should be cooled as rapidly as possible in a pure atmosphere; for this purpose, where practicable, open-air cooling sheds should be provided. Failing these, the cooling-room must be well ventilated. It goes without saying that the cooling loaves must be adequately protected from rain.

468. Summary of Conditions affecting Speed of Fermentation.—While fermentation starts with the first addition of yeast to the other materials, it does not conclude till the bread has been for some time in the oven, and possibly not even then. At this stage of work, with both principles and details of methods of working explained, a bird's eye view of the whole course of fermentation should be of service.

A ferment, when used, is a means of making yeast by a process of reproduction from that originally added. Steps are taken at the same time to ensure vigour in the new yeast formed. The speed of fermentation of the ferment is hastened by increase of temperature, but beyond a certain point that of acid-producing organisms is also more than proportionately stimulated. Æration during fermentation tends to increase the vigour of the produced yeast. (Compare Adrian Brown on the action of oxygen on fermentation.)

Assuming a start has been made with either sponge or off-hand dough, the same laws govern fermentation.

First, let us see **what conditions accelerate fermentation.**

With regard to yeast, the greater the quantity, the more quickly it proceeds: with *sound* yeast there is no fear of imparting a yeasty taste to bread with many times more than necessary for ordinary bread-making. The strength of the yeast will also directly tend to increase the rate at which fermentation proceeds.

Flour.—Soft flours tend to hasten fermentation; they contain more sugar and more starch in a condition susceptible to diastasis. Their proteid matter is more likely to act as a yeast stimulant, while the softness of the gluten lessens a physical obstacle to rapid action of yeast.

Potatoes, Saccharine Extracts.—These act as stimulants, and tend to increase the speed of fermentation.

Water.—The principal way in which this acts is in virtue of the proportionate quantity used. When doughs are slack, fermentation proceeds much more rapidly.

Æration.—Flour well ærated is likely to work more rapidly, especially in slack sponges. Notice how in Vienna bread the batter sponge is beaten and worked, and how much more vigorous and "lively" it is in consequence.

Temperature.—This governs all; with low temperatures yeast works very slowly, if at all, and with higher temperatures fermentation is accelerated.

Next, as to **conditions retarding fermentation**: these may be summed up as the opposite of the accelerating agents—yeast, weak or in small quantities; hard, dry flours; stiff, unærated doughs; low temperature; and finally, the addition of salt, which has a very marked retarding effect.

By modifying one or more of these conditions, the baker is able to regulate the speed of his fermentation; and, where certain of them are altered by causes beyond his control, is able to more or less compensate the disturbance by introducing changes in one or more of the others. Suppose, for example, the working of a sponge is unduly hastened by having to use a softer flour than usual, this may be modified by making it tighter, or working with less yeast, or at a lower temperature. A good deal of the art of the baker consists in properly adjusting these variable factors so that they shall properly balance each other, and all conduce to the production of a good loaf of bread.

469. Summary of Course of Fermentation.—A very useful lesson may be learned by making a batch, say of 20 lbs. of flour, into a slack dough, with a full allowance of distillers' yeast, say 3 ounces; salt and water in proportion, and working the batch fairly warm. Let a piece be cut off and moulded into a loaf immediately the dough is made, and at once baked—the result will be a close, small, very moist loaf, not much bigger than the piece of dough cut off. Next bake a similar loaf from the same piece of dough at the end of every hour from the time of starting, keeping the main mass covered, and in a warm place. An instructive series of changes will be observed in the successive loaves. In boldness, the bread improves for some hours, then remains stationary, and finally becomes "runny" and flat. The colour of the crust is at first "foxy," then of a golden yellow or brown tint, and finally abnormally pale. The crumb during the first three or four loaves of the series gradually improves, and becomes more bloomy, then changes to a greyish white, losing the bloom, and then "saddens" and darkens, becoming a dull, cold grey, merging ultimately into a brown. At the same time it becomes ragged on the outside edges, and dark where a soft crust has been produced by two loaves being in contact with each other in the oven. In flavour, the first loaf will be sweet, but "raw" and "wheaty," characters which will be lost as fermentation proceeds; at its best the raw taste will have gone, leaving only a sweet, clean-palate flavour. This will be succeeded by a gradual disappearance of the sweetness, the bread being neutral and tasteless: at the same time the loaf will have lost its moisture, and will be harsh and crumbly. As fermentation is pushed still further, the bread commences to be "yeasty" (to taste of the yeast); but this depends somewhat on the original soundness or otherwise of the yeast. This condition merges into one of slight sourness, first of pure lactic acid flavour, accompanied by buttermilk odour; but gradually becoming worse, until, finally, not only is the taste offensive, but so also is the smell, partaking not only of sourness in character, but also of incipient putrefaction and decomposition. During these latter stages the bread again becomes soft and clammy. The first drying off, until the bread reaches the harsh stage, is due to the disappearance of soluble starch and dextrin by diastasis into sugar, and then fermentation: the subsequent clamminess is the result of degradation, not only of a portion of the starch, but also the insoluble proteids of the dough.

Such are, in brief, the changes observable in dough under ordinary conditions of working, from the first start of fermentation to the commencement actually of putrefaction. These may be slightly modified by character of the flour and other constituents of the dough; but if the conditions of fermentation be healthy and normal, the whole series of changes substantially follows the order here given. Changes in temperature, degree of stiffness of doughs, &c., within

recognised and approved limits, may accelerate or retard fermentation as a whole, but they do not alter its character and general course.

SOUR BREAD.

470. Souring of Bread.—Quite a literature has grown up and around this subject since the author's earlier work was written, to which important contributions have been made both by bakers and chemists. Among the earliest of these was a reference in a paper read by W. A. Thoms at the meeting of the Bakers' National Association, Birmingham, in 1887. In this paper he expresses himself as inclined to "Jago's opinion, that in butyric acid we have the cause of sour bread." He further states that in excessive acid fermentation lactic acid is produced, and that, further, the two acid fermentations may proceed side by side, lactic acid being produced, and a part of it, at least, simultaneously converted into butyric acid. T. Fletcher dissented from this view of the cause of sourness of bread, and in 1888 contributed to one of the meetings of the same Association an important bakers' practical paper on *Sour Bread: how it is caused, and how it may be avoided.* Reference is made to the fact that commercial yeast contains foreign organisms, and that these produce acidity or putrefaction; further, that among them are lactic germs producing lactic acid, and acetic germs producing acetic acid. Dealing with the fermentation of a sponge, he points out that by alcoholic fermentation alcohol and carbon dioxide are produced, and that the falling of the sponge depends on the gas tearing asunder the distended sponge and escaping. If the working of the sponge is permitted to proceed beyond the point experience teaches is most suitable, unpleasant results follow, particularly as the energy of the yeast fails. In this stage the sponge or dough contains considerable quantities of alcohol, and Fletcher argued that the well-known change of alcohol into acetic acid by oxidation,

$$\underset{\text{Alcohol.}}{C_2H_5HO} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Acetic Acid.}}{HC_2H_3O_2} + \underset{\text{Water.}}{H_2O},$$

was the cause of the acidity of sour bread, especially from overwrought sponges or doughs.

At the same meeting of the Association, Laurence Briant read a paper on *The Purity of Bakers' Yeast*, during which he remarked that "The chief result produced by the presence of false ferments is acidity, and acidity means sour bread, and whether or no *that* is desirable we need not here argue." Further, he states that he (Briant) "was formerly of opinion that a considerable portion of the acidity of dough was due to the oxidation of the alcohol distributed in its pores; but although this may, no doubt, be partially the case, he has been able to prove by careful experiment that the sourness of dough is due chiefly to lactic and butyric acids; at least, such is the result he has obtained in the analysis of several specimens of overworked dough."

These two statements are of considerable importance, and at this point it will be convenient for the author to state that there appear to him cogent reasons for dissenting from the view that "acidity means sour bread," using each of these terms in their generally accepted sense. As a particular and separate meaning will be attached by the writer to each in the following remarks, it will be well to exactly define the sense in which they are used. "Acidity" is a chemists' term, and is caused by the presence of free acid; the measure of acidity is the amount of alkali of definite strength required to produce neutrality. "Sour bread" is a baker's term, and is applied to bread which has a sour odour and flavour to the organs of smell and taste respectively. Experiments show that *acidity*, as measured by chemical means, and *sourness*, as judged in bread by the nose and palate, are not necessarily alike in intensity or entirely dependent on each other: for this reason the limitation of the sense in which the author personally uses each term is here indicated.

It will be noticed that Briant's opinion at this date differs from that of Fletcher as to the part played by acetic acid in the acidity of bread. Prior to the publication of these papers, the author had enunciated the view of acidity being the result of the presence of lactic and butyric acid in bread. From the known properties of yeast he had formed an opinion adverse to the view of bread acidity being due to acetic acid. Yeast, it will be remembered, has a great avidity for oxygen, and according to Pasteur's view, alcoholic fermentation was a starvation phenomenon in the absence of oxygen. This theory is no longer tenable, but in any case the fact remains that yeast readily absorbs oxygen from any fluid in which it is actively at work. Thus, Schützenberger points out that yeast "introduced into a liquid medium containing oxygen in solution (pure water, a saccharine solution, with or without nutritive material and nitrogenous elements), absorbs oxygen with great rapidity, and develops a corresponding quantity of carbon dioxide." As the acidity of a sponge or dough is the effect of acid fermentation following the normal alcoholic, there cannot be within the mass of dough any oxygen by which the alcohol disseminated through it can be oxidised to acetic acid. For this reason, therefore, it is only on the surface of the dough exposed to air that such action is possible. And even here it must be exceedingly superficial, for in the presence of the possibly slow, but continuous, exhalation of gas *from* the sponge, it is very improbable that any perceptible absorption of oxygen is occurring. Even when quiescent, it must be remembered that a sponge contains an abundance of yeast ready to start again in active fermentation as soon as supplied with food. There will therefore be on the surface of such a sponge yeast in far greater plenty than acetic acid germs, and with the greater vigour of the former organism, it is a fair assumption that of the very limited amount of surface assimilation of oxygen, the lion's share will be taken by the yeast and converted into carbon dioxide. As both lactic and butyric acids are products of anærobic ferments, and are the result of chemical changes which are absolutely independent of external free oxygen, the same objections do not apply to these as sources of acidity. For these very cogent *a priori* reasons, the author has viewed the presence of acetic acid as being (under any normal conditions such as are commonly found in a bakery) an exceedingly limited and practically negligeable cause of acidity.

471. Briant's Researches.—The next most important contribution to this subject was another very valuable paper by Briant, contributed to the Bakers' Association Review, No. 4, Vol. VI., 1893, and No. 7, Vol. VII., 1894. Briant points out that there are degrees of acidity, and that "a sample of perfectly sweet dough, which on baking produced excellent bread, was found to contain 0·144 per cent. of acid expressed as lactic; another sample of dough, producing a flavourless, brittle loaf, yet not appreciably acid to the taste, contained 0·27 per cent. of acid expressed as lactic." Briant then refers to his opinion expressed in 1888, and previously quoted, that the acid in sour dough and bread consisted largely of lactic and butyric acids. He next proceeds to give the results of analyses of several samples of dough, about which he remarks that

> "The first sample was one analysed a considerable time ago, and it was upon the basis of the figures I then obtained that I made the statement in my paper on 'Pure Yeast' as to the acids present in sour dough. The sample was obtained from a London bakery. It was analysed as regards its volatile acids by the method of fractional distillation devised by Duclaux, whilst the non-volatile acid residue was analysed by separating out the zinc salt. Into the details of this it is hardly necessary to enter here, but the methods are perfectly well known to those chemists who have worked upon the subject, and have been used by myself many times before for the examination of acids present in distillers' wash, wort and beer. The particular sample of dough operated upon smelt strongly of butyric acid, more strongly, in fact, than any of the later samples which I have obtained; and I have reason to believe that in this respect it cannot be taken as quite representative, for as a rule I do not find sour dough to possess any, or at any rate but a slight, butyric smell. The amounts of acetic, lactic, and butyric acids were estimated by the method I have mentioned, and the following were the figures obtained:—

Lactic Acid, ...	·21	per cent.
Acetic Acid, ...	·05	,,
Butyric Acid, ...	·04	,,

> "These figures are probably not quite accurate, for I was dealing with a small quantity of dough, far smaller than used in my more recent experiments; and, as I have mentioned, I believe the amount of butyric acid present in this dough was exceptionally large.
>
> "The following experiments give figures obtained from the analyses of different samples of dough, and these were in each case analysed by the methods I have quoted.
>
> "I should mention that the yeast used was in each that of the Delft Company, a brand which may be regarded as practically free from bacteria. This point is one of much importance, as will be seen when in the second section of this paper we consider the causes of the production of these acids.
>
> "It is well also to bear in mind that lactic acid does not, weight for weight, correspond to the same acidity as acetic acid. Three parts by weight of lactic acid have the same acidity as two parts by weight of acetic acid.

'A.' (Fresh dough)—

Lactic Acid, ...	·024	per cent.	
Acetic Acid, ...	·038	,,	
Butyric Acid, ...	None.		

'B.'—

Lactic Acid, ...	·405	per cent.	
Acetic Acid, ...	·150	,,	
Butyric Acid, ...	·06	,,	(about).

'C.' (Very acid dough)—

Lactic Acid, ...	·622	per cent.	
Acetic Acid, ...	·245	,,	
Butyric Acid, ...	Trace.		

'D.' (Same dough kept another day)—	
Lactic Acid,	·742 per cent.
Acetic Acid,	·249 ,,
Butyric Acid,	Distinct trace.
'E.'—	
Lactic Acid,	·493 per cent.
Acetic Acid,	·175 ,,
Butyric Acid,	Trace.
'F.'—	
Lactic Acid,	·460 per cent.
Acetic Acid,	·197 ,,
'G.' (The same dough kept three days longer, then extremely acid)—	
Lactic Acid,	1·08 per cent.
Acetic Acid,	·231 ,,
Butyric Acid,	Heavy trace.

"In addition to the determination of the above by Duclaux's method, I have also devised a method of my own which I have used in addition, and have by this means checked the preceding figures, but I prefer to quote Duclaux's figures, as his method is a recognised one, and as there is practically no difference between the results yielded by the two processes.

"It will be recollected that Duclaux himself detected butyric acid in sour dough by the fractional distillation process which I have used.

"The above results clearly show that the bulk of the acidity in acid bread is due to lactic acid, but that a certain proportion, varying from one-third to one-fifth, consists of acetic acid, and that in most of the samples the amount of butyric acid is very small. The samples in which I have found butyric acid have been made in most cases from inferior flour and bad yeast, and the connection between these and butyric acid is very close, as I shall be able to show in my next article on the subject. I believe, on the strength of the above figures, that I may claim to have proved what are the acids present in flour, for I have separated the acids by recognised methods in a fair number of samples.

"Of course, all these samples were badly acid; I purposely used such samples in order to obtain more sharp distinctions. It must not, therefore, be presumed that these figures represent the normal acidity of an acid dough. With the exception of one or two samples, they represent dough at what may be considered its maximum of acidity; but although the acidity varies, as will be seen in the different samples, yet the same general rule holds for all, viz., that the bulk of the acid in sour dough is lactic, but that there is also a considerable, and indeed, in some cases, a large amount of acetic present also. It is this acetic acid which, together with butyric acid (if present), gives the smell to sour dough—lactic itself being non-volatile has no smell—therefore, were dough acid with lactic acid alone, it would have no sour smell, although, of course, it would taste acid."

Briant then remarks that

> "Practical experience has shown that sour bread is obtained most readily with bad yeast, common flour, and when high temperatures are employed, whilst the same result is favoured by over-fermentation, a slack dough, dirty yeast troughs, and over-exposure to the air during the doughing stages. Any satisfactory solution should be able to explain why it is in practice that the conditions which I have named favour the production of sour bread."

By systematic bacteriological investigation, Briant found micro-organisms; and in sour dough identified lactic and acetic ferments, and in some cases, also the butyric ferment. On inhibiting bacterial action by the addition of chloroform, dough is absolutely prevented going acid. The conclusion is therefore drawn that acidity is due to bacterial action. The next point for consideration was the source of these bacteria, which were searched for among the following—water, air, yeast, dirty vessels, and flour.

Practically, the results were negative with water and air. It was found just as easy to get sour bread with sterilised water as with an ordinary town supply. So, too, exposure to ordinary air containing micro-organisms did not produce any appreciable difference in the acidity of dough from that produced by sterilised air.

Many modern yeasts are practically bacteria-free, and while an impure yeast may cause sour bread, yet Briant produced sour dough with a pure yeast-culture from a single cell. Whilst yeast therefore may cause sour bread, it is at any rate not the only cause for it. Dirty vessels, it almost goes without saying, are a most fruitful source of acidity.

Briant found flour itself to be a most potent factor in producing acidity. Thus, he remarks that

> "Until I had examined a considerable number of flours, I did not realise fully how important an influence they must have upon the soundness of bread. But having made bacteriological examinations of a large number of samples, I am led to the conclusion that it is here that we meet with a very decided cause of sourness in bread. The differences between flours in this respect are very great, indeed some are comparatively—although none are absolutely—free from bacteria, but others contain very large quantities, and amongst them it is possible to very readily separate the lactic and the acetic ferment. In every case of sour dough I have found the flour to contain acid-producing ferments. In a low-class flour, which in practice was found to very readily yield sour bread, unless worked with much care, we find in the flour itself precisely those ferments which are afterwards found in the dough and act as acid producers, and here we have the real cause of the acidity. Where the flour used by a baker contains any but a very small proportion of bacteria, there will always be a certain risk of acidity. By careful working the baker may reduce this risk, and particularly if he uses a commercially pure yeast and observes scrupulous cleanliness. He *may* find it perfectly possible to produce bread which is quite sound, despite the fact that the flour contains many bacteria. For several considerations bear upon the growth of these bacteria. First is that of temperature. The activity of the lactic ferment, according to De Bary, increases as the temperature rises, up to a certain point. It grows and produces acidity comparatively slowly at a temperature of 60°, but at temperatures exceeding 70° it becomes extremely active. It reaches its maximum of activity at about 108°, above which temperature it rapidly declines in power. The acetic ferment reaches its maximum at a temperature between 85° and 93°, at which latter temperature its power of reproduction and acidification is enormously rapid.[1] From these considerations it is therefore

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[1] Of interest in this connection are some experiments published by Briant in 1888, in which he fermented dough with yeast in the proportion of 12 oz. to the sack at various temperatures, and determined the amount of acidity, reckoned as lactic acid, produced. No. 1 was a moderately pure distillers' yeast, while No. 2 could not be considered other than as decidedly impure. The brewers' yeast was, however, very good indeed, but worked extremely slowly, and was over two hours longer than the others. The following is the

PERCENTAGE OF ACID EXPRESSED AS LACTIC ACID.

TEMPERATURE. F.	No. 1. DISTILLERS'.	No. 2. DISTILLERS'.	No. 3. BREWERS'.
65°	0·020 per cent.	0·020 per cent.	0·020 per cent.
75°	0·025 ,,	0·030 ,,	0·020 ,,
85°	0·040 ,,	0·050 ,,	0·030 ,,
95°	0·050 ,,	0·075 ,,	0·032 ,,

The value of these experiments would have been much greater had particulars also been obtained of the amount of alcoholic fermentation in each instance. Thus, supposing that in each case the action was arrested, when the same quantity of sugar had undergone fermentation, and then the acidity determined, one would have much more definite data from which to decide as to the relative suitability of high, compared with low, fermenting temperatures for bread-making.

at once apparent that whilst high temperatures for panary fermentation are in all cases undesirable, yet in cases where low-class flours are used, they are almost fatal. In low-class flours also there is almost invariably present a large excess of objectionable nitrogenous bodies. These bodies are particularly suitable as a *nidus* upon which the bacteria can feed, so that in low-class flour we have these additional causes of risk. Again, another very important circumstance which contributes to sour bread is over-fermentation, and the cause of this is very simple. So long as the yeast is vigorously working, so long are the bacteria kept in check, and just as in the fermentation of wort in a brewery, we find that though bacteria are present, yet the wort itself remains free from acid until the yeast has ceased its work, so in baking the bacteria are held in check whilst the fermentation is vigorous. Immediately, however, the fermentation flags, the bacteria commence to act, and this is particularly the case with the acetic ferment, which at this stage is supplied with the alcohol which it converts through aldehyde into acetic acid. In fact, whilst it is possible for some small quantity of lactic acid to be produced concurrently with the procedure of fermentation by the yeast, this is practically impossible in the case of the acetic ferment, which will only commence to act after the yeast has finished its work. But in order that the acetic ferment may convert the alcohol into acetic acid, it requires the presence of some oxygen. Therefore it is, that the more a dough is kept free from exposure to air, the less chance of production of acetic acid there is, and the practical experience of the baker has led him to adopt what is practically accurate from a scientific point of view, viz., the exclusion of air so far as is possible during the fermentation process. Again, the production of acidity is far more rapid if the dough is slack. When this is the case, the bacteria are able to thrive far more rapidly and vigorously than is the case with a stiff dough, and in some experiments which I have made as to the speed of souring of a stiff *versus* slack dough, I have found a remarkably increased rapidity of souring with the latter, and there can be no question but that, from the point of view of soundness of bread, the dough should be kept as stiff as is practicable.

"Finally, therefore, I may summarise my conclusions as follows:—

"1. The acids of sour bread are acetic and lactic acids, with occasional small quantities of butyric acid. Lactic acid in most cases is present to the extent of two or three times that of the acetic acid.

"2. The acid is produced by bacteria to be found in the dough.

"3. These bacteria may be introduced by the yeast, by the use of dirty vessels, and by the flour, but their presence in the flour is the most general cause of acidity. Some high-class flours contain very few bacteria; low-class flours are often simply teeming with them.

"4. The use of high temperatures facilitates the activity of the bacteria which may be present, and is therefore objectionable.

"5. The bacteria are present, but do not to any large extent become active until the alcoholic fermentation commences to flag. Hence, over-proved dough is specially liable to acidity.

"6. Slackness of dough contributes to the activity of bacteria, and therefore is undesirable.

"7. Exposure to air, by supplying the acetic ferment with oxygen, favours its activity, and therefore fermenting dough should be kept as much out of contact with air as is possible."

Briant's papers represent a most important piece of work on the subject of sour bread, and embody some most valuable conclusions, the principal among these being the establishment of the connection between bacteria present in dough and its acidity, and the further emphasising of the fact that a most fruitful source of acidity is the presence of bacteria in flour. It has long been known to bakers that, working under precisely the same conditions, sourness is far more likely to occur in "seconds" than in "best" bread, but this particular reason—the greater prevalence of bacteria in low-grade flours—has here for the first time its due importance ascribed to it.

472. Personal Researches by the Author.—The author has for some years devoted much attention, both in the bakery and also the laboratory, to this problem of sour bread. As a result, he finds himself unable to agree with some of the opinions expressed by Briant, and in the following paragraphs endeavours to explain the reasons for his inability to confirm the whole of Briant's conclusions.

The first point is the promulgation of the view that acetic acid is so largely found in sour dough. As already explained, there are very cogent *a priori* reasons for the improbability of any great amount of acetic acid being found in panary fermentation; and Briant recognises that acetous fermentation must be an after fermentation, "*which will only commence to act after the yeast has finished its work.*" On examination of Briant's analytic results, we are at once confronted with the fact that in fresh dough, sample A, there is a higher proportion of acetic acid than in any of the others. Analyses C and D are of the same sample, made at an interval of a day: during this time the lactic acid has materially increased, while the acetic acid remains stationary. Analyses F and G are also made on the same dough, but with a three days' interval; the lactic acid has increased from 0·464 to 1·08, or to 2·35 times its original quantity. The acetic acid has similarly risen from 0·197 to 0·231, and is 1·17 times its original quantity. Although acetic acid is undoubtedly the result of an after fermentation, yet a relatively higher proportion is found in fresh than in stale doughs; in these experiments almost the whole of the after developed acidity is due to lactic, and not acetic, acid.

Following is an account of an independent series of experiments, made with the view of investigating the causes of souring of bread. Some of this work was done prior to the publication of Briant's researches, and a portion of the remainder was suggested by the results of his researches.

The determinations of the different acids were made by various processes described in Chapter XXIII, including the application of the method of Duclaux. (It will be remembered that Briant fractionally distilled off his volatile acids, and estimated them by Duclaux's method; he then determined the lactic acid in the residue by separating out the zinc salt, zinc lactate.)

As a preliminary to the analyses, various tests were made on the methods themselves. It is obvious that the separation of lactic from acetic and butyric acids by the process of distillation is only trustworthy on the assumption that, under the conditions of the estimation, lactic acid is non-volatile. But in Miller's "Elements of Chemistry" *(fifth edition, Armstrong & Groves)*, it is stated that "*on distilling an aqueous solution of lactic acid, a certain amount of acid volatilises with the steam.*" In order to investigate this point, the following experiments were made:—A sample of lactic acid was taken, which had been sold as chemically pure; this was tested for acetic and butyric acids, but gave no indication whatever of a trace of them being present. This was diluted with pure distilled water, free from carbon dioxide, and absolutely neutral to phenolphthalein, until of a strength equivalent to $\frac{7}{10}$ of that of centinormal acid. In a distilling apparatus, consisting of a Wurtz flask and glass (Liebig's) condenser, 110 c.c. of this dilute acid was subjected to distillation until 100 c.c. had come over: the distillate on titration possessed an acidity equal to 2·1 c.c. of centinormal acid. The residuum in the flask when titrated was found to require 63·3 c.c. of centinormal soda. In another experiment the original acidity was equivalent to 45 c.c., that of the 100 c.c. of distillate to 3·7, and that of the residual 10 c.c. to 35·1 c.c. of centinormal acid. In the one case about a thirty-seventh, and in the other a twelfth, of the total lactic acid had come over with the distillate. It may be taken as a general result that, working with very dilute acids, the quantity of lactic acid found in the distillate is not very large, but it is to be feared that it is liable to obscure conclusions based on Duclaux's system of fractionation. It will be noticed that in these experiments there is a considerable loss of acid, as the sum of the acidity of the distillate and the residuum does not agree with that of the quantity of acid originally taken. In order to determine whether there was any loss by a portion of the acid escaping condensation, the apparatus was fitted with nitrogen bulbs containing centinormal soda, as shown in Figure 77. In a number of experiments higher and more regular results were thus obtained, showing that some of the acid escaped as steam. This was particularly noticeable when the distillation was accompanied by "bumping." Still the amount of loss thus accounted for was nothing like sufficient to cover the whole of the deficiency.

A further investigation was made as to the reaction to acids of the flasks themselves, and it was found that the alkalinity of a number of flasks was more than sufficient to entirely vitiate the result of experiments made with them. Thus, for the purpose of testing, 110 c.c. of distilled water, free from carbon dioxide and neutral to phenolphthalein, were distilled in a Wurtz flask until reduced to 10 c.c. This residuum was titrated, and required 13·6 c.c. of centinormal acid. Another 110 c.c. of the same water was boiled down in a platinum basin, and the remaining 10 c.c. titrated: 0·1 c.c. of $\frac{N}{100}$ acid produced distinct acid reaction. New flasks are found to yield a much larger quantity of alkali to water than old, and no doubt the glass of some flasks is far more soluble than that of others. Thus, a new 400 c.c. Wurtz flask was washed thoroughly, rinsed in dilute sulphuric acid, then washed with distilled water, and attached to a "return condenser" (see fat determination, figure 75, Chapter XXII.). In the flask were placed 250 c.c. of distilled water, 3 drops phenolphthalein, and 1 c.c. of decinormal acid. The leading tube of the flask was closed, and the water caused to boil until a pink colouration appeared. Another c.c. of decinormal acid was then added and the boiling continued, this operation being several times repeated. The following are the results:—

1st c.c. of acid was neutralised by alkali dissolved from flask in	...	...	...	35 minutes.
2nd c.c. of acid	,,	,,	,,	28 ,,
3rd c.c. of acid	,,	,,	,,	37 ,,
4th c.c. of acid	,,	,,	,,	45 ,,
5th c.c. of acid	,,	,,	,,	40 ,,

In the next place a flask of the recently introduced "Jena Utensil Glass" was similarly tested. One c.c. of decinormal acid was added to water, as before, and the boiling continued for $2\frac{1}{2}$ hours; at the end of which the contents of the flask were titrated, and found to possess an acidity of 0·5 c.c., showing that only 0·5 c.c. of decinormal acid had been neutralised in that time.

The following experiment may now be described:—A mixture of one part "Red Dog" flour with four of baker's grade spring American flour was made. There were taken 3 lbs. of this mixture, $\frac{3}{4}$ oz. distillers' yeast, $\frac{1}{2}$ oz. salt, and very warm water. A sponge was first made, which had a temperature of 109° F., afterwards a dough which stood at 84° F. The sponge and dough stood altogether 24 hours in a warm place, and then smelt sour and incipiently putrescent. During the time of standing it was freely exposed to the air, and several times was "handed up" so as to work the outer skin into the mass of the dough.

At the end of this time a portion of the dough was reserved for direct tests, and the remainder baked slowly in a slack oven. (The object of the whole of the treatment was, of course, to get as sour a sample as was well possible.)

Dough.—To determine total acidity 10 grams of the dough were taken, broken down with neutral distilled water and titrated with $\frac{N}{10}$ soda and phenolphthalein (this indicator was used throughout):—required, 10·9 c.c. = 0·981 per cent. of total acidity, reckoned as lactic acid.

For the subsequent tests 50 grams of dough were taken and made up to 400 c.c. with distilled water, 1 c.c. of chloroform having been added. This was thoroughly mixed by repeated shakings, and allowed to stand over night: of the clear supernatant liquid, 230 c.c. were pipetted off the the next morning. In 10 c.c. of this the acidity was determined, being equivalent to 11·8 c.c. of centinormal acid. Of this liquid, 110 c.c. were taken and subjected to distillation by Duclaux's method in a "Jena" flask: the liquid frothed so that distillation could only be conducted with extreme slowness, occupying altogether about two hours. The following are the results:—

1st	10 c.c. distillate,	0·35	c.c. $\frac{N}{100}$ acid	= 3·6 %	of total distillate.
2nd	,,	0·45	,,	= 4·7	,, ,,
3rd	,,	0·55	,,	= 5·7	,, ,,
4th	,,	0·55	,,	= 5·7	,, ,,
5th	,,	0·60	,,	= 6·2	,, ,,
6th	,,	0·60	,,	= 6·2	,, ,,
7th	,,	1·05	,,	= 10·9	,, ,,
8th	,,	1·70	,,	= 17·7	,, ,,
9th	,,	1·75	,,	= 18·2	,, ,,
10th	,,	2·00	,,	= 20·8	,, ,,
11th in flask,		115·4	,,		

Total acidity of 110 c.c. = 129·8; total acidity of distillate = 9·6; acidity of residuum = 115·4; loss, 129·8 − 125·0 = 4·8 c.c. (The same flask evolved, in the blank experiment, alkali equivalent to 5·0 c.c. of $\frac{N}{100}$ acid in $2\frac{1}{2}$ hours.)

These results not only afford no evidence of the presence of butyric acid, but are even lower in the early stages than those of pure acetic acid. It seems probable that with the very slow rate of distillation absolutely necessary, the acid in the earlier stages recondenses in the upper parts of the flask, and so the proportion distilled over does not conform to Duclaux's table. Another 110 c.c. of the same 230 c.c. of liquid was evaporated to dryness in a platinum basin over a water bath, re-diluted with 50 c.c. of water, and again evaporated to dryness: the residual acidity was equivalent to 113·5 $\frac{N}{100}$ acid. The division of acid in this liquid into fixed and volatile agrees closely in both tests. Taking that in the platinum basin as being the more correct, we have out of 129·8 of total acidity, 113·5 of fixed, and 16·3 c.c. of volatile acidity. Reckoning these as percentages on the whole dough, we have in solution 0·74 of fixed acid (lactic) and 0·07 per cent. of volatile (acetic) acid. In strictness, it must also be remembered that any carbon dioxide present in the dough is also estimated as acetic acid, making this result too high rather than too low. Bearing in mind Balland's investigations, Chapter XXIII., in which he shows that a considerable quantity of the acid of flour is retained by the solid matter, and not given up to a filtered solution, the acidity of the remaining 170 c.c. of mixed liquid and residual flour solids was also determined. This was found to contain acid equivalent to 275 c.c. $\frac{N}{100}$ acid. As dough contains approximately 42 to 45 per cent. of water, the 50 grams taken will contain about $50 - 22 = 28$ grams of solid matter. Therefore the residual 170 c.c. will consist of about

$170 - 28 = 142$ c.c. of liquid and 28 grams of solid residue: and the total 400 c.c., of 372 c.c. of liquid and 28 grams of solid. But as the residual 170 c.c. contains 142 c.c. of liquid, the acidity of which is 1·18 per c.c. (by direct determination), then

$142 \times 1{\cdot}18 = 167{\cdot}5$ c.c. acidity due to the liquid portions.

Its total acidity, $275 - 167{\cdot}5 = 107{\cdot}5$ acidity remaining in the solid matter. Calculating this as lactic acid,

$107{\cdot}5 \times 0{\cdot}0009 \times 2 = 0{\cdot}193$ per cent. of acid remaining in solid matter.

The 372 c.c. of solution must contain, as by estimations on 110 c.c., the following quantities of fixed and volatile acid:—

$$\frac{113{\cdot}5 \times 372 \times 0{\cdot}0009 \times 2}{110} = 0{\cdot}792 \text{ per cent. fixed acid reckoned as lactic.}$$

$$\frac{16{\cdot}3 \times 372 \times 0{\cdot}0006 \times 2}{110} = 0{\cdot}066 \text{ per cent. volatile acid reckoned as acetic.}$$

Summing up these results, we have,

Dissolved fixed acid (lactic), ...	0·792	per cent.
,, volatile (acetic), ...	0·066	,,
Undissolved acid, remaining in solids, ...	0·193	,,
	1·051	
Total acidity by direct determination, ...	0·981	
Difference, ...	0·070	

Bread.—In common with the dough, the bread smelt not only sour, but of putrefactive products. The first estimation made was of moisture, of which there was 40·4 per cent., leaving 59·6 per cent. of dry bread solids. The percentages of acid are given on both the moist and dry bread. The total acidity was determined on 10 grams, and amounted to 10·1 c.c. of $\frac{N}{10}$ acid = 0·912 per cent. of acid reckoned as lactic acid on the moist bread. It may be of interest here to point out that 10 grams of dough = 10·9 c.c. of $\frac{N}{10}$ acid, and that approximately 10·6 grams of dough are required to make 10 grams of bread.

10·6 grams of dough have an acidity = 11·55 c.c. $\frac{N}{10}$ acid.
10·0 ,, bread ,, = 10·10 ,,

Acidity lost during baking, = 1·45 ,,
1·45 × 0·006 = 0·0087 grams acetic acid.

By this estimation, therefore, the bread has lost of acidity, reckoned as acetic, 0·08 per cent. As the bread still contains volatile acidity, and this amount is slightly less than the volatile acidity of the dough, the assumption is that a slight amount of lactic acid has been volatilised in the oven.

An aqueous extract of the bread was made in precisely the same manner as with the dough, 50 grams being taken and made up to 400 c.c. with the addition of 1 c.c. of chloroform. The following data were obtained on the clear supernatant liquid, of which 220 c.c. were removed :—

Total acidity of 10 c.c. = 9·3 $\frac{N}{100}$ acid.

110 c.c. were subjected to distillation by Duclaux's method, and boiled regularly and speedily. The following are the results :—

1st 10 c.c. distillate,	0·80 c.c. $\frac{N}{100}$ acid	= 6·5 % of total distillate.
2nd ,,	0·85 ,,	6·9 ,, ,,
3rd ,,	0·85 ,,	6·9 ,, ,,
4th ,,	0·95 ,,	7·7 ,, ,,
5th ,,	1·10 ,,	9·0 ,, ,,
6th ,,	1·10 ,,	9·0 ,, ,,
7th ,,	1·25 ,,	10·2 ,, ,,
8th ,,	1·45 ,,	11·7 ,, ,,
9th ,,	1·65 ,,	13·5 ,, ,,
10th ,,	2·20 ,,	17·2 ,, ,,
11th in flask,	90·7	

Total acidity of 110 c.c. = 102·3 ; total acidity of distillate = 12·2 ; acidity of residuum = 90·7 ; gain, 102·9 − 102·3 = 0·6 c.c. of $\frac{N}{100}$ acid.

These results are not very far apart from acetic acid, but are slightly on the formic rather than the butyric acid side.

100 c.c. were evaporated in a platinum basin, and gave 79·0 c.c. $\frac{N}{100}$ acidity, equal to 86·9 on 110 c.c. 102·3 − 86·9 = 15·4 c.c. of volatile acid. Working these out as percentages of lactic and acetic acids, we have 0·626 of lactic and 0·075 of acetic acid on the whole bread.

The residual liquid together with bread solids was next examined : the total volume was 400 − 220 = 180 c.c. As 50 grams of bread were taken, the bread solids were 30 grams. Therefore the residual 180 c.c. consisted of

180 − 30 = 150 c.c. of liquid and 30 grams of solids, and the total 400 consisted of 370 c.c. of liquid and 30 grams of solid.

The total acidity of the residual liquid and solids together is 306·0 c.c. $\frac{N}{100}$ acid. But as this contained 150 c.c. of liquid, the acidity of which is 0·93 per c.c., then

150 × 0·93 = 139·5 c.c. acidity due to the liquid portion.

The total acidity, 306·0 − 139·5 = 166·5 acidity remaining in the solid matter. Calculating this as lactic acid,

166·5 × 0·0009 × 2 = 0·299 per cent. of acid remaining in solid matter.

The 370 c.c. of solution must contain, as by estimation on 110 c.c., the following quantities of fixed and volatile acid:—

$$\frac{86{\cdot}9 \times 370 \times 0{\cdot}0009 \times 2}{110} = 0{\cdot}526 \text{ per cent. fixed acid reckoned as lactic.}$$

$$\frac{15{\cdot}4 \times 370 \times 0{\cdot}0006 \times 2}{110} = 0{\cdot}062 \text{ per cent. volatile acid reckoned as acetic.}$$

Summing up these results, we have,

Dissolved fixed acid (lactic), ...	0·526 per cent.
„ volatile acid (acetic), ...	0·062 „
Undissolved acid remaining in solids, ...	0·299 „
	0·887
Total acidity by direct determination, ...	0·912
Difference, ...	0·025

Distillation in Vacuo.—In the next place, 500 grams of the bread were taken and distilled in vacuo by the method described in Chapter XXIII., figure 76; the bread being raised to a temperature of 120—125° C. The amount of distillate was 220 c.c., of which 10 c.c. were taken for determination of total acidity, and were found to possess acidity equal to 11·4 c.c. $\frac{N}{100}$ acid. Ten grams of the residual dry bread had an acidity equal to 16·0 $\frac{N}{10}$ acid. Calculated as percentages on the whole bread, these are equivalent to 0·30 per cent. of volatile (acetic) acid, and 0·864 per cent. of fixed (lactic) acid.

Of the distillate, 100 c.c. were evaporated to dryness in a platinum basin and taken up with distilled water; the addition of one drop of $\frac{N}{100}$ soda gave an alkaline reaction with phenolphthalein, showing that the distillate was to this extent free from fixed acid. The remaining 110 c.c. were distilled by Duclaux's method in the "Jena" flask, with the following results:—

	$\frac{N}{100}$ acid =	A. Per cent. of total distillate. =	B. Per cent of total acid in 110 c.c.
1st 10 c.c. distillate,	5·80 c.c.	6·4	4·6
2nd „ ...	6·60 „	7·3	5·3
3rd „ ..	7·70 „	8·5	6·2
4th „ ...	8·30 „	9·2	6·6
5th „ ...	8·40 „	9·3	6·7
6th „ ...	8·80 „	9·8	7·1
7th „ ...	9·65 „	10·7	7·7
8th „ ...	9·80 „	10·9	7·9
9th „ ...	11·35 „	12·6	9·1
10th „ ...	13·50 „	15·0	11·0
11th in flask, ...	34·35 „	...	27·9

Total acidity of 110 c.c. = 125·4; total acidity of distillate = 89·9; acidity of residual 10 c.c. = 34·35; loss, 125·4 – 124·25 = 1·15 c.c. of $\frac{N}{100}$ acid.

On referring to the table of distillation of mixtures of acetic and butyric acids, Chapter XXIII., and comparing column A with that for a mixture of 20 parts acetic to 1 part of butyric acid, the figures closely agree, being distinctly on the butyric acid side of pure acetic acid. It may be considered proved that a trace of butyric acid is present, equal to approximately $\frac{1}{20}$ of the amount of acetic acid.[1] Calculating into percentages, we have of the total acidity,

$$\frac{125 \cdot 4 \times 20}{21} = 119 \cdot 4 \text{ c.c. } \frac{N}{100} \text{ acid due to acetic acid;}$$

$$\frac{125 \cdot 4}{21} = \quad 6 \cdot 0 \text{ c.c.} \quad \text{,,} \quad \text{butyric acid.}$$

Then as 110 c.c. of distillate were obtained from 250 grams of bread,

$$\frac{119 \cdot 4 \times 0 \cdot 0006 \times 2}{5} = 0 \cdot 028 \text{ per cent. of acetic acid in whole bread,}$$

and $$\frac{6 \cdot 0 \times 0 \cdot 00088 \times 2}{5} = 0 \cdot 002 \text{ per cent. of butyric acid in whole bread.}$$

Summing up, we have the following as the general results of the different analyses, expressed in percentages, those on bread being calculated on both the whole bread and dry residue:—

	DOUGH.	BREAD.	
		Whole.	Dried.
Total acidity by direct determination,	0·981	0·912	1·521
Dissolved fixed acid (lactic), ...	0·792	0·526	0·876
,, volatile acid (acetic), ...	0·066	0·062	0·103
Undissolved acid, remaining in solids, ...	0·193	0·299	0·498
Distillation in Vacuo—			
Fixed acid (lactic), ...	...	0·864	1·440
Volatile acid (acetic), ...	...	0·030	0·050
Fractional Redistillation of Vacuum Distillate—			
Acetic acid, ...	...	0·028	0·047
Butyric acid, ...	...	0·002	0·003

Comparing the results of the two different methods of analysis employed, we find that with aqueous distillation about $\frac{1}{15}$ of the total acid in both dough and bread was found to be volatile. Employing the dry distillation method on bread, $\frac{1}{30}$ of the total acid was volatile at

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[1] Duclaux points out that with the use of a larger distilling flask a higher proportion of acid remains in the residual 10 c.c., that is, that with a greater proportion of return condensation, more acid escapes distillation. As slow distillation also means more return condensation, the same result follows. The use of charged trap-bulbs, E, F, Figure 77, with the distilling apparatus, necessitated slow working; hence the general error of experiment is in the direction of lessening the apparent quantity of butyric acid.

120° C. *in vacuo*. As to the relative accuracy of the two methods, the former presents the initial difficulty that the whole of the acid is not obtained in the aqueous extract; and, further, that a portion at least of the lactic acid distils over with the steam. It may, on the other hand, be objected that the whole of the acetic acid is not volatilised by the treatment *in vacuo*. Weigert, however, has shown that by distilling wines in a vacuum, the whole of the acetic acid can be obtained (*Zeitsch, für Analyt. Chemie.*, 1879, 207). A number of other comparative determinations were made, but in all cases the aqueous extract method gave considerably higher volatile acids than distillation *in vacuo*.

The following experiments were conducted with the view of studying the progress of sourness with the prolongation of fermentation :—

A. Series.—Quantities taken—15 lbs. spring American 1st patent flour, 9 lbs. water at 40° C. (104° F.), 4 oz. compressed distillers' yeast, and 2 oz. salt.

A ferment was first set with all the water and a portion of the flour: in 40 minutes the dough was made, and had a temperature of 27° C. (80° F.). It was maintained at this temperature for 20 hours, and then allowed to stand at the temperature of the room for another 24 hours. At intervals, as given in the following table, the dough was "knocked down," re-kneaded, and a portion of 2 lbs. 3 oz. taken and baked into a loaf.

B. Series—Quantities taken—12 lbs. spring American bakers' grade and 3 lbs. low grade (red dog) flour, other ingredients as in A. Treatment precisely as in A.

The following are the times at which loaves from both series were baked :—

No. 1. Put in oven 3½ hours after setting ferment.
,, 2. ,, 6 ,, ,,
,, 3. ,, 9 ,, ,,
,, 4. ,, 12 ,, ,,
,, 5. ,, 15 ,, ,,
,, 6. ,, 20 ,, ,,
,, 7. ,, 44 ,, ,,

The following were the characteristics of the respective loaves :—

A. Series.

No. 1. Sweet in smell and taste.
,, 2. If anything, slightly darker in colour; slightly mawkish smell and taste, not sour or yeasty, crust paler.
,, 3. Colour darker, mawkish flavour disappeared, incipient sour smell, but no sour taste.
,, 4. Colour darker, loaf heavy and close, somewhat yeasty smell, but no decided sour flavour.
,, 5. Small and close, colour about same as 4, sour smell, taste acid and disagreeable.
,, 6. }
,, 7. } Sour and putrescent.

B. Series.

No. 1. Characteristic odour of bread from low grade flours, but perfectly sweet in taste and smell.
,, 2. Colour very dark, sour smell, taste slightly sour.
,, 3. Colour changed from yellowish to dark reddish brown. Less sour smell than 2. Unpleasant taste, rather of decomposition than acidity.
,, 4. Reddish brown colour much intensified. Slightly sour smell. Taste similar to 3, but more marked.
,, 5. Colour as 4. Smell and taste intensified.
,, 6. Sour and putrescent.
,, 7. Sour and putrid.

None of these had had the characteristic sour smell of *bakers'* sour bread.

The following are the results of determinations of acidity, the total being determined on the whole bread; the volatile by distillation in vacuo; and the fixed or non-volatile, in the dried residue from this distillation.[1] As the moisture in the different samples varied, the results are throughout calculated on the dry solids. These can be approximately converted into those on the whole bread by multiplying by 0·6.

PERCENTAGES OF ACIDITY IN SOUR BREAD.

No.	A. Series.				B. Series.			
	Total.	Volatile.	Fixed.	Ratio of Volatile to Total.	Total.	Volatile.	Fixed.	Ratio of Volatile to Total.
1	0·477	0·003	...	$\frac{1}{160}$	1·140	...	1·125	...
2	0·407	0·015	0·405	$\frac{1}{27}$	1·041	0·042	0·972	$\frac{1}{25}$
3	0·491	0·030	0·441	$\frac{1}{16}$	1·300	0·102	1·143	$\frac{1}{12}$
4	0·671	0·090	0·549	$\frac{1}{7}$	1·647	0·252	1 269	$\frac{1}{7}$
5	1·108	0·120	0·720	$\frac{1}{9}$	2·289	0·128	1·314	$\frac{1}{17}$
6	1·110	0·087	0·747	$\frac{1}{12}$	2·600	0·113	1·746	$\frac{1}{23}$
7	1·457	0·059	0·900	$\frac{1}{24}$	2·828	0·131	1·980	$\frac{1}{21}$

Curiously in both series the total acidity is less in the second than in the first loaf: with this exception the total acidity steadily rises throughout the two series. The volatile acidity (reckoned as acetic) attains its maximum in Series A. in 12 hours, and in series B. in 15 hours, after which it diminishes. The ratio of volatile to total acidity is in both cases highest with the No. 4 loaf. Apparently after that

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[1] The whole of these distillates were subjected to fractional distillation by Duclaux's method. Owing, however, to subsequently finding that the flasks used gave a strong alkaline reaction, the author does not feel justified in quoting the results as trustworthy, and therefore has not inserted them. The same remark applies to a large number of other Duclaux estimations.

time the production of volatile acid does not keep pace with its evaporation from the dough. (It should also be mentioned that, as the loaves were analysed in the order made, the latter ones had become somewhat drier when subjected to analysis.) Owing to the dark colour of the dried bread, the determination of fixed acid was difficult owing to uncertainty as to the exact point of neutrality as shown by the indicator. In these breads No. 2's are worked more than the baker would work them in actual practice; while No. 3 of each series is far sourer than even a *baker's very sour* loaf. The others, of course, represent extreme results altogether outside those of actual practice. Note that in No. 3 A. the volatile acidity is only $\frac{1}{16}$ of the total, and in No. 3 B. $\frac{1}{12}$ of the total acidity.

In the next place are given the results of an experiment with a potato ferment, purposely allowed to proceed to *extreme* sourness. A potato ferment was made from 30 grams of potato, 100 grams of water in which the potato was boiled, 5 grams raw flour, and 10 grams of yeast. This was fermented at 95° F., and maintained at that temperature over night in an uncovered shallow basin. The next morning the ferment was made up to 300 c.c., with water at 120° F, and sufficient flour added to make a slack sponge, which had a temperature of 95° F. The total acid reckoned as lactic was determined in 10 grams of the whole sponge, and the volatile and fixed acids in the filtered chloroformed aqueous extract in the manner previously described. The following were the results :—

Total acidity as lactic acid, ...	1·197	per cent.
Dissolved fixed acid (lactic)	0·248	,,
,, volatile acid (acetic), ...	0·053	,,
Ratio of volatile to total acid, ...	$\frac{1}{22}$	

The sponge was allowed to work for six hours and then doughed up with more flour, allowed to work $1\frac{1}{2}$ hours and baked. The following are the results of determinations on the bread. The total acidity was determined on the whole bread, and volatile and fixed acids by distillation *in vacuo*.

	Whole Bread.	Dried.
Total acidity as lactic acid, ...	1·158	1·935
Fixed acid by distillation *in vacuo* (lactic),	1·015	1·692
Volatile ,, ,, (acetic),	0·038	0·064
Ratio of volatile to total acid, ...	$\frac{1}{30}$	$\frac{1}{30}$

The principal feature is that again neither in sponge or in dough is there more than a very small proportion of volatile acid.

Following on these were some experiments made on bakers' breads. One firm in the south of England, and another in Glasgow, were kind enough to reserve a loaf of one batch baked in the usual manner (No. 1), and also to set aside dough for two other loaves, one of which (No. 2) was baked in each case when at the utmost limit of sourness ever found in practice, and the other (No. 3) several hours after. The following are the results of analysis made as before by vacuum distillations, and in filtered, chloroformed, aqueous extract :—

		English.		Scotch.	
		Whole Bread.	Dried.	Whole Bread.	Dried.
No. 1.	Total acidity as lactic acid, ...	0·362	0·604	0·258	0·431
	Fixed acid by distillation *in vacuo* (lactic),	0·351	0·585	0·243	0·406
	Volatile ,, ,, (acetic),	0·0006	0·001	0·005	0·008
	Ratio of volatile to total acid, ...	...	$\frac{1}{604}$	...	$\frac{1}{50}$
	Dissolved fixed acid (lactic) by aqueous distillation, ...	0·184	0·307	...	...
	Dissolved volatile acid (acetic), ...	0·009	0·016	...	...
	Ratio of volatile to total acid, ...	$\frac{1}{19}$	$\frac{1}{19}$	...	...
No. 2.	Total acidity as lactic acid, ...	0·535	0·891	0·342	0·570
	Fixed acid by distillation *in vacuo* (lactic),	0·491	0·819	0·324	0·540
	Volatile ,, ,, (acetic),	0·025	0·042	0·008	0·013
	Ratio of volatile to total acid, ...	$\frac{1}{21}$	$\frac{1}{21}$	$\frac{1}{44}$	$\frac{1}{44}$
No. 3.	Total acidity as lactic acid, ...	0·759	1·265	0·342	0·570
	Fixed acid by distillation *in vacuo* (lactic),	0·696	1·161	0·318	0·531
	Volatile ,, ,, (acetic),	0·036	0·060	0·017	0·028
	Ratio of volatile to total acid, ...	$\frac{1}{21}$	$\frac{1}{21}$	$\frac{1}{20}$	$\frac{1}{20}$

Throughout this series also the proportion of volatile acid is very low. Excluding those examples in which acidity was pushed far beyond any instance ever occurring in practice, the volatile acids found by distillation amounted to from $\frac{1}{20}$ to $\frac{1}{30}$ the total acid of the dough. In the instance quoted of a loaf in the last stage of sourness, an amount of butyric acid was found approximately equal to about $\frac{1}{20}$ the total volatile acid. The acidity of bread may be divided among the following acids in approximately the following proportions:—

Lactic acid, ...	about 95 per cent.
Acetic ,, ...	5 ,,
Butyric, ...	from 0·0 to about 0·5 ,,

The question has been already raised as to how far the *bakers'* sourness is dependent on the *chemists'* acidity of bread: this problem merits further examination. The particulars of the progressive series of tests given on page 379 should be studied in this connection. Taking first the A. series on patent flour, No. 4 loaf had no decided sour flavour, while No. 5 tasted acid. No. 4 had a total acidity of 0·671, while that of No. 5 was 1·108 per cent., so that a marked increase had occurred. Comparing the B. series, No. 2 was slightly sour with an acidity of 1·041, although No. 1 with a slightly higher acidity was sweet to the taste. It must be remembered that in the B. series the naturally strong coarse flavour of the flour used made it difficult to detect shades of acidity with the palate. Dealing with the smell, No. 3 A. was found to have incipient sour smell, with volatile acidity of 0·030: turning to the B. series, No. 2 has a sour smell with a volatile acidity of 0·042. On studying the higher number of each series there is a steady increase of total acid, but in both A. and B. the volatile acid is lower in these higher numbers. So that 7 A., with an exceedingly sour smell, has less volatile acid than No. 4, which it far transcends in odour. The same applies to the B. series where No. 6 contains practically the same amount of volatile acid as does No. 3, although No. 3 smells less sour than 2, while No 6 smelt sour and putrescent. Speaking in a general way, sourness and acidity go together, and bread with a total acidity of about 0·5 per cent. and a volatile acidity of about 0·025 begins, especially in the highest class breads, to both taste and smell sour. But lower grade breads can carry a much higher proportion of total acidity, and have its taste marked with the natural strong flavour of the flour. But although sourness and acidity are closely associated, yet the bakers' sourness comprehends more than is expressed by acidity, as is shown by the increasing "sourness" to the nose of Nos. 5, 6, and 7 of both series, and the simultaneously decreasing volatile acidity. As indicated in the description of the various breads, bakers' sourness also includes and takes cognisance of incipient putrefactive changes. If this be the case, "sourness" should be accompanied by evidence of other chemical changes: as proteids break down in putrefaction into compound and simple ammonias, the following determinations were made on bread. Five grams of the bread were taken, broken down in water, and large excess of caustic soda added: the mixture was then distilled in a current of steam and the distillate collected in 50 c.c. of $\frac{N}{10}$ acid. Determinations were made on the three samples of English bread, particulars of which are given on page 381. The following are the percentages of ammonia (reckoned as NH_3), calculated on the whole bread:—

English Bread, No. 1.	...	...	0·39 per cent.
,, No. 2.	...	...	0·40 ,,
,, No. 3.	...	...	0·42 ,,

The amount of increase is not very great, but as a similar increase of ammonia has been noted in other breads tested, evidence is afforded that bakers' sourness is accompanied by other changes in the constituents of the bread in addition to the development of acidity.

This question of sourness is of vast importance to the baker, and is also the baking problem on which chemistry has the most direct bearing; it therefore merits most careful attention in all its details. Among Briant's observations is that lactic and acetic ferments flourish best at a high temperature, and therefore that "high temperatures for panary fermentation are in all cases undesirable." The assumption that high temperatures are more usually accompanied by the production of sour bread than lower ones is so directly the opposite of many bakers' practical experience that it merits most careful examination. Among breads which are normally worked at a high temperature, the following stand out pre-eminent:—Nevill's bread, made in London from straight grades of comparatively weak flour; and Hovis bread, made from a meal containing 25 per cent. of germ. The temperature of the dough for the latter is about 90—95° F., and yet if two breads were to be named in which sourness was most rare, the two mentioned would first present themselves to the mind of the author. In preceding paragraphs a summary of the course of fermentation has been given, while high temperatures have been mentioned as accelerating the whole of that course; consequently, at a high temperature, everything else being equal, the sour stage is reached in less time from the commencement of setting a ferment, sponge, or dough, than if a lower temperature be adopted. But if fermentation be arrested at the same stage of its progress, there is no more danger of bread worked warm becoming sour than that which is worked cold. The crucial point as to temperature is whether, for the same amount of carbon dioxide gas evolved during alcoholic fermentation, more acid is produced at a high temperature than a low one. In order to elucidate this point the following experiments were made :—Mixtures were prepared of 50 grams flour, 200 c.c. water, and 2·5 grams distillers' yeast, and 10 grams brewers' yeast respectively. These were placed in the yeast-testing apparatus, Figure 20, and fermented at the respective temperatures of 75° and 95° F., which in each case were maintained constant until 350 c.c. of gas had been evolved. The original acidity of the mixtures was determined in duplicates made up for the purpose. As soon as the 350 c.c. of gas had been obtained, 2 c.c. of chloroform were added to the contents of the bottle, which was shaken up and allowed to stand until all were ready for titration, when the acidity was once more determined. Two complete series of estimations were made on successive days. In another similar experiment with distillers' yeast the fermenting mixture was first maintained at 95° F. until 175 c.c. of gas had been evolved : it was then cooled to 75° F., and kept at that temperature until 90 c.c. more had come over. The temperature was then again raised, and maintained at 95° until the whole 350 c.c. of gas had been evolved. The following table gives the time required for the evolution of 350 c.c. of gas, the original acidity, the final acidity, and the amount produced during fermentation, reckoned in each case as lactic acid :—

	Time taken, Hours.	Original Acidity.	Final Acidity.	Produced during Fermentation.
Distillers' yeast at 75° F., ...	10½	0·175	0·394	0·219
,, ,, 95° F., ...	3½	0·175	0·290	0·115
Brewers' ,, 75° F., ...	11	0·228	0·424	0·196
,, ,, 95° F., ...	6	0·228	0·442	0·214
Repeats—				
Distillers' yeast at 75° F., ...	11½	0·315	0·540	0·225
,, ,, 95° F., ...	4¼	0·315	0·495	0·180
Brewers' ,, 75° F., ...	11	0·157	0·679	0·522
,, ,, 95° F., ...	5¾	0·157	0·670	0·513
Distillers' yeast, partly at 75° F. and partly at 95° F., ...	7¼	0·315	0·495	0·180

With the distillers' yeast, in both instances there is for the same amount of alcoholic fermentation a greater development of acidity at the lower temperature ; while with the brewers' yeast there is in the one case slightly more acid at 75° F., and in the other a slightly greater quantity at the higher temperature. In passing, attention is directed to the much higher acid-producing power of the brewers' yeast on the second day (with a different sample) than the first. Both the practical experience of the bakery and these tests go to show that **for the same amount of alcoholic fermentation a comparatively high tem-**

perature is at least not more productive of acidity than a much lower one. The last experiment was made with the object of determining whether a sudden lowering of temperature during fermentation had a tendency to increase acidity. The results show that no such increase was caused in this instance.

Slackness of dough is only a cause of acidity in the same sense as high temperature, in that it accelerates the whole course of fermentation. Among breads made from *very slack* doughs are Manchester tin bread and Vienna bread, but neither of these are specially liable to sourness.

Holding the view that much of the acidity of bread is due to acetic acid, and that the production of this acid is stimulated by the presence of oxygen, Briant advises that "therefore fermenting dough should be kept as much out of contact with air as is possible." If the quantity of acetic acid present in doughs which are most intensely sour in character is but trifling, then this reason for exclusion of air no longer exists. To refer again to Vienna bread, the ferments and dough for this are beaten and exposed to air almost as much as an egg in the act of whisking, and these are rarely, if ever, sour. If a baker finds a sponge working too rapidly, and in such a condition as his experience tells him means that fermentation is likely to have overshot the mark by the time he wishes to take it, then, *in order to lessen risk of sourness*, he very commonly throws off the trough lid and freely exposes it to air. He finds practically that this treatment, instead of causing sourness by oxidation of alcohol, obviates it by lowering the temperature, and so retarding the whole course of fermentation.

The following may be taken as a summary of the author's views on sour bread. (It will be noticed that it endorses several of Briant's conclusions) :—

1. "Sour bread," as understood by the baker, is the result of a combination of bacterial fermentations. Principal among these is that producing lactic acid, which constitutes about 95 per cent. of the total acidity. The remainder is due to acetic acid, with, in very bad cases, traces of butyric acid. In addition to the development of acidity, sour, as distinct from acid bread, shows signs of putrefactive decomposition.

2. The acid and putrefactive fermentations are produced by bacteria to be found in the dough.

3. These bacteria may be introduced by the yeast, by the use of dirty vessels, and by the flour ; but their presence in the flour is the most general cause of "sourness."

4. The activity of these bacteria is dependent on that of the yeast : while the latter is active, the bacteria are comparatively quiescent. With the exhaustion of the yeast, or cessation of active fermentation through the assimilation of all fermentable material, a stage is attained in bread fermentation when bacteria are excessively active, and sourness rapidly develops.

5. Temperature and slackness of dough have but little effect on sourness, except in that indirectly they affect the speed of the whole course of fermentation, and so hasten or retard the arrival of the bacterial fermentation stage. This stage being reached, the production of sourness is accelerated both by high temperature and slackness of dough.

6. Exposure to air has no appreciable effect on sourness, and may even through its cooling action be beneficial.

7. The two principal causes of sourness are—Allowing the fermentation to proceed beyond the normal into the souring stage; and the use of materials or vessels containing abnormally high proportions of bacteria, especially when employed with weak and inactive yeasts.

473. Effect of Baking on Bacterial Life.—Differences of opinion exist as to whether the act of baking destroys the life of all organisms that may be present in the dough. Unless the baking is most inefficiently conducted, the temperature within the loaf should be sufficiently high to kill the yeast. The doubt is whether or not the germs or spores of other organisms are also destroyed—thus, the spores of some of the *bacilli* can withstand a quarter of an hour's boiling, while a sensible proportion outlive an hour's subjection to a boiling heat. These experiments afford grounds for supposing that such germs might continue to exist even during an hour's baking. The observed facts of the souring of bread also point in the same direction. Two loaves may be taken, each of which is sweet when removed from the oven, and kept under precisely the same conditions; the one after a few hours becomes sour, the other retains its sweetness. Here there is a difference in behaviour which is not due to external conditions, but to some inherent quality of the two loaves. The undestroyed germs of acid fermentation have, in the bread in which they are present, induced sourness. The only other explanation of souring is that the germs of the specific *bacilli* have found their way from the atmosphere into the baked loaf.

Walsh and Waldo have recently subjected this matter to exhaustive investigation. Using the accustomed precautions in bacteriological work, they procured a number of loaves of bread, and sowed portions of the interior crumb in sterilised gelatin and glucose mixture, and made plate cultivation. As few of the loaves were found to be practically sterile, while others contained a large number of organisms, including *bacillus sublitis* and other *bacilli*, also *sarcina* and *micrococcus*. Many of these organisms were unidentified by Walsh and Waldo, but it may fairly be assumed that, with lactic and butyric ferments present in the dough, they may be among those organisms which have lived through the baking. Hence they may set up their characteristic fermentations in the baked bread.

It should be mentioned in passing that Walsh and Waldo base a very powerful argument for sanitation in bakehouses on this fact, that baking does not necessarily sterilise bread. Their view is that if non-pathogenic organisms may thus survive, so may also the pathogenic forms; and so bread, if contaminated during manufacture, may afterwards become a source of infection.[1]

The conditions of keeping make a considerable difference in the after-sweetness of baked bread. Where bread is kept in a close, warm, moist atmosphere, from the time of baking or when new, it is far more likely to develop sourness and mould than if stored where it may rapidly cool and lose any excess of moisture.

474. Remedies for Sour Bread.—These are to a large extent indicated in the preceding paragraphs, but as one possible cause of sour bread is a want of absolute cleanliness, it should be seen that all the precautions to insure the same are rigidly adopted. Supposing, as is sometimes the case, that batch after batch of bread is sour, or rapidly becomes so; then see that the flour is sound; next examine the yeast; see more especially whether disease ferments are plentiful, and whether the yeast-cells themselves look healthy and vigorous. The baker who is not able to do this for himself should place himself in the hands of an analyst to do it for him. If any suspicion whatever attaches to the yeast or the flour, change to some other variety which is known to be doing good work. In the next place, thoroughly clean the bakehouse from floor to ceiling. Procure some solution of bisulphite of lime, and with a brush wash floor, walls, and ceiling with it. Clean out all troughs and boards, and also wash them with the bisulphite, letting it remain in the troughs for some time. Then either scald or steam them out, and dry as rapidly as possible. These steps should succeed in freeing the bakehouse from any disease ferments which may be present.

In conducting fermentation, use a sufficient quantity of good yeast, and work at such a temperature as to get sponging and doughing over quickly.

As souring is largely produced by some cause unduly accelerating fermentation, investigate the whole of these, and modify one or more, according to which seems faulty, so as to retard to the normal rate. Or, if deemed preferable, set later or take sooner so as to use sponges or doughs at the right stage of fermentation. Use regular brands of yeast and flour, watching and adjusting these as may be necessary. Souring, if due to sudden atmospheric changes, is to a certain extent beyond control; but it may be checked somewhat by cooling, if the too quickly working material can be caught in time. The addition of salt to a too rapidly working sponge retards the whole rate of fermentation, and particularly that of *bacteria*. In exceptional cases, through the presence in undue quantities of *bacteria*, and the use of weak yeasts, the fermentation may become abnormal, and "sour" fermentation accompany, or even precede, the full development of normal alcoholic

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[1] While these pages are passing through the press, Goodfellow informs the author that he has been engaged for some months in the investigation of this subject of the sterilisation of bread. He finds that, provided the bread be allowed to stand for three hours in a germ-free atmosphere after being baked, the loaf is absolutely sterile. That is, the act of baking, coupled with the continuance of the baking heat on the loaf, for the period of time mentioned, is sufficient to destroy the life of all micro-organisms. The publication of Goodfellow's proof of this assertion will practically render the position assumed by Walsh and Waldo untenable.

fermentation. Give the bread a good baking, as bread which leaves the oven in a damp sodden condition is specially liable to become sour. When baked, cool rapidly in a pure atmosphere. Weak, unstable flours used with excess of water very frequently turn sour; the reason is that the gluten breaks down, and much of the starchy interior of the loaf is dextrinised: the damp, clammy mass resulting constitutes a favourable *nidus*, or home, for after-fermentation.

FAULTS IN BREAD.

475. Holes in Bread.—Instead of the even sponginess which should characterise the crumb of good bread, one is occasionally confronted with loaves in which large holes occupy considerable spaces in the interior of the loaf. For their occurrence various explanations have been offered, many of which are ingenious, while others are impossible. An interesting object lesson in their production may be gained by taking a basin of strong solution of soap in water, and blowing into it through a glass tube. A mass of bubbles is formed on the surface of the solution, which fills the whole vessel. Let it rest, and watch the gradual disappearance of the bubbles—careful inspection will show in the interior of the mass some of the bubble walls getting thinner and thinner, until at last they collapse, and several small bubbles coalesce to form one of large size. Practically the same thing occurs in dough; if allowed to get over-proved, it will be seen, on being cut, to contain a number of large holes. Good firm moulding will remove the gas from these, and make a piece of homogeneous dough for the loaf, thus remedying one cause of holeyness; for if a loaf containing these large holes be placed in the oven, they will expand there, and thus give still more irregular æration. The same process of a number of small holes breaking down into one big one may occur during baking in a piece of dough, which, if cut prior to its going into the oven, would show no signs of large holes. Here the cause must be lack of tenacity in the dough which forms the hole-walls, and the cause of such holes must be found in the constituents of the dough. The elasticity of dough at this stage is principally due to the gluten present, and when fermentation has been carried sufficiently far to destroy the tenacity of the gluten, breaking down into holes is a normal result: holeyness, therefore, for this reason may be an accompaniment of over-worked dough. If a series of loaves be made as suggested in paragraph 469, it is very rarely that holes are found in the earlier and under-fermented loaves. Another cause of this irregularity is the insufficient breaking down and mixing of the sponge with the water and flour of the dough. The latter is frequently made from a comparatively soft, weak flour, and if not thoroughly incorporated with the sponge, leaves portions of inferior tenacity which may readily break into holes. The production of holes by dusting flour being folded up in the interior of the loaf during moulding, and then not thoroughly worked in, thus leaving blebs, which expand into holes on baking, is so absolutely a result of carelessness as to need no further reference.

A curious problem about holes is the liability of cottage loaves to this fault. If some of the same dough be made into "cakes" or "Coburg" loaves, while the remainder is made into cottages, the latter are far more likely to contain holes than the former. One cause of this is possibly the inefficient "bashing" down of the tops of the cottages. A more likely reason is, however, the actual shape of the loaf itself. The top, being smaller, acquires a rigid crust before the lower part of the loaf, and therefore forms a sort of protecting cap over the centre. As expansion goes on in the interior during baking, there is a line of comparatively little resistance immediately underneath the top, and greater expansion takes place in this direction. Evidence of this is afforded by the species of risen waist one sometimes sees in a cottage loaf, consisting of what looks like a third or middle piece in the loaf. This development occurs after the rest of the loaf has set; and, as probably the interior dough has also lost much of its elasticity, there is the formation of a large hole rather than even expansion. Of course the occurrence of such holes means a predisposition of the dough to breaking down into irregular æration.

The causes of holes in bread may be summed up as being—careless moulding, especially of over-proved dough; lack of tenacity and elasticity of the dough itself, due to soft and irregular flours; insufficient mixing of sponge and dough. Cottage loaves are prone to holes because of the physical effect of their shape on expansion during baking.

476. Protruding Crusts.—On crusty bread being packed a little too close in the oven, the loaves, on expanding, touch their neighbours, and a soft crust is formed when they are in contact. Occasionally, when the dough is weak and inclined to "run," it may be observed that the loaves definitely grow toward one another, forming a distinct protuberance on the side of each, as though an endeavour was being made on the part of the loaves to effect actual contact. This apparent attraction is due to the mutual cooling effect of the loaves retarding the formation of a rigid crust on the contiguous parts: expansion continues there after the other parts of the loaves are set, and hence the "kissing" growth toward each other.

477. Crumbliness.—The crumbling away, instead of cutting cleanly, exhibited by some bread, may be due to the use of harsh, dry flours, not sufficiently fermented; or may also be caused by over-working and proof, making the loaf bigger than the gluten of the dough, at the stage of fermentation when baked, is able to stand and still hold the bread well together. A deficiency of dextrin and soluble starch in the bread also contributes to crumbliness.

478. Dark Line in Cottages.—At times, on cutting a cottage loaf, a dark line is seen across the contact surface between the top and bottom of the loaf. Generally when this is the case, if the loaf has any soft crust, that too is seen to be discoloured. The bread is under these circumstances frequently either sour, or approaching it. The primary cause of this dark line is the darkening by oxidation of some of the constituents of the flour; this darkening goes on more rapidly in doughs made from low grade flour or which have been over worked. Proof of this darkening of dough is afforded by pressing a piece of dough down into contact with colourless glass, and letting it stand a time. The air-exposed surface rapidly becomes the darker of the two. In making sample loaves, especially from dark flours, a streakiness is often observed. The proportionately large external surface darkens, and each time the dough is moulded, the dark portion is worked into the interior, and hence the streaky-baked bread. In any loaf which has been allowed to stand there is more or less darkening of the exterior by oxidation—on baking, this colouration is altogether masked by the caramelisation of the crust. But where the two exteriors have been placed together, as in the surface of contact of the two parts of a cottage, the darkening effect of oxidation is preserved, and may be noticed in the baked loaf.

479. Working with Unsound or very Low Grade Flours.—In the older literature of bread-making it is interesting to read the directions given under this head; when, through a bad harvest, wheat has either not ripened properly, or has after the reaping been badly wetted, great care is necessary in order to make a passable loaf of bread from the flour produced. Thanks to the abolition of the Corn Laws, the United Kingdom can now command the markets of the world, and without any difficulty secure sound wholesome wheats at a fair price. In the present day there is practically no excuse for a baker having a sack of unsound flour in his flour room.

In composition the unsound flours have a low percentage of gluten, and that badly matured; while the soluble proteids are high, and in a comparatively active diastasic condition. The starch granules have their walls softened down and often fissured. The moisture is high, so also, owing to the degradation of starch and proteids, is the soluble extract. These flours are found on testing to be weak and unstable. So far as their treatment is concerned, that commences with the wheats rather than with the flours. A wheat harvested damp is not necessarily unsound; these chemical changes are to a great extent an after consequence of the dampness. Such wheats should immediately on being harvested be kiln-dried at a gentle heat of about 38° C. (100° F.), until the moisture present is reduced to 10 per cent. of the whole grain. While the flour produced from the wheat thus treated may be weak, it will be fairly stable and not unsound. The gluten will be higher, and the soluble extract and proteids comparatively low. The experiments described in paragraph 368 of the preceding chapter show that even weak, damp flours may be considerably improved by gentle kiln-drying of the flour itself. Such treatment is also by far the best that can be adopted with unsound flours; those flours which are not amenable to it should be entirely rejected for bread-making purposes.

Having by preliminary treatment made the best of an unsound flour, it should be used in the *dough*, which should be got into the oven as speedily as possible. A little compressed yeast added at the dough stage will often be found of service by hastening the fermentation. As unsound flours are particularly liable to produce sour bread, special attention should be paid to the suggestions made in the preceding paragraph. Further reference to unsound flours will be found in the paragraphs describing other methods of ærating bread.

The low grade flours of gradual reduction processes are, if from a sound wheat, perfectly sound in themselves; yet they require some care in manipulation, because they contain the active diastasic constituent of the bran, cerealin, in considerable quantity. Where these flours are employed, a sponge should be prepared from a strong flour and the low grade used in the dough.

480. Use of Alum, Copper Sulphate, and Lime.—Alum, the double sulphate of aluminium and potassium, $Al_2K_2(SO_4)_4 24H_2O$, was formerly largely used as an adulterant of bread. This, and the other substances mentioned, behave as retarding agents to diastasis; with unsound flours they prevent or lessen the degradation of the gluten and starch during fermentation, and so cause a loaf made from a bad flour to be larger, less sodden, and whiter, giving it the appearance of bread made from far better flour. So far, and considered from this aspect alone, the action of alum is remedial; it prevents undesirable changes occurring in the flour during fermentation. There is no doubt that by the use of alum, flour, so bad as to render bread-making in the ordinary manner impossible with it, can be converted into eatable loaves; but if necessity arises for recourse to such flours for bread-making, other processes are now known which achieve the same object by methods that are absolutely unobjectionable. The continued use of alum, even in small quantity, is, according to medical evidence, injurious to health: in particular, the alum remaining, as it does, unchanged in the bread, retards the digestive action of the secretions of the mouth and stomach. **As alum is injurious, and as it is used with the object of enabling inferior flour to be substituted for that of good quality, to the predjudice of the consumer, it is rightly considered as an adulterant, and its use made penal.**

Minute quantities of copper sulphate, $CuSO_4$, have also been employed: its action is very similar to that of alum; but **as all copper salts are very poisonous, its use is even more reprehensible than that of the former adulterant.**

Liebig suggested the employment of lime in solution, lime-water, CaH_2O_2, as a means of preventing excessive diastasis during panary fermentation. This substance is quite as effective as alum so far as the effect on diastasis is concerned, but unlike alum it exerts very little retardation on the alcoholic fermentation caused by the yeast. Lime is soluble in about 780 parts of cold water: its solution, or what is commonly called lime-water, may be prepared by adding about two ounces of recently burned quicklime to ten gallons of water, and stirring up. A better plan is to add the lime in considerable excess, stir thoroughly, and then allow the superfluous lime to settle. In a few hours the upper liquid becomes clear, and may be dipped off without disturbing the sediment. Some more water may then be added and the mixture again stirred; another quantity of lime-water is thus made. This operation may be repeated several times if sufficient lime has been taken in the first place. Any vessels containing lime-water have to be kept covered, as carbon dioxide is rapidly absorbed from the air, with the formation of calcium carbonate. Richardson states that Liebig's directions were that the flour and lime-water should be used in the ratio of 19 of flour to 5 of lime-water, and then goes on to say that that quantity of liquid not being sufficient to convert the flour into dough, the requisite quantity of ordinary water was added. He then proceeds to quote an experiment in which 19 lbs. of flour were made into bread with ordinary water, and yielded 24 lbs. 8 oz. of bread. A like quantity of the same flour, kneaded with 5 quarts of lime-water, produced 26 lbs. 6 oz. of bread. There is evidently a mistake here somewhere: 5 quarts of water to 19 lbs. of flour means 73 quarts of water to the sack; this quantity, so far from not being sufficient to convert the flour into dough, is something like 10 quarts more water than is ordinarily used by the London baker. As on the continent the metric system of weights and measures is that commonly used, Liebig's ratio was in all probability 19 kilograms of flour to 5 litres of water, the exact English equivalent of which would be 19 lbs. of flour to 5 lbs. or two quarts of water: this equals 29 quarts of lime-water to the sack. The deficiency is then made up by the addition of ordinary water. The baker desiring to use lime-water may make it and employ it in the proportion just stated, or he may add not more than 1½ ounces of lime to the water per sack of flour. In this latter case he must stir the water thoroughly so as to ensure the complete solution of the lime: a milkiness throughout the whole of the water would not hurt, but any lumps must be avoided. The safest method is to prepare the lime-water as a previous operation. Lime-water is used by some of the Glasgow bakers, who advertise bread containing it as a speciality. The bread made with lime-water is more spongy in texture, pleasant to taste, and quite free from sourness. In the finished bread the lime no longer exists as free alkali, because the carbon dioxide gas generated during fermentation will have completely changed it into calcium carbonate—

$$\underset{\text{Lime.}}{CaH_2O_2} \quad + \quad \underset{\text{Carbon Dioxide.}}{CO_2} \quad = \quad \underset{\text{Calcium Carbonate.}}{CaCO_3} \quad + \quad \underset{\text{Water.}}{H_2O.}$$

Calcium carbonate, which is identical in composition with chalk, has in small quantities no deleterious action when taken into the system.

So far as Richardson's quotation of experiment may be depended on, it indicates an increased yield of bread by the use of lime-water: he ascribes this increase to the loss caused by fermentation when working in the ordinary manner; but his views on this subject have already been shown to be fallacious. The true explanation is a very simple one: the lime-water, by preventing the degradation of the gluten and the diastasis of the starch, increases the water-retaining power of the flour, and so enables the same weight to yield a greater quantity of bread.

A recently advertised bread-making process is based on treatment of the sponge with lime-water.

481. Special Methods of Bread-making.—There are certain special processes employed for bread-making which must next be described.

482. "Vienna Bread."—This is the name applied to rolls and other light fancy bread. Vienna bread is made with patent flour and compressed yeast. No potatoes or ferment is used. Instead of water, the bread is sometimes made with milk or a mixture of milk and water. The following recipe is quoted from "The Miller":—

Proportions.—8 lbs. of flour, 3 quarts of milk and water in equal proportions, 3½ ounces of compressed yeast, and 1 ounce of salt. The warm water is first mixed with the milk, so as to give a temperature of from 80 to 85° F. Sufficient flour is then added to make a weak sponge, not much thicker than a batter. The yeast is crumbled, mixed well in, and the sponge allowed to stand for about forty-five minutes. The rest of the flour is next added slowly, together with the salt; the dough is then thoroughly kneaded and set to ferment for 2½ hours. All Hungarian flour may be used throughout, or the finest Spring American Patent may be substituted in the sponge. The bread is glazed during baking by the introduction of a jet of steam into the oven.

483. Leavened Bread.—In France and other parts of the continent bread is made from leaven, which consists of a portion of dough held over from the previous baking. The following description is given on the authority of Watt's Dictionary of Chemistry. A lump of dough from the preceding batch of bread is preserved; this weighs about twelve pounds, made up of eight pounds of flour to four of water, and is the fresh leaven *(levain de chef)*. This fresh leaven, after remaining for about ten hours, is kneaded in with an equal quantity of fresh flour and water, and thus produces the *levain de première;* again, this is allowed to stand for some hours (about eight), and is kneaded in with more flour and water. After another interval of three hours, 100 lbs. of flour, 52 of water, and about ⅓ lb. of beer yeast are added; this produces the finished leaven *(levain de tout point)*. The finished leaven weighs about 200 lbs., and is mixed, after standing two hours, with 132 lbs. of flour, 68 lbs. of water, ½ lb. yeast, and 2 lbs. of salt. The dough thus formed is divided into two moieties; the one is cut into loaves, which are kept for a time at a moderate temperature (77° F.) and then baked. The bread thus produced is sour in taste and dark in colour. The remaining half of the dough is kneaded with more flour, water, yeast, and salt, and divided into halves; the one quantity is made into loaves, which are allowed to ferment and then baked; the other is subjected again to operation of mixing with more flour, &c., and working as before. This sub-division is repeated three times; the bread improving at each stage, and the finest and whitest loaves being produced in the last batch. Readers will doubtless have already noticed that as the quantity of leaven decreases, and that of yeast increases, the quality of the bread improves. In the latter stages they "reform the leaven indifferently;" the English baker is in this matter more logical, and "reforms it altogether." As a consequence, he produces from flour and yeast a bread better as a whole than that resulting from the complicated French system of leavening. In the more important towns this mode of bread-making seems now to have largely given place to methods more nearly allied to Viennese and English processes.

484. Theory of Leaven Fermentation.—In May, 1883, Chicandard communicated to the Academy of Sciences, Paris, a theory of panification adopted by him as the result of recent researches. He first expressly states that his conclusions do not apply to fermentation as conducted in England, but to bread made on the leaven system. English bread is excepted because of its being customary to add potatoes to the ferment, the gelatinised starch of which he admits may be susceptible of alcoholic fermentation. But as many English bakers make their bread from flour, yeast, salt, and water only, any alcoholic fermentation which occurs cannot be explained by the general statement that English bakers use fruit. Briefly summing up Chicandard's conclusions, they are—"The fermentation of bread does not consist in the hydrolysis of starch, followed by alcoholic fermentation, and is not determined by *Saccharomyces*, but is a result of the solution and after peptonisation of the gluten, this effect being caused by a *bacterium* which develops itself normally in the dough, yeast merely accelerating its development."

In proof that the gas evolved during panification is not the result of alcoholic fermentation, Chicandard states that the presence of alcohol has never been proved : in this he is contradicted by Moussette, who detected alcohol in the gases of an oven in use in France so early as 1854, and at a time when the bread was undoubtedly being made by the leaven process. In a further communication Chicandard states that he made a dough with flour, dextrose, yeast and water, testing it immediately on being made, and again after standing three and seven days respectively : he found in each case that 10 grams of the dough contained 0·55 grams of dextrose.

Girard has since pointed out in the "Comptes Rendus," that he has examined the gas contained in dough at various stages of preparation, and finds it to consist mainly of carbon dioxide, mixed with the air originally contained in the flour. In some cases part of the oxygen had been absorbed, most probably, Girard thinks, as a consequence of the secondary formation of acetic acid. [The author's opinion is that this absorption is due to the direct action of the yeast ; which organism, as has been already demonstrated, exhibits a remarkable avidity for oxygen.] On mixing the dough with water and distilling, the distillate was found to contain alcohol in quantity amounting to 3·15 c.c. or 2·5 grams per kilogram of dough. The same results were obtained whether the dough was mixed with leaven or with yeast, thus affording additional evidence that the rising of dough is due to alcoholic fermentation.

Boutroux, also in "Comptes Rendus" (**113**, 203—206), states the results of investigations on this point. He finds, in leavens to which no yeast had ever been added since time immemorial, that he always found yeasts, and isolated five distinct species, two of which are very active in producing alcoholic fermentation. From the flour he isolated three distinct species of bacteria : *a*, which secretes a diastase that dissolves cooked gluten and saccharifies starch paste, but does not attack sugar ; *b*, which produces fermentation with evolution of gas, in a mixture of flour and water sterilised by heat ; and *c*, obtained from the bran, which produces a fermentation, with evolution of gas in a mixture of bran and water. Bacillus *a*, followed by yeast, produces alcoholic fermentation. Direct experiment showed that the yeasts active in producing alcoholic fermentation can readily be cultivated in paste, but this is not the case with yeasts little active in alcoholic fermentation, nor with the bacteria, *a*, *b*, *c*. The yeasts can be cultivated in paste containing 0·3 per cent. of tartaric acid, but this quantity of acid completely prevents the rising of paste to which no leaven has been added, a result which shows that the yeast is the essential agent in bread fermentation, and if the bacteria play any useful part, it is only in the production of the sugar. Flour charged with its natural microbes, mixed with salt and water and pure yeast, and allowed to rise, contains practically the same proportions of gluten as the original flour, and hence the fermentation of the gluten is not essential, but is a perturbation. Starch also is not affected to any great extent during the process. An aqueous extract of bran, freed from bacteria, saccharifies starch paste, but not crude starch, and this is true also of the amylose secreted by the bacillus *a*. No other fermentable material remains but the soluble part of the flour containing the preformed sugar, dextrin, and salts. Boutroux concludes that bread fermentation consists essentially of the alcoholic fermentation of the sugar pre-existing in the flour. The yeast not only produces the gas which ærates the bread, but it also prevents the development of bacteria. The difficulty of detecting the yeast in the paste arises from the intimate manner in which it is mixed up with the dough, but the presence of the yeast cells is more readily recognised than the presence of bacteria.

Laurent regarded leaven fermentation as being due to the so-called *Bacillus panificans*. Peters found a number of yeasts in leaven, and several species of bacteria, none however of which agreed with Laurent's *Baccilus panificans*, but rather shared the properties of this so-called organism between them. Laurent most probably was dealing with an impure cultivation. Peters found that these bacteria gave no alcoholic fermentation, and no appreciable evolution of gas in sterilised dough.

485. Methods of Ærating Bread other than by Yeast.—Carbon dioxide is not only produced by alcoholic fermentation, but may also be generated within dough by purely chemical means, or may be mechanically introduced by first effecting its solution in water.

486. Baking Powders.—The carbon dioxide gas within the dough is sometimes generated by the action of baking powders of various kinds; these are mixtures which, under the influence of either water or heat, evolve carbon dioxide, usually from the decomposition of sodium bicarbonate by some acid present. Baking powders are used more extensively in America than this country for bread-making purposes, and their composition has recently been made the subject of an investigation by one of the State departments. They are classified according to the nature of the acid constituent they contain into three groups:—

I. *Tartrate Powders*, in which the acid constituent is either free or partly combined tartaric acid.

II. *Phosphate Powders*, in which the acid constituent is some form of phosphoric acid.

III. *Alum Powders*, containing sulphuric acid in the form of some alum salt. (A sub-division of this class contains acid potassium sulphate as its acid constituent.)

Practically all baking powders may be arranged either in one of these classes, or consist of mixtures of two or more classes.

In Class I, on the addition of water a change occurs, which is illustrated in the following equation :—

$$\underset{\text{Tartaric Acid.}}{H_2C_4H_4O_6} + \underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} = \underset{\text{Sodium Tartrate.}}{Na_2C_4H_4O_6} + \underset{\text{Water.}}{2H_2O} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

Instead of tartaric acid, cream of tartar, $KHC_4H_4O_6$, is sometimes employed ; the reaction then becomes :—

$$\underset{\text{Cream of Tartar.}}{KHC_4H_4O_6} + \underset{\text{Sodium Bicarbonate.}}{NaHCO_3} = \underset{\substack{\text{Potassium Sodium}\\\text{Tartrate.}}}{KNaC_4H_4O_6} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Potassium sodium is sometimes termed "Rochelle Salts."

The chemical reaction in the case of the phosphate powders is represented by the following equation, in which potassium phosphate is the acid salt :—

$$\underset{\substack{\text{Acid Potassium}\\\text{Phosphate.}}}{H_2KPO_4} + \underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} = \underset{\substack{\text{Disodium Potassium}\\\text{Phosphate.}}}{Na_2KPO_4} + \underset{\text{Water.}}{2H_2O} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

With alum powders the following reaction occurs :—

$$\underset{\text{Potash Alum.}}{Al_2K_2(SO_4)_4,\ 24H_2O} + \underset{\text{Sodium Bicarbonate.}}{6NaHCO_3} =$$

$$\underset{\text{*Aluminium Hydrate.}}{Al_2(HO)_6} + \underset{\text{Potassium Sulphate.}}{K_2SO_4} + \underset{\text{Sodium Sulphate.}}{3Na_2SO_4} + \underset{\text{Water.}}{24H_2O} + \underset{\text{Carbon Dioxide.}}{6CO_2}.$$

The sodium bicarbonate is also decomposed by the action of heat ; on heating its solution, carbon dioxide gas is evolved, with the formation at first of a so-called sesquicarbonate, and afterward of the normal carbonate. This later body is thus formed :—

$$\underset{\text{Sodium Bicarbonate.}}{2NaHCO_3} = \underset{\text{Sodium Carbonate.}}{Na_2CO_3} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

Under the name of "Volatile," the commercial ammonium carbonate is also sometimes used as a source of carbon dioxide gas. This body is really a mixture of ammonium carbonate and carbamate, and may be represented by the formula $2(NH_4)_2CO_3.CO_2$, and contains in 100 parts, NH_3, 28·81 ; CO_2, 55·93 ; and H_2O, 15·26. On being dissolved in water and heated, the normal carbonate is first formed with the liberation of carbon dioxide, after which the whole of the carbonate completely volatilises, being converted into gaseous ammonia and carbon dioxide :—

$$\underset{\substack{\text{Commercial Ammonium}\\\text{Carbonate.}}}{2(NH_4)_2CO_3.CO_2} = \underset{\substack{\text{Normal Ammonium}\\\text{Carbonate.}}}{2(NH_4)_2CO_3} + \underset{\text{Carbon Dioxide.}}{CO_2}.$$

$$\underset{\text{Ammonium Carbonate.}}{2(NH_4)_2CO_3} = \underset{\text{Ammonia.}}{4NH_3} + \underset{\text{Water.}}{2H_2O} + \underset{\text{Carbon Dioxide.}}{2CO_2}.$$

On being heated, therefore, the whole of the carbonate is converted into gaseous products.

In the manufacture of baking powders, the acid ingredient, together with the proportionate quantity of bicarbonate of soda, is mixed with air-dried starch. This latter component increases the weight of the baking powder; it also, owing to the hygroscopic nature of starch, helps to keep the active ingredients free from moisture.

487. Tartrate Powders.—The division of these into two groups is dependent on the comparative solubility and insolubility respectively of tartaric acid and cream of tartar. The former produces a very quick action powder. The latter dissolves very slowly, and so produces a very gradual evolution of gas, until the dough mixture to be raised is placed in the oven. With the elevation of temperature, the cream of tartar dissolves and causes an abundant disengagement of gas, just when the dough, through the softening effect of heat, is most readily distended. Unfortunately, commercial tartaric acid and cream of tartar frequently contain lead, and this metal is a very dangerous poison, as, even when taken in small quantities, its effects accumulate in the system. The resultant tartrates all possess an aperient action; hence their continued use is to be deprecated.

488. Phosphate Powders.—As substitutes for tartaric acid or cream of tartar in baking powders, phosphoric acid, and the acid- or bi-phosphates of lime, potash and ammonia are now employed: these substances are in many ways preferable to tartaric compounds, and can readily be obtained free from lead and other metallic impurities. They readily evolve carbon dioxide when their mixture with the sodium bicarbonate is dissolved in water. The resultant phosphates have but a very slight and harmless aperient action.

Among the most interesting of those substitutes for cream of tartar which have as yet been examined by the author, are two preparations introduced by the Manchester Chemical Company; under the names respectively of "Cream Powder" and "Citrolene."

Cream Powder is essentially a mixture of acid ammonium and calcium phosphates, together with from 5 to 10 per cent. of corn flour, for the purpose of preventing dampness. Citrolene is composed of practically the same constituents arranged in somewhat different proportions: the result is that citrolene, being somewhat more soluble, is the quicker of the two, approaching more to the character of a mixture of tartaric acid and cream of tartar. Both are so arranged in composition as to have approximately the same acid strength as cream of tartar, so that two parts of either are neutralised by one part of sodium bicarbonate. On testing a sample of each against good ordinary cream of tartar, the following volumes of gas were obtained from equal weights of each (4 grams) against half the weight (2 grams) of the bicarbonate:—

Cream Powder evolved 100 volumes of gas.
Citrolene ,, ,, 137 ,,
Cream of Tartar ,, 108 ,,

On using the powders for bread-making, both cream powder and citrolene yielded loaves distinctly lighter in colour than did cream of tartar. Physiologically, both these powders have a distinct advantage over cream of tartar, inasmuch as the latter leaves as a residuum, Rochelle salt, which, as already stated, is a distinctly laxative and weakening body when taken regularly with food. On the other hand, the potassium and calcium phosphates have a direct and most important dietetic value. For several reasons, powders of this type are a great advance over those composed of cream of tartar or tartaric acid.

489. Alum Powders.—Among other proposed substitutes for tartaric acid in baking powders have been potassium bisulphate, $KHSO_4$, and alum. The potassium and sodium sulphates produced when these substances are neutralised by sodium bicarbonate are powerful purgatives, and as such, are absolutely unfitted for introduction into bread. These powders constitute the third group, or alum powders. A curious anomaly of the law on adulteration is that, while the addition of alum to bread is considered to be adulteration, and therefore penal; yet, because baking powder is not in the eyes of the law an article of food, its preparation from alum is not a legal offence.

The action of alum in bread on its artificial digestion was demonstrated by a number of experiments made by Knights, and communicated to the Society of Public Analysts in 1880. Hehner has since (in November, 1892) published the results of researches on the effect on artificial digestion of alumed baking powders. The baking powder used had the composition:—

Crystallised Alum, ...	45·80
Sodium Bicarbonate, ...	18·71
Starch, ...	33·40
Moisture, and not determined, ...	2·06
	100·00

Using the directions given with the wrapper, this powder, if employed for bread-making, would yield a 4-lb. loaf containing 210 grains of alum. On treating hard-boiled white of egg with pepsin solution, the addition of the alum baking powder, and also pure alum to the same extent as the baking powder contained, both equally retarded digestion.

There were next some experiments made on flour; and with this, while alum has a most injurious influence upon the digestion, that of alumed baking powder is but slight. With bread a series of experiments was made, in which pure bread was digested with pepsin solution and alumed baking powder and alum respectively; with amounts of baking powder recommended to be taken by the manufacturer, the influence of alum and of alumed baking powder is about equal, both producing very marked retarding action. A physiological experiment, in which four persons took each a dose of baking powder dissolved in water and then sweetened, was made. The amount so taken was 2 grams, equal to that contained in 4 ounces of bread made according to manufacturers' directions—the resultant symptoms were those resembling an attack of indigestion, being slight difficulty in breathing, headache, and ultimately slight diarrhœa, which symptoms lasted for several days.

Subsequently to this, in 1893, a case of prosecution for the sale of alumed baking powder came before the Glamorganshire Quarter

Sessions. Among other evidence given there was that of the scientific witnesses, of which the following is a summary :—

Dr W. Morgan, Public Analyst, stated that a 4-lb. loaf made according to directions given would contain 360 grains of baking powder, of which 144 grains were alum. On addition of water to the baking powder a reaction occurs, in which potash-alum and sodium-bicarbonate produce aluminium hydrate, sodium sulphate, potassium sulphate, carbon dioxide gas, and water. The quantity of aluminium hydrate might be taken as one-sixth of the alum, or 24 grains to the 4-lb. loaf. On being eaten, the hydrochloric acid and pepsin of the gastric juice dissolved the aluminium hydrate, with formation of soluble aluminium chloride, which latter body was noxious to the stomach. Aluminium hydrate was prepared from this baking powder, mixed with water, and taken with a mid-day meal. At the same meal another person drank nothing. Artificial vomiting was shortly afterwards in both cases induced, and hydrate of alumina added to the contents of the stomach in the case of the subject who had drunk nothing. Both vomits were then dialysed, and aluminium chloride found in each, thus showing that the alumina had been converted to the soluble form.

Professor Dunstan stated that aluminium hydrate dried at 212° F. was soluble in the diluted gastric juice of a dog; and, further, that such gastric juice dissolved aluminium hydrate from bread baked with the powder. Further, aluminium hydrate dried at 212° F. was soluble in a dilute solution of sodium carbonate of 0·3 per cent. strength, the strength of the alkali in intestinal juice. He consequently found that this alumed baking powder interfered with the digestion of starch by ptyalin, and also with peptic and pancreatic digestion. Hehner, Lauder, Brunton, and others gave corroborative evidence.

The line of defence was that the preceding evidence had not shown that the baking powder was injurious to health, but only that it might be. Among witnesses called for the defence was Mr. F. Sutton, who described an experiment he had made, in which a coachman ate a pound of bread made with the baking powder, and about two hours after had the contents of his stomach removed; these were subjected to dialysis, and found to contain no aluminium chloride. Dr. Luff and Mr. Wynter Blyth, who were also present at this experiment, concurred with Sutton; they all considered aluminium hydrate to be insoluble under the conditions of bread digestion in the human stomach, and viewed Morgan's experiments as valueless, because feebly precipitated aluminium hydrate was much more soluble than aluminium hydrate baked in a state of actual dissemination through a loaf of bread. Dr. B. Ward Richardson followed on the same side, and was of opinion that the use of alumed baking powder was not injurious to health. Mr. Wynter Blyth considered that Dr. Morgan's aluminium hydrate was not in the same condition as that of aluminium hydrate baked in bread; and, further, that alumed baking powder was not injurious to health.

The decision of the Court was that the baking powder was mixed with a certain ingredient, to wit, alum, which is injurious to health, and therefore the conviction of the person selling the same was upheld. Since that date the same matter has been made the subject of appeal to one of the High Courts, and Justices Hawkins and Lawrence have held that such sale of alumed baking powder is not illegal, because baking powder is not food within the meaning of the Act.

Very considerable difference of opinion was expressed during the giving of the above cited evidence as to the condition of the aluminium hydrate and its behaviour in the stomach. Of all experiments that of Sutton was far the most conclusive, because of being made on bread manufactured with the powder. The separate addition of alum or alumed baking powder to pure bread undergoing artificial digestion, or to the contents of the stomach, involves conditions so distinct from those which hold in the actual use of alumed baking powder that comparatively little importance can be attached to the results, whatever they may be. The obvious course would be to artificially digest bread prepared from alumed baking powder against breads prepared with and without admixture of alum ; and in case of human digestion, to also experiment in the same manner as Sutton with the prepared bread.

To throw additional light on this matter, the author has recently made the following series of experiments :—Three loaves of bread were prepared from, in each case, 2 lbs. 3 oz. of flour, 1 lb. 8 oz. of water, 1 oz. of yeast, and $\frac{3}{4}$ oz. of salt. At the time of mixing there was also added to No. 1, 9·35 grams of alum ; and to No. 2, 9·35 grams of alum and 4·80 grams of sodium bicarbonate ; No. 3 was left plain. The total proteids in each were determined, and a portion of the bread subjected to artificial digestion with pepsin, the following being the method adopted :—5 grams of the bread were taken and rubbed down in a mortar with 25 c.c. of 0·01 per cent. solution of pepsin in 0·2 per cent. hydrochloric acid, then made up to 100 c.c. with water, and digested $1\frac{1}{2}$ hours at 43·5° C. The solution was filtered, and the amount of digested proteid determined in the filtrate. The comparative starch digestion was estimated by rubbing down 5 grams of bread in a solution of malt diastase, making up to 100 c.c., and digesting at 21° C. for one hour. Maltose was then determined in the filtrate from each. The following are the results of analysis in percentages :—

	1. Alum.	2. Alum and Bicarbonate.	3. Plain.
Total proteids before digestion, ...	8·15	7·95	8·20
Proteids digested, ...	1·99	1·95	3·83
Maltose found, being evidence of digestion of starch, ...	36·36	41·34	43·6

Other series of experiments were made, in which the same general results were obtained. The quantity of alum present, under the conditions of the experiment, retarded proteid digestion to about half the rate in its absence. Practically no difference was made in this retarding action by the presence of sodium bicarbonate : in other words, the alumed baking powder was equally injurious with alum used alone. The difference in amount of starch digestion was not so marked as probably it would have been had a diastase solution of less strength been used. There is a marked difference between the alumed and the plain loaf, but in this case the retarding action of alum is largely overcome by the presence of bicarbonate in No. 2, a result, doubtless, of the neutralising effect of the alkaline salt on the alum.

490. Self-Raising Flour.—The articles sold under this name consist of flour, mixed with acid tartrates or phosphates, and the bicarbonate of soda: as with baking powder, the addition of water causes the evolution of gas. Self-raising flours may be viewed as being flours sold with baking powder already mixed with them. It is claimed for the use of phosphates in this manner that it replaces these important salts which are removed from the wheat in the bran.

491. Use of Hydrochloric Acid.—In the manufacture of whole-meal bread it is customary to employ hydrochloric acid and sodium carbonate in the exact proportions in which they neutralise each other: they then not only evolve carbon dioxide gas, but also yield sodium chloride, or common salt, thus:—

$$\underset{\substack{\text{Sodium}\\ \text{Bicarbonate.}}}{NaHCO_3} + \underset{\substack{\text{Hydrochloric}\\ \text{Acid.}}}{HCl} = \underset{\substack{\text{Sodium}\\ \text{Chloride.}}}{NaCl} + \underset{\text{Water.}}{H_2O} + \underset{\substack{\text{Carbon}\\ \text{Dioxide.}}}{CO_2}.$$

The salt thus formed lessens the quantity which otherwise would have to be added to the bread. Great care is requisite in the proper mixing of the acid and the carbonate with the meal: it is also important that exactly the right proportions should be taken. A rough measurement of the strength of the acid may be made by taking a weighed quantity, say an ounce, of the bicarbonate of soda, dissolving it in boiling water in a beaker, and then adding a few drops of litmus solution. The hydrochloric acid should be measured, or else a quantity placed in a beaker, and weighed in it: then add the acid little by little until one drop changes the colour of the bicarbonate of soda solution from blue to red. Then again weigh the acid containing beaker; the loss in weight gives the quantity of the hydrochloric acid, equivalent to an ounce of the bicarbonate. Commercial hydrochloric acid is usually sold with a guaranteed density of 1·15; this is equivalent to about 30 per cent. of the anhydrous acid. As 84 parts of sodium bicarbonate are exactly neutralised by 36·5 of anhydrous hydrochloric acid, and as this amount is contained in 122 parts of the commercial acid, the bicarbonate of soda and hydrochloric acid of this density should be used in the proportions of 84 of the bicarbonate to 122 of the acid, or practically in the proportions of 2 to 3 by weight. It has been recommended that 3 lbs. each of the acid and bicarbonate be used to the sack of flour: these proportions leave, however, a considerable excess of the carbonate in the bread. The great objection to the hydrochloric acid method is that the commercial acid almost invariably contains traces of arsenic, and thus a minute quantity finds its way into the loaf.

492. Whole-Meal Bread.—It is principally in making whole-meal bread that the hydrochloric acid and bicarbonate method is employed. The reason is that, with the presence of the bran, cerealin is introduced into the dough in such quantity that, if ordinary fermentation processes be employed, diastasis proceeds to a very serious extent. The excess of dextrin thus produced causes the dough to become soft and clammy, and so to offer a matrix in which sour and other unhealthy fermentations are apt to proceed rapidly. The brown colour is due to the excess of dextrinous matter contained in the bread. The rapidity of the acid treatment enables the bread to be got into the oven before diastasic action can have proceeded to any extent. When the fermentation method is employed for making whole-meal bread, it is customary to make a sponge with a small quantity of very strong flour, and only add the whole meal at the dough stage. However made, whole meal bread has a great tendency to become sodden: in order to drive off excess of moisture it has to be baked for a considerable time, consequently the loaf has often a very thick crust, while the interior is still unduly moist. In summer time particularly the making of whole-meal bread is an unsatisfactory operation, as great difficulty is often experienced in producing a sound and well-risen loaf. The whole of the precautions necessary in the manufacture of whole-meal bread are strongly suggestive of the unsuitability of such meal for the purposes of making bread at all. It is to be deplored that, for the sake of getting the nutriment *supposed* to be contained in the bran, a section of the public should demand a form of bread so unhealthy in other respects.

In all the operations just described, carbon dioxide is formed in dough, and thus raises it. The chemical action which under these circumstances takes place is not, however, a complete representative of that which occurs with yeast. One of the functions of this body during the fermentation of bread is to act on the proteids, and also to a certain extent on the starch; the result of such action, when normal, is to impart to the bread a characteristic flavour that can be obtained by no other means at present known.

493. The Æration Process.—One other method of ærating bread remains for consideration, and that is the system associated with the name of Dr. Dauglish. The carbon dioxide is in this method prepared apart from the bread and forced into water under pressure; this water, which is akin to the ærated water sold as a beverage, is then used for converting the flour into dough, the whole operation of kneading being performed in a specially prepared vessel in which the pressure is maintained. The kneading being completed, the dough is allowed to emerge from the kneading vessel, and immediately rises, from the expansion within it of the dissolved carbon dioxide. Such was the nature of the method originally employed by Dauglish; but now the following modification is used:—A weak wort is made by mashing malt and flour; this is allowed to ferment until through the agency of *bacteria* it has become sour, in all likelihood through the presence of lactic acid. The water to be ærated is first mixed with a portion of this weak acid liquid: it is then found to absorb the carbon dioxide gas much more readily. The acid also softens the gluten. So far as the actual æration process is concerned, this method is mechanical rather than chemical. The great objection is that those more subtle changes by which flavour is produced do not occur here more than in the other purely chemical methods of bread-making before described. A common experience in eating ærated bread for some time is that it after a while gives the impression of rawness. This is doubtless due to there being no such peptonisation of the proteids as results from fermentation. It is partly to meet this want that the fermented wort is now added as a part of the process. On the other hand, as a compensation for this lack of flavour-producing changes, the operation is one in which there is no danger of those injurious actions occurring of which much has already been said. Working with flours that are weak and damp, or even bordering on the verge of unsoundness, it is still possible to produce a loaf that should be wholesome and palatable, certainly superior to many sodden and sour loaves one sees made from low quality flours fermented in the ordinary manner. In thus stating that it is possible to treat flours of inferior quality by this ærating method, the author wishes specially to carefully avoid giving the impression that it is the habit of those companies which work Dauglish's method to make use of only the lower qualities of flour; he has never had any reason whatever for supposing such to be the case. His object in the present remarks is simply to point out the advantages possessed by this method, should circumstances unfortunately arise rendering it necessary to have recourse to inferior flours for bread-making purposes.

Richardson claims for the æration process that it is eminently suited for the manufacture of whole-meal bread. Of this there is not the slightest doubt: whole-meal is not fitted for fermentation processes, and the æration process distends the dough with gas, without the addition of any foreign substance whatever.

It is also claimed for the æration process that it enables the cerealin to be retained within the bread; and that this is "a most powerful agent in promoting the easy and healthy digestion of food." It is stated that this agent is retained uninjured by the ærated bread process. The author of this statement apparently overlooks the fact that diastasic action is destroyed by the subjection of proteids to a temperature approaching 212° F. However active, therefore, cerealin may be in effecting diastasis of starch during panary fermentation, its power is destroyed by efficient baking, and the bread contains no active diastasic principle. This remark applies with equal force to bread containing malt; it is so well known that malt infusion converts starch into dextrin and maltose, that from time to time it has been introduced into bread. It must here, too, be remembered that the baking entirely destroys its diastasic action, and so causes the malt to be inert as a digestive substance.

494. Gluten Bread.—It is important that the diet of diabetic patients should contain no sugar, starch, or other compounds capable of being converted into sugar. For their use bread is prepared containing the gluten only of the flour. A strong flour should be selected and made into a stiff dough with water only; this is allowed to stand for almost an hour, and then carefully kneaded in small pieces at a time in a vessel of water; the starch escapes and the gluten remains behind.

Care is necessary in performing this operation, as otherwise the lump of dough does not hold together. Should there be any difficulty, the dough may be enclosed in muslin prior to being kneaded. The gluten must be washed in successive waters until it no longer contains starch; at this point the gluten ceases to render the washing water milky. When properly washed the gluten is ready for the oven, and is usually baked in small rolls or buns. As it swells enormously during baking, a very small piece is sufficient for each roll.

495. Relative Nutritive Values of Different Varieties of Bread.—From time to time an agitation crops up in favour of using whole-meal for bread instead of finely-dressed flour. Yet in spite of this the public are found to steadily demand a white loaf. The millers, who have found themselves forced, at an enormous expense, to revolutionise the machinery of their mills in order to produce a whiter flour, are painfully aware of this fact.

Every baker is familiar with the injurious action of the cerealin of the bran during panification: any reasons which are sufficiently powerful to outweigh the disadvantages of this action must indeed be cogent. The advocates of whole-meal bread assert that the whole-meal is more nutritious than the dressed flour. But this opinion is not altogether borne out by facts. Thus Bell, in "Analysis and Adulteration of Foods," remarks that—"Contrary to the views sometimes put forward by the advocates of the use of wheat-meal bread, the samples of household flour submitted to analysis were found richer in nitrogenous matter than the entire wheat grains." Whole-meal, however, contains a higher proportion of phosphates than does the dressed flour. The whole-meal is, of course, the flour *plus* the bran; this latter substance is rich in proteids, but contains no gluten. The bran is also rich in phosphates. But from a dietetic point of view, the value of an article of food depends not only on its composition, but on what substances it yields during the ordinary processes of digestion. In Chapter XVI., paragraph 361, it is shown that bran yields comparatively little soluble extract to water, so that its actual composition is not a fair criterion of what it yields to the human system. Rübner, at the Physiological Institute in Munich, made some careful determinations of the value of bran as an article of food: by direct experiments on men he investigated the amount of material assimilated from three varieties of flour; 1, a fine quality; 2, medium; 3, flour made from whole-meal with the bran. The dough was prepared with pressed yeast. In the excreta the following amounts of unused material were found, expressed in percentages of the quantity eaten:—

	Variety of Flour.		
	No. 1.	No. 2.	No. 3.
Dry Substance	4·0	6·7	12·3
Nitrogen	20·1	24·6	30·5
Carbohydrates	1·1	2·6	7·4

The quantity of excreta was high with the whole-meal, the excess consisting of the indigestible hull of the grain.

A remarkable series of physiological experiments have been carried out upon himself by Girard (Ann. Chim. [6] **3**, 289) in order to determine the alimentary value of the proteids of the aleurone layer of the bran. He shows conclusively that the aleurone grains (in so-called gluten cells) pass through the alimentary canal apparently unaltered. The protection of the proteids against the action of the digestive secretions is, doubtless, entirely due to the highly impermeable nature of the cell-walls.

Further, in an ordinary mixed diet the retention of bran in flour is a false economy, as its presence so quickens the peristaltic action as to prevent the complete digestion and absorption, not only of the proteids present in the branny food, but also of other foods taken at the same time. Doubtless with the bran ground finer it yields its constituents the more readily to digestive action, but the fine bran is even more objectionable during panification. The most important loss resulting from the rejection of the bran is that of the phosphates; this loss is, however, more than made up by the presence of these salts in the other food-stuffs of an ordinary mixed diet. The whole of the advantages of whole-meal bread, without any of its evils, might be obtained by the addition of phosphates in appropriate quantity to white flour. One argument often adduced in favour of whole-meal bread is, that it is specially suitable where little meat is eaten. Now in Scotland the people are notoriously little meat eaters: so also in Ireland the quantity of meat eaten is proportionately far less than in England. Yet in both these countries the demand is for a white loaf: the Scotch labourer and the Irish peasant would reject not merely brown, but also the dirty coloured white bread made from low-grade flours.

496. Unsuitability of Barley Meal, &c., for Breadmaking.—Questions often arise as to why barley and other cereals do not make such good bread as does wheaten flour. One reason has already been given: wheat is distinguished from the other somewhat similar food stuffs by its containing gluten; it is the presence of this peculiar albuminous body that confers on wheat flour its characteristic bread-making qualities. The proteids of the other cereals, and also of peas and the other leguminous seeds, possess more active diastasic properties—consequently during fermentation they yield much dextrin, and produce dark coloured, sodden, and often sour breads. The diastase of rye is particularly active. In addition to the colour produced by diastasis, peas have naturally a dark colour of their own, so that their introduction into bread would very materially affect the colour. In comparing barley and rye flours against that of wheat, the differences in the respective milling processes must not be ignored. The bran and germ of wheat are separated from the flour by most refined methods, while barley and rye are still ground, and the meal purified, by the crudest appliances. This must of necessity make a difference in the character of the flour.

497. Wheat and Flour Blending.—The consideration of the whole problem of blending flours and wheats has been purposely postponed until this stage, in order that the reader may have before him an account of the various changes which flour undergoes during the operations of panary fermentation. These changes, in short, consist in more or less conversion of starch into dextrin and maltose, and in the gradual softening and otherwise altering the gluten of the flour. As has been previously insisted on, the gluten must have had during fermentation sufficient opportunity to hydrate and soften sufficiently; but must not have been allowed to further change, as if so it will have lost its tenacity, and will produce an inferior loaf. A great deal of the success of a skilled baker depends on his having acquired the experience which enables him to take his dough and place it in the oven just at this right point when fermentation has proceeded sufficiently far to get the gluten of the flour in its best possible condition.

The problem is further complicated by the fact that different flours require, in order to arrive at this stage of maturity, different lengths of time in fermentation; hence, as already explained, flours from hard wheats are commonly used in the sponge, while those from soft wheats are employed in the dough. There can be no doubt whatever that by this arrangement far better bread is produced than if the flours be used in the reverse order. It is, then, perfectly safe to state that **the length of time flours require to stand in fermentation is in proportion to their hardness or stability.** This being the case, the question arises as to how this end may best be secured.

Probably the most keenly contested question on this whole problem of blending is whether it shall be done by the miller or the baker. There is much to be said on both sides of this question. Of prior importance, however, to this matter of by whom the blending shall be performed is that of the baker's actual requirements in flour. Evidently the baker who works either with a ferment and dough, or an off-hand dough, needs but one flour for each quality of bread, and may therefore either buy a flour which suits his requirements, ready mixed by the miller, or may purchase individual flours and mix them together. On the other hand, the baker who employs the sponge and dough system will, in the great majority of cases, find it advantageous to use flours of a different class for his sponges and doughs respectively. As already explained, for the former he almost invariably selects a hard, strong flour, which is best made from either Spring American or the harder Russian wheats. For some methods of working an admixture of a small proportion of softer flour is an improvement, as the proteids of the latter exercise a distinct mellowing and ripening effect on the glutens of the hard flours. In practice, bakers select for this purpose either home or foreign milled flours from Spring American wheats, or home-milled flours from mixtures of Spring American and Russian grades, with at times more or less hard Indian. A distinct recent advance is the supply, by British millers, of flours specially prepared for sponging purposes from hard, tough wheats.

For doughing purposes the wheat or flour mixture is more varied; thus the soft, sweet, "coloury" flours are used at this stage; so also is usually a certain proportion of hard flour, which, if not too much, is sufficiently softened by the diastasic action of the softer flours by which it is accompanied.

A very interesting paper on Flour Blending was read before the Bakers' National Association, at Belfast, by W. T. Hibbard, of

Gloucester, who discussed the question of whether millers or bakers should do the blending, arguing that this should be the duty of the miller. This view was principally based on the assumption that the miller's education and training best fitted him for making accurately the necessary selections of wheat and then blending them. So long as the miller possesses this knowledge, and the baker does not, the argument is unanswerable; but there is no real reason why the baker should not himself acquire this information and experience, and then the argument no longer applies. Dealing with the question of blending, apart from by whom performed, Mr Hibbard's paper contained some most useful information conveyed on somewhat the same lines as laid down in the wheat and flour dictionaries given earlier in this work. The ideal mixture recommended for making a loaf that shall be sweet and nutty flavoured, of good size and appearance, of fine bloom, and which shall keep nice and moist for days, in fact perfection, is the following :—

	Per cent.
For Sponging—	
High-grade Spring American Patent	20
High-grade firm white Dantzic	10
For Doughing—	
High-grade Cones flour	25
Talavera straight-grade	25
Fine Winter American or Polish Patent ...	10
Fine Hungarian	10
	100

For some years there has been a demand by the more advanced bakers for flours milled from single wheats, a demand evidently based on the greater individuality which such flours would naturally possess. It is safe to predict that for some single wheat flours there will always be a market, and a good one; among these are hard Spring Americans, which can be differentiated into Manitoban wheat flours, Northern Minnesota flours, and Southern Minnesota flours, all of which have their special characteristics. Prime hard Russian wheat flours would also find a market were they obtainable. Winter American flours, both from soft wheats and also the hard Kansas wheats, may also be included in this group. So, too, may best English wheat flours, and also those from Hungarian wheats.

The following are among the advantages which accrue to the baker by working on the principle of blending flours :—

(1.) There are frequently offering parcels of flour which possess in a marked degree some one quality, but are deficient in others. Because they cannot well be used alone, they may be purchased at a lower figure, and the blender, by mixing, can utilise such flour to advantage. In other words, given the requisite knowledge, it is often cheaper to prepare the quality and character of flour required for use from a mixture of different qualities obtainable on the market, than to buy the actually wanted quality mixed ready for use.

(2.) The baker who blends flours has a greater control over the quality and character of the flour he uses in his work. Thus, he can readily either improve or diminish the value of his sponging flours by the addition of a bag or a sack of a better or worse flour: so, too, colour, flavour, and other characteristics of his flours can be readily modified at will, and much more effectively than if he simply obtains one ready-made flour from the miller.

(3.) The baker can introduce each particular variety of flour at that stage of fermentation which best suits its particular characteristics.

Blending affords greater chances of successful work with flour, but at the same time entails greater risks, because accurate knowledge of the properties and the characters of the various flours blended is requisite, and also of their effect on each other when blended.

The baker who blends should lay himself out to obtain, where practicable, single wheat flours, and also well defined flour of special characteristics. Thus, he will select flours for their predominant quality; for example, one brand for strength, another for colour, another for flavour, and so on. By appropriate means he will judge the exact character of each of these flours in the separate state, and then can readily, with a little care, prepare whatever blends best suit his work. The modern baker will have no difficulty in finding his requirements in this direction met by the modern miller, and particularly by such as those whose flours are fully described in Chapter XXI. on flour testing. These are essentially millers who make it their object to meet the requirements of advanced and, in the absolutely practical sense, scientific bakers.

Millers, in blending, usually first mix their wheats, and let them lie a time before sending to the rolls—if hard and soft wheats are thus blended, each exerts a favourable influence on the other in the way of rendering it more amenable to milling. Thus, a very hard wheat, and also a very soft one, are each more difficult to mill successfully than a mixture of intermediate character; and consequently a miller's argument is this—if the two flours are to be mixed after being milled, why not have the wheats first mixed, as the resultant flour is of better quality, everything else being equal, than if the two separate flours are mixed after milling? On the other hand, certain millers have distinct and separate plants, the one for hard wheats and the other for soft, and mill and treat each separately, afterwards mixing the flours. The evidence, therefore, of even millers themselves is undecided on this point of blending before or after milling.

Whether blending be done by the miller or the baker, an undoubted advantage arises from the latter having a clear idea of his exact requirements in flour, and how they may best be met. With clear and full knowledge on these points, whether the baker blends himself or gets that service performed for him by the miller, the result is the more economic production of a better and higher class loaf.

CHAPTER XVII.

SPECIAL BREADS AND BREAD-MAKING PROCESSES.

498. These are now so numerous that a description of some few of the leading and characteristic types may well be here included as a special chapter.

499. Whole-Meal Breads.—As a type of these may be mentioned the bread made from decorticated wheat meal, such as is supplied by the Vale of Evesham Co., which is specially favourably situated for obtaining the finest English wheats grown. As a preliminary to preparing the meal, the wheat is thoroughly cleaned, and then machine scoured, until the whole of the outer siliceous skin of the bran is practically removed. A description of analytic and baking tests on this meal is given in Chapter XXI.

500. Hovis Meal and Bread.—In Chapter XV., paragraph 426, an account is given of the effect of germ on flour, in which it is shown that, notwithstanding the high nutritive value of this body, it has a most injurious effect on flour. This effect is partly due to the tendency of its high percentage of fat to become rancid, and also to the active diastasic character of its proteid constituents. For these reasons every effort was made to obtain flour as perfectly freed as possible from germ, which, as a waste product, found its way into the offal bin. The problem of utilising germ as a bread food for many years engaged the attention of R. Smith of Macclesfield, who finally invented and patented a process by which the pure wheat germ, as extracted by modern milling processes, is subjected to the action of superheated steam. The result of this is to partly cook the germ, absolutely destroying all diastasic properties, and converting a highly unstable body into one with good keeping qualities. At the same time, this heating develops in the germ a flavour akin to that so highly valued in malt, and also produced by the action of heat. One part of this prepared germ, together with salt in about the quantity used in bread, is then mixed in with three parts of white flour of the finest quality, and constitutes Hovis flour or meal. (The name "Hovis" is registered, and can only be applied to meal as above described, made under Smith's Patents.) Hovis flour is manufactured by Messrs. S. Fitton & Sons, Hovis Mills, London and Macclesfield.

The following instructions are given by the patentee for bread-making:—"Quantities, 14 lbs. Hovis flour, 4 oz. compressed distillers' yeast, 1 gallon and 4 oz. water. Break down the yeast in 4 oz. of water. Take the temperature of the Hovis flour, and if, for example, it is 50° F., the water must be 130° F.; or if it is 70° F., the water must be 110° F.; the two added always making 180° F. The dough should be from 90° to 95° F. Mix about 10 lbs., or say two-thirds of the Hovis flour, with the gallon of water till it is a very smooth batter, stir in the dissolved yeast, then complete the mixing with the remaining 4 lbs. of flour, weigh off and tin immediately. It will require from 20 to 40 minutes' proof (according to the temperature of bakehouse, &c.), and should be thoroughly well baked, say from 10 to 15 minutes more than white bread. Use no salt. N.B.—The dough should be thin enough to be unpleasantly sticky; and no other flour should be used with the Hovis flour, not even for dusting." The result is a very moist, sweet, and pleasant flavoured loaf of bread of a rich golden yellow colour. In a comparatively recent issue the *Lancet* deals somewhat exhaustively with Hovis bread and flour. It points out as a result of analysis that in the case of the former, its food value, both as regards nitrogen and phosphates, is, broadly speaking, double that of bread made with ordinary wheaten flour. The coarse, woody fibre of the grain is entirely absent, and the cellulose is in a very finely divided flour. The bread is not only highly nutritious, but also very digestible, while it is distinctly laxative without being in the slightest degree irritating.

The writer has made a number of experiments with Hovis flour as an infants' food. He recommends it to be baked in the dry state until just brown, and then diluted down by an admixture of about six ounces corn flour or other starch to each lb. of Hovis flour. The reason for this dilution is the very high proportion of flesh-forming material in the Hovis flour.

Subjoined are analyses by the author of various Hovis preparations, with average white flour and bread results, for purposes of comparison.

ANALYSES OF HOVIS PREPARATIONS.

	Hovis.				White.		
	Meal.	Bread.		Biscuits.	Flour.	Bread.	
		Whole.	Dried.			Whole.	Dried.
Moisture, ...	12·20	42·93	...	4·56	...	...	...
Proteids, Insoluble, ...	14·21	8·80	15·12	11·25	9·5	7·51	12·52
,, Soluble, ..	1·38	1·27	2·22		1·5		
Cellulose, *Finely divided*,	0·54	...	...	...	...	...	...
Starch, &c., Undissolved,	57·66	32·85	57·86	...	...	...	...
Maltose, ...	8·34	4·44	7·77	...	...	...	...
Soluble Matter other than Proteid and Maltose,		6·15	10·79	20·84[1]	4·52[1]	4·74[1]	7·90[1]
Phosphoric Acid, P_2O_5,	0·87	0·56	0·96	0·91	0·25	0·17	0·28
Other Mineral Matter, ...	1·55	0·92	1·63	1·93	...	...	...
Fat, ...	3·25	2·08	3·65	...	1·00	0·68	1·14

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[1] These particular figures represent the total soluble matter, including proteids.

The amount of fat in the meal works out to 3·75 on the dried solids. The fats and other determinations on white flour will naturally vary according to its source.

501. Malt Extract.—This substance is prepared by evaporating *in vacuo* the filtered wort from mashed malt until the resultant liquid is of the consistency of a thick syrup. In order to investigate the composition of malt extract under different conditions, the following experiments were made:—

A high quality sample of pale malt was finely ground; and of this 500 grams were taken, mixed with 2000 c.c. of water, and mashed for two hours, at a temperature of 60° C., in a water-jacketted pan. The resultant wort was then filtered bright, and the "grains" washed, dried and weighed, their weight being 113 grams, showing that over 75 per cent. of the malt had gone into solution. This wort was called Preparation I., Unevaporated. A portion was reserved for analysis, and the remainder evaporated *in vacuo*, the operation being pushed as far as possible: this constituted Preparation I., Evaporated.

Another 500 grams of the malt were then taken, mixed with 2000 c.c. cold water, continually stirred during three hours, and then allowed to stand overnight. The clear liquid was poured off in the morning, the residual malt drained moderately dry. The liquid was filtered bright, and constituted Preparation II., Unevaporated. A part of this was evaporated in precisely the same manner as with No. I., and is termed Preparation II., Evaporated.

The residual malt from No. II. was next taken, mashed with 2000 c.c. more water for six hours, at 60° C., and then raised to 100° C., and filtered bright. This constituted Preparation III., Unevaporated. A portion was evaporated *in vacuo* as before, and this formed Preparation III., Evaporated.

Each of these was then subjected to analysis, determinations being made as given in the table on page 413, in which are also included similar analyses of a commercial sample of guaranteed pure malt extract supplied by Montgomerie & Co., of Partick, Glasgow; and likewise another pure commercial sample obtained by the author.

Various determinations, as given below, were made on the Unevaporated Preparations.

	No. I.	No. II.	No. III.
Specific gravity at 15·0° C.	1057·5	1020·7	1050·0
Dry Solids, grams per 100 c.c. calculated from gravity	14·93	5·37	13·00
Dry Solids, grams per 100 c.c. by evaporation and weighing	14·06	4·93	12·78
Dry Solids, weight in percentages	13·30	4·83	12·17

The method of analysis employed is that described in Chapter XXIV., paragraph 647, and is subject to the limitations of accuracy there explained. It should be mentioned that all the figures, both on the liquids and the extracts, are the results of direct determinations; the percentage composition of "Dried Solids" being calculated from those obtained in the liquid or extract with water present. The dextrin was precipitated by alcohol and corrected for solubility and amount of precipitated proteid: it no doubt contains not only pure dextrin, but also the other gum-like substances frequently returned as "indeterminate bodies."

The No. I., or whole extract, contained sucrose in the wort, but this disappeared during concentration. The glucoses also show a diminution, while dextrin increases. The dextrin precipitate in the evaporated extract was much darker, and evidently contained a considerable proportion of products of caramelisation.

The cold water extracts, No. II., are very interesting. The proteids and phosphates are very high: so also is the sucrose, which, however, diminishes on concentration. The quantity of maltose is very small, while the glucoses represent about half the total weight of the solids present. The sugars here again diminish during concentration, while dextrin increases, no doubt for the same reason as in No. I.

In No. III., as might be expected, sucrose is absent, any traces in the original solution being doubtless destroyed during the prolonged mashing. Dextrose and lævulose are present in very small quantity, the sugar being almost entirely maltose. As might be expected, the dextrin is high, and the act of concentration has produced practically no alteration in the proportions of the constituents present, the lengthened period of mashing and subsequent boiling having reduced all bodies present to a stable condition.

The samples of commercial extract call for but little remark; that from Montgomerie is a very excellent specimen of what a baker's malt extract should be; the dextrin is fairly high, and so also is the maltose, sucrose, dextrose, and lævulose being present in small quantity. At the same time, the sample is well concentrated, but 22·23 per cent. of water being present. With any less moisture the extract would be too stiff to pour out of tins or drums when cold. The second commercial sample affords evidence of having been worked at a higher temperature, although the degree of concentration is less. Both these extracts show all signs of being nothing beyond pure, normal extracts of malt.

In bread-making, the addition of malt extract, in the first place, increases, to the extent to which it is used, the quantities present of the various ingredients of the extract, among which are sugars which impart sweetness; dextrin, by which the bread is caused to remain moister; and phosphates, which add to the bone-forming materials, and also act as a yeast stimulant. There is in addition a specific effect on the constituents of the flour caused by the diastase present in the extract.

502. Comparative Results of Various Modes of Employing Malt Extract.—The author, some time ago, made a somewhat extensive series of experiments for Messrs Montgomerie & Co., Limited, of Partick, on various methods of using malt extract in bread making. He has received their permission to publish the same. With the same extract, and under the same comparative conditions, bread was made according to the following processes:—

I. *Plain Bread.*—This was bread made simply with flour, water, salt, and yeast.

	No. 1 Unevaporated		No. 1 Evaporated.	
	Whole Liquid.	Dried Solids.	Whole Extract.	Dried Solids.
Water	86·70	...	14·70	...
Mineral Matter (Phosphates)	0·24	1·77	1·70	1·99
Proteids	0·86	6·44	5·27	6·18
Dextrin	1·32	9·95	10·82	12·68
Sucrose	0·43	3·23	Absent	Absent
Maltose	9·04	68·03	60·97	71·48
Dextrose and Lævulose	1·41	10·58	6·54	7·67
	100·00	100·00	100·00	100·00
Cuprous Oxide, Cu_2O, from 100 grams. ...	13·99	105·2	87·50	103·70
Reducing Sugars, calculated entirely as Maltose	11·30	84·98	70·67	82·85
	No. 2 Unevaporated		No. 2 Evaporated.	
Water	95·17	...	22·90	...
Mineral Matter (Phosphates)	0·32	6·52	4·80	6·23
Proteids	0·80	16·56	12·71	16·49
Dextrin	0·60	12·36	13·66	17·72
Sucrose	0·45	9·31	4·79	6·21
Maltose	0·21	4·20	2·69	3·48
Dextrose and Lævulose	2·45	51·05	38 45	49·87
	100·00	100·00	100·00	100·00
Cuprous Oxide, Cu_2O, from 100 grams. ...	5·11	106·43	79·49	103·10
Reducing Sugars, calculated entirely as Dextrose and Lævulose	2·57	53·66	40·08	51·99
	No. 3 Unevaporated		No. 3 Evaporated	
Water	87·83	...	11·20	...
Mineral Matter (Phosphates)	0·17	1·40	1·11	1·24
Proteids	0·44	3·61	3·37	3·79
Dextrin	2·44	20·03	17·40	19·60
Sucrose	Absent	Absent	Absent	Absent
Maltose	8·82	72·45	66·06	74·40
Dextrose and Lævulose	0·30	2·51	0·86	0·97
	100·00	100·00	100·00	100·00
Cuprous Oxide, Cu_2O, from 100 grams. ...	11·52	94·67	83·5	94·03
Reducing Sugars, calculated as Maltose ...	9·31	76·48	67·44	75·94
	Montgomerie's Extract.		Second Commercial Extract.	
	Whole Extract.	Dried Solids.	Whole Extract.	Dried Solids.
Water	22·23	...	27·64	...
Mineral Matter (Phosphates)	1·10	1·42	1·40	1·93
Proteids	3·01	3·88	4·74	6·55
Dextrin	12·90	16·59	5·80	8·02
Sucrose	3·59	4·61	1·92	2·66
Maltose	54·84	70·51	53·65	74·14
Dextrose and Lævulose	2·33	2·99	4·85	6·70
	100·00	100·00	100·00	100·00
Cuprous Oxide, Cu_2O, from 100 grams. ...	72·5	93·22	80·0	110·5
Reducing Sugars, calculated as Maltose ...	58·55	75·28	64·61	89·29

II. *Malted Bread.*—This was similar to the plain, except that malt extract was added, at the doughing stage, in the same proportion as in Nos. III. and IV.

III. *Montgomerie's Patent Bread.*—This was made according to Montgomerie's patent, the essential point being that a portion of the flour is separately treated with malt extract and water, and mashed together at a temperature between 130° and 150° F. for a few hours as a preliminary operation to its being mixed with the remaining flour and other ingredients at the doughing stage.

IV. *Alternative Mashing Process Bread.*—In this method, the flour for the "mash" is mixed with water and gelatinised by raising its temperature to 190° F. It is then cooled and malt extract added, the mixture being maintained at about 165° F. for about 30 to 45 minutes. The mash prepared in this manner is then added to the other ingredients precisely as in No. III.

The following are the results of experiment on the "mash" in Nos. III. and IV.:—

Quantities Taken.

No. III.	Flour 2 lbs.	= 907·2 grams		No. IV.	Flour 2 lbs.	= 907·2 grams
,,	Water 3 lbs.	= 1360·8 ,,		,,	Water 6 lbs. 8¼ oz.	= 2955·5 ,,
,,	Malt Extract 1 lb.	= 453·6 ,,		,,	Malt Extract 1 lb.	= 453·6 ,,

These were mashed as described. The larger quantity of water was necessary in the second case because of the starch being gelatinised. It will be noticed that the essential point of distinction between Nos. III. and IV. is that in the former the mashing temperature is below that of starch gelatinisation, and at the optimum for diastasic action; while in the latter the starch is gelatinised, and mashing conducted at a temperature at which diastase is much weakened, being near that at which it is absolutely destroyed. The composition of the solids in the mash, at the end of the treatment, was in each case ascertained by analysis. A mash prepared by Montgomerie, on the manufacturing scale, from similar proportions, was also subjected to analysis. The following are the results in percentages:—

COMPOSITION OF SOLIDS OF MALT EXTRACT AND FLOUR MASHES.

	No. III		No. IV.
	Laboratory Quantities.	Manufacturing Quantities.	Laboratory Quantities.
Undissolved Matter	38·45	6·70	7·07
Total Maltose	48·70	66·00	56·88
Nett Maltose	28·70	46·00	36·88
Total Dextrin	11·88	21·58	29·42
Nett Dextrin	8·55	18·25	26·09
Total predigested Starch, being nett Maltose, plus nett Dextrin	37·25	64·25	62·97
Other dissolved Solids ...	0·97	5·71	6·62

The nett maltose and dextrin are simply the total quantities, less a deduction made for maltose and dextrin introduced in the extract, from the general composition of which the amount to be deducted was calculated. It will be noticed that in No III. when manufacturing quantities were employed, and probably a longer mashing, a much higher proportion of the flour was predigested. In No. III., the filtered soluble portion of the mash contained neither starch nor amylo dextrins, the proportions of dextrin and maltose being as nearly as possible 1 to 4. In No. IV., the filtered soluble portion contained traces of starch and large quantities of unstable amylo-dextrins: the proportions of dextrin and maltose were approximately 1 to 2.

Bearing in mind the rapidity with which diastase acts on gelatinised starch, a modification of No. IV. mash was made in the following manner. The gelatinised flour solution was cooled to 150° F., and then the cold malt extract added and thoroughly stirred in—the temperature fell to 140° F. The mixture was then heated as rapidly as possible by means of a boiling water bath, and reached 150° F. in between two and three minutes. Half the mixture was then removed, and dextrin and maltose at once determined: the remainder was then raised to 165° F. and maintained at that temperature for 30 minutes, after which dextrin and maltose were determined, with the following results, which are expressed in each case on the filtered solution:—

First half taken at 150° F.		Second half after mashing at 165° F.
Dextrin, 9·120 grams per 100 c.c.	...	11·198 grams per 100 c.c.
Maltose, 9·309 ,,	...	9·568 ,,

Practically, therefore, almost the whole of the conversion occurs below 150° F., and within the first two or three minutes after the addition of the extract.

In the next place, bread was prepared from the mashes made by the two processes.

QUANTITIES TAKEN.

	No. III. Mash prepared as described, weight 6 lbs 15½ oz.		No. IV. Mash prepared as described, weight 9 lbs. 1¼ oz.
Solids of Mash,	2 lbs. 7½ oz.	...	2 lbs. 7½ oz.
Water of Mash,	4 ,, 8 ,,		6 ,, 9¾ ,,
Fermented Sponge,	7 ,, 0 ,,	...	7 ,, 0 ,,
Flour, ...	7 ,, 0 ,,	...	10 ,, 0 ,,
Salt, ...	3 ,,	...	3 ,,
Dough, ...	21 lbs. 2½ oz.	...	26 lbs 4¼ oz.
Baked Bread, about	19·35 lbs.	...	24·01 lbs.

The following determinations were then made on the bread:—moisture, matter dissolved by treatment with water at 212° F. for two hours (mixture being repeatedly shaken during that time); also starch, dextrin, and maltose, each by direct estimation in the filtered soluble extract prepared as just described.

PERCENTAGE COMPOSITION OF BREADS.

	No. III.	No. IV.
Moisture, ...	38·98	39·19
Undissolved solid matter, ...	40·57	46·29
Dissolved matter by direct weighing,...	20·45	14·52
In filtered soluble extract,		
Starch, by direct estimation, ...	8·05	6·08
Maltose, ,, ...	6·92	5·35
Dextrin, ,, ...	7·11	4·70
	22·08	16·13
Nett Maltose, ...	3·40	1·83

In each case there was an absence of amylo-dextrins. In No. III. the proportions of dextrin and maltose were approximately as 1 to 1, the dextrin being in slight excess; in No. IV., as 1 to 1·14, the maltose being in slight excess. In both cases the sum of the three direct estimations of starch, dextrin, and maltose exceeds that of the total dissolved matter by direct weighing by 1·63 and 1·61 respectively: this is doubtless due to the fact that the sugar is not wholly maltose, but is partly glucose, produced by the inverting action of the yeast and the malt extract. Although No. IV. process yields more dextrin and amylo-dextrins in the mash, yet there is less in the finished bread, as these latter bodies are converted into maltose and dextrin by the subsequent diastasic action which proceeds in the fermenting dough. The figure in the above table called nett maltose is the total maltose, less that calculated as due to that naturally present in bread, and introduced with the extract.

In the next place a series of experiments were made by the author in conjunction with Goodfellow, in which bread was prepared by processes Nos. I., II., and III. The quantities and methods of manipulation adopted were the same as in the preceding experiments, except that in Nos. II. and III. double the amount of malt extract was taken. Some biscuits were also made, in which the same quantity of malt extract was introduced in each case; in one, simply as a condiment, as in No. II. process; and in the other, after mashing with a portion of the flour, as was done in No. III. The following are the results of analysis:—

ANALYSES OF BREADS AND BISCUITS.

	Breads.			Biscuits.	
	No. I. Plain.	No. II. Malt.	No. III. Montgomerie.	No. II. Malt.	No. III. Montgomerie.
Maltose	1·02	9·11	14·23	8·61	18·46
Nett Maltose	...	2·06	7·18	0·00	8·46
Total Soluble Matter	3·35	18·50	36·24	18·70	31·60
Soluble Matter, not Maltose ..	2·33	9·39	22·01	10·09	13·14
Nett Soluble Matter, not Maltose	...	7·03	19·68	...	...

Nett maltose is in each case that estimated to be produced by diastasic action, after allowance for that normally present in plain bread, and introduced in the extract.

There is abundant evidence, throughout the whole of these experiments, of malt extract thus used producing a considerable quantity of maltose over and above that introduced by the extract itself. It was principally for the purpose of measuring this effect that the preceding experiments were made.

503. Montgomerie's Patent.—As previously explained, the essence of this patent is the preliminary mashing together of a portion of the flour to be used with the malt extract, at a temperature of 140—150° F. for some hours, so as to convert a sufficiency of the starch into dextrin and maltose. This special mixture is then added to the remainder of the flour and other ingredients employed in making bread, biscuits, or other articles. In the working of the patent for commercial purposes, other substances are also employed which greatly increase the palatability of the articles produced. Subjoined are analyses of bread, biscuits, and rusks so made, which by direction of the author were purchased for him at Messrs. Montgomerie & Co.'s place of business. All of these are excellent in flavour, and characterised by great digestibility.

ANALYSES OF MONTGOMERIE'S BREAD, BISCUITS, AND RUSKS.

	BREAD.		BISCUITS.	RUSKS.
	Whole.	Dried.		
Moisture	38·60	...	4·20	6·90
Proteids, Insoluble	7·85	12·79	10·19	10·54
,, Soluble	0·74	1·20	1·24	1·06
Starch, &c., undissolved	39·48	64·28	67·03	60·42
Maltose	6·22	10·13	6·86	14·22
Soluble Matter other than Proteid and Maltose	5·56	9·06	8·96	6·06
Phosphoric Acid, P_2O_5	0·44	0·73	0·82	0·38
Other Mineral Matter	1·11	1·81	0·70	0·42

Montgomerie's extract of malt is also well adapted for employment as an adjunct in ordinary bread-making operations: as such it possesses yeast stimulating properties, and at the same time confers a distinct malt flavour.

504. Further Experiments on Diastasic Action.—In order to study more closely the exact effects produced in bread-making by the action of diastase, the following experiments were made:—Diastase was first extracted from malt by Lintner's process of treating the ground malt in the cold for twelve hours with 20 per cent. alcohol: this was filtered off and precipitated with concentrated alcohol. The precipitate was collected on a filter, washed first with absolute alcohol, then with ether, and dried over sulphuric acid *in vacuo*. This preparation is termed malt diastase. From a sample of low-grade spring American flour, flour diastase was prepared in a precisely similar manner. From malt a fresh 10 per cent. cold-water infusion was prepared and filtered ; this is termed malt infusion. No. 4 preparation is a commercial product sold as "diastase," and obtained by evaporating a cold-water infusion of malt to the consistency of a syrup *in vacuo*. The fifth was a high-class sample of carefully prepared and guaranteed pure malt extract.

Their diastasic value was first determined by Lintner's process on soluble starch, with the following results :—

		Diastasic value.	
No. 1.	Malt Diastase,	266·6°	Lintner.
,, 2.	Flour Diastase,	228·5°	,,
,, 3.	Malt Infusion,	15·6°	,,
,, 4.	"Diastase,"	222·2°	,,
,, 5.	Malt Extract,	3·1°	,,

It was decided to make a series of baking tests with these substances, taking such quantities as would contain throughout the same number of units of diastasic activity : knowing the diastasic value of each, it becomes a matter of simple calculation to determine what quantities must be taken in order to attain this object. Taking the malt diastase as a standard, the amount of 0·125 gram was fixed on : the equivalent quantities of the others were as follows :—

No. 1.	Malt Diastase,	0·125	gram.
,, 2.	Flour Diastase,	0·145	,,
,, 3.	Malt Infusion,	21·36	c.c.
,, 4.	"Diastase,"	0·153	gram.
,, 5.	Malt Extract,	10·75	grams.

For baking tests the following quantities were taken :—

Flour, equal quantities of Spring American and English wheat patents,	140	grams.
Water, in which was included solutions of the equivalent quantity of each diastasic body,	80	,,
Compressed yeast,	10	,,

In one series of tests, *a*, the diastasic ingredient was in its normally active state : in a second series, *b*, precisely similar in every other respect, the diastase solution was first placed in a boiling water bath for five minutes with the object of destroying the diastase, and subsequently cooled prior to mixing it in with the flour and yeast. A plain loaf, No. 6, was also made from flour, water, and yeast only.

The doughs were allowed to ferment at a moderate temperature, and the following observations made on their being ready to go into the oven.

No. 1. Difference between *a* and *b* very marked ; *a* slacker and more sticky.
,, 2. Very slight difference, if any.
,, 3. *a*, slightly sticky, difference between it and *b* not very marked.
,, 4. Clearly marked difference between *a* and *b*.
,, 5 *a*, fairly stiff, not sticky ; *b*, tougher than *a* ; both brown in colour as a result of presence of extract.
,, 6. Plain loaf. Compared with all others, stiff.

The loaves were baked in a moderate oven for 45 minutes, and were of Coburg shape, giving as much facility for expansion and formation of crust as possible.

The following was the character of the crust:—

No. 1. *a* browner than *b*.
,, 2. No difference between *a* and *b*: both much like No. 6.
,, 3. *a* slightly browner than *b*.
,, 4. *a* slightly browner than *b*.
,, 5. Both full brown in colour of surface, and dark in breaks: *a* browner than *b*.
,, 6. Plain loaf.

As a rule the crusts of series *a* seemed more pliable than those of *b*. Throughout the whole series, with the exception of the No. 2's, there was a distinct difference of flavour distinguishable before the loaves were cut.[1]

The crumb of each had the following characters:—

No. 1. Good volume: *a* in centre sticky and gummy; *b*, better colour. Flavour in both decidedly sweet, but far more so in *a*.
,, 2. *a*, only slightly sweeter than *b*; *b*, better colour, both slightly darker than No. 6.
,, 3. *a*, sweet and malty; *b*, ditto in less degree, and slightly better in colour.
,, 4. *a* has more flavour than *b*, and is also very slightly better in colour than *b*. Duplicate loaves were baked with No. 4 to see if the colours were relatively the same. Found *b* again to be darker than *a*, and of considerably less volume.
,, 5. Both *a* and *b* were brown, with very slight difference in colour. Flavour of *b* distinctly that of malt extract. Flavour of *a* different, being that of malt extract with an additional flavour of a more purely saccharine character (doubtless the result of the presence of sugars of conversion).
,, 6. Plain loaf, slightly yeasty in flavour.

A portion of each sample of bread was taken, dried to a constant weight in the hot water oven, finely powdered, and stored in stoppered bottles. A soluble extract was prepared from each in the following manner:—10 grams of the powdered solids were taken during the afternoon, mixed with 100 c.c. of cold water, and vigorously shaken several times during the afternoon and evening. They were then allowed to stand overnight, and the supernatant-liquid decanted in the morning, without disturbing the residue, and filtered. A portion of this was evaporated to dryness for soluble extract, and the maltose determined in another portion. The following are the results of analysis expressed in percentages on the dried solids:—

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[1] This is a somewhat curious instance of the baker's use of the term "flavour": bakers habitually examine bread in the first instance by the *smell* of a loaf, and judge flavour through its subtle association with smell. Such flavour judgment may be described as "how the bread tastes to the nose."

ANALYSES OF DIASTASE BREADS.

No.	Variety.	Soluble Extracts.		Maltose.		
		a	*b*	*a*	*b*	*a*—*b*
1	Malt Diastase	27·24	8·04	7·83	2·90	4·93
2	Flour Diastase	10·40	9·65	1·61	1·61	0·00
3	Malt Infusion	17·75	10·55	4·44	3·63	0·81
4	"Diastase"	9·20	6·12	2·5	1·13	1·37
5	Malt Extract	16·04	8·76	5·60	3·23	2·37
6	Plain Loaf	7·60	...	1·61	...	...

In examining these results, the first noticeable point is that in No. 1, *b*, there is a considerable quantity of maltose over that in No. 6. The same is particularly observed also in No. 3: it would seem therefore that the means employed in order to destroy the diastase were not sufficient. As No. 3 was by far the largest amount of liquid solution of diastasic ingredient acted on, its temperature was taken at the end of the five minutes in the water-bath, and found to be 198° F.; at the same time there was an abundant flocculent precipitate of coagulated proteids. That the maltose in No. 3, *b*, is the highest of that series also points to insufficient heating, for the other solutions, which were considerably less in volume, had apparently much more of their diastasic action destroyed. That a solution is able to exert diastasic action after subjection to this temperature is contrary to hitherto recorded observations on this point.

The following are the approximate percentages of maltose in each bread, due to that actually added in the extract preparation:—

		Diastase.
No. 1.	Malt Diastase	0·00
,, 2.	Flour	0·00
,, 3.	Malt Infusion	0·38
,, 4.	Diastase	0·08
,, 5.	Malt Extract	5·10

In the last case the maltose thus added is very nearly the whole of that found in No 5, *a*, and more than in No. 5, *b*. The mode of extraction employed, although giving strictly comparative results, does not however remove the whole of the maltose in solution from the solids. The vesicular nature of bread, in which the various constituents are locked up within films of coagulated proteid matter, makes the entire extraction of the soluble ingredients a task of considerable difficulty and uncertainty.[1]

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[1] The plan of determining soluble extract in *dried solids* is no doubt responsible for generally low figures. The great advantage of the method is that the solids can be kept in an unaltered form until a convenient time for their analysis arrives. This is obviously impossible with moist breads. Recently the author has, in the absence of enzymes (as in bread analysis), used the modification of direct extraction from moist bread. He then simply places the bread and water together in a flask, adds a few drops of chloroform, corks and shakes, and sets aside without fear of change occurring during an interval of waiting. This is particularly applicable to determinations of maltose.

In studying the column headed *a—b*, we have undoubtedly maltose due to conversion of starch, though not necessarily the whole of such maltose. Flour diastase, the quantity of which taken had an equal diastasic value by Lintner's method on soluble starch, effects no conversion whatever. So also the malt infusion effects comparatively little change. It will be remembered that certain forms of diastase are able to convert starch paste, while others can only act on soluble starch: raw grain diastase belongs to the latter group, and hence, doubtless, its inability to convert the starch of flour. The diastasic value of any preparation for bread-making depends not simply on its activity as measured on soluble starch by Lintner's method, but on its power of converting starch paste, and even the imperfectly gelatinised starch occurring in bread.

ANALYSIS OF FLETCHER'S "DIASTASE."

	Whole Extract.	Dried Solids.
Water	27·90	...
Mineral Matter (Phosphates)	3·32	4·60
Proteids	13·41	18·60
Dextrin	6·40	8·88
Sucrose	2·20	3·05
Maltose	15·09	20·93
Dextrose and Lævulose	31·68	43·94
	100·00	100·00
Cuprous Oxide, Cu_2O, from 100 grams	81·75	113·4
Reducing Sugars, calculated as Dextrose and Lævulose	41·09	56·99

505. Fletcher's Diastase.—Under this name is sold by the Diastase Bread Improvement Co., of 42, Castle Street, Liverpool, a compound consisting essentially of the concentrated cold-water extract of malt, so prepared as to retain the diastasic activity of malt in the highest possible degree. Various samples examined by the author have given a diastasic capacity on Lintner's scale varying from about 220° in the lowest to considerably over 300° in the highest. The effect of this body on bread made therefrom is explained in the preceding paragraph: it may be taken that this preparation, although not possessing so high a converting power in bread-making operations as apparently indicated by Lintner's tests, still is remarkably active in this direction. The addition of a small quantity to the bread at the dough stage suffices for the conversion of a very marked amount of starch into dextrin and maltose, thus conferring both moistness and sweetness on the bread. It also exerts a considerable action on the proteids of flour, producing a softening and peptonising effect on the gluten. In the case where strong, harsh, and dry flours are in use, the result is to make the resultant bread approach far more closely in character to that made from softer and sweeter flours. One word of caution may be here introduced as to the employment of "diastase"; this preparation is so energetic as to be capable of carrying too far the changes in starch and other flour ingredients, and thus yielding a wet, clammy loaf. The obvious remedy is to employ the substance in less proportion. The precise amount is easily determined by a very few trials. In addition to its diastasic action this body is, owing to its high proportion of proteids and phosphates, an energetic yeast food. On page 421 is an analysis made by the author of a sample of "diastase."

506. Manchester Chemical Co.'s Diastasic Super-Malt Extract.—This preparation is a compound extract, containing, in addition to malt, other ingredients of value for baking purposes. It is characterised by an exceedingly bright tint, and has little or no darkening effect on the colour of bread. The saccharine constituents and percentage of phosphates present cause this body to act as a yeast stimulant. It may be employed either in the preparation of a ferment, when it forms a substitute for potatoes, or may be added at either the sponge or dough stage. During the act of baking this extract exerts decided diastasic effects, increasing the quantity of dextrin and maltose in the bread. An essential feature in its preparation is the addition of certain absolutely harmless antiseptic bodies; these retard the growth and development of lactic and other foreign ferment organisms, and so render the bread much less liable to sourness or mouldiness on keeping. These properties of this extract have been verified by a number of baking tests and after-analysis of the bread.

The Manchester Chemical Company also supplies another preparation possessing diastasic properties. This consists of diastase from malt in a comparatively isolated form, which is carefully dried, and sold as "Desiccated Diastase Powder," being recommended for use in the same manner as their malt extract. To this preparation is added a small quantity of hydrofluoric acid; this compound, as explained in the earlier part of this work, possesses marked inhibitory effects on bacterial life and development, and consequently is being somewhat extensively used as a yeast cleanser. A result of its presence should be the diminution of foreign organisms in the bakers' ferments and sponges. Doubtless its employment by bakers who prepare their own patent yeasts would cause these to become much purer yeast growths. A small proportion of it might be employed, mixed in with the malt and mashed with it in the ordinary manner. "Desiccated Diastase Powder" has an energetic action on starch, and when used in bread-making causes an increase in the percentage of dextrin and maltose present, at the same time imparting to the bread a full malt flavour.

CHAPTER XVIII.

BAKEHOUSE DESIGN.

507. Selection of Site.—In selecting the site for a bakery, one of the first things is to decide on its commercial suitability; thus, a practical baker would at once see whether or not a neighbourhood looked as though it were growing and improving, or the reverse; whether it was already overstocked with bakeries, or whether there were still openings; whether full prices were being obtained, or whether the locality was an undercutting one. The nature of the roads, whether hilly or level, and all items bearing on the cost of getting flour into the bakehouse and delivering of bread from the bakehouse, would be duly noted, and the proper weight given to them in forming a judgment as to the suitability of the spot. All these may fairly be termed commercial aspects of the question; but beyond these there are considerations which are more intimately associated with the practical necessities of bread-making.

Among these a leading place must be given to the degree of fresh air obtainable, and general hygienic surroundings. The situations best adapted for *selling* bread are rarely those also best suited for *making* the same. A good shop will be naturally where rents rule high and property is valuable; in consequence, baking operations are frequently conducted in a far too limited space for efficient and healthy working. It is an open secret that many of the best bakers' shops in busy towns are attached to lamentably inadequate bakehouse accommodation. As a result of this, the system of having bakeries in more thinly populated districts, where there is breathing space, and using the shops as selling places only, is being more and more adopted. With large firms having abundance of capital this is comparatively easily managed, but in the case of smaller concerns greater difficulty exists. But except where good bakehouses, readily fulfilling all reasonable sanitary conditions, exist, it is serious matter for consideration whether the bakehouse should not be altogether distinct from the shop. However crowded a locality, there may generally be found at a not unworkable distance a site where a bakehouse, pure and simple, may be erected. The bread rounds may be served direct from where the bread is baked, and only those goods brought to the shop which are requisite for a counter trade. The difficulty is that this means two places to be supervised instead of one, but even when under the same roof the bakehouse is absolutely distinct from the shop. With the advent of the telephone, business communication between the two is such that orders and messages may be readily transmitted. Granted that arrangements of this kind mean extra expense, still, in the matter of hygienic requirements the public is master, and will insist, in no uncertain tones, on bread-making being carried on under satisfactory sanitary conditions.

There is no doubt that a bakery on the ground floor has a far better chance than one situated under ground. No one more thoroughly recognises than the author the difficulties, in many cases, of finding in old bakers' shops accommodation for the bakehouse other than below the shop, and also that many bakeries exist below the street level, and are yet clean and healthy; but it is in spite of their situation, and not because of it, that they are thus clean. To keep them so requires far more effort and attention than when they are above ground. When a new building is being erected, it may frequently be an advantage to have a sloping site, thus permitting two approaches on different floor levels; this, however, is not often obtainable. It may further mean that the district is hilly, and so difficult for the delivery of bread. The site should be dry and well-drained; also well-ventilated, but sheltered so far as possible from exposure to cold winds, especially on the north and east sides. The top of a hill has advantages over the bottom for the delivery of bread, inasmuch as the full vans have a down hill journey.

508. Requirements in the Building.—These will be best grouped under various headings, each of which will be considered in turn.

509. Sanitation.—Among requirements, those of most vital importance are demanded for sanitary purposes. The various Factory Acts lay down a minimum in this direction which by law is made compulsory. It will be well here to examine these somewhat in detail, so far at least as they affect the question of actual design as distinguished from precautions in after use of the bakery.

It is first of all required that—

"(i.) No water closet, earth closet, privy, or ash pit may be within, or communicate directly with, the bakehouse.

"(ii.) Any cistern for supplying water to the bakehouse must be separate and distinct from any cistern for supplying water to a water closet.

"(iii.) No drain or pipe for carrying off fæcal matter or sewage water may have an opening within the bakehouse."

To fulfil the first of these conditions closets are preferably erected in an open yard where an air space intervenes between them and the bakery. But while theoretically it may be good designing to place closets and urinals completely away from the bakehouse, with a good space between, we are met by the practical difficulty that bakers work in a warm atmosphere, and find it dangerous to freely expose themselves suddenly to the cold. If such accommodation be provided too far away, there is the danger of a nuisance being created by the improper use of some other part of the bakery and its surroundings. A very good arrangement is that in which a door opens, preferably from the stokehole or some similar part of the building, into a small yard, with a passage intervening between the closets and the bakehouse. By a proper system of roofing, free ventilation is secured, while protection is afforded from rain and cold.

In some of the best fitted bakeries, dressing-rooms are provided for the workmen, and out of these lead lavatories and closets, with adequate ventilating provisions, so that a current of air leads from the bakery toward the lavatories, and thus out of the building.

The second condition, which applies to the water supply, is one easily arranged for. As a contigency against accidents, bakeries should possess a water cistern holding at least one day's supply. To this the draw-off for bakehouse use may be affixed direct, but closets should be supplied with an intervening cistern, such as the ball-cock flush cistern now seen as an almost universal accompaniment to the closet.

The third requirement, as to drains, is also a matter the necessity of which is self-evident. It follows from it that, whether trapped or not, there should be no direct drain communication with the sewers. All drains within the bakehouse should be carried out by means of as short and straight a pipe as possible into the open, and there allowed to pour into a trapped outside drain. It is not advisable even to place a trap in this short length of drain; for wet flour and dough so quickly undergo putrefaction, that no lodgment should be permitted for them by even the simplest of traps.

Following on the conditions already quoted, the Factory Acts proceed to enact that—

> "No room or place may be used as a bakehouse if, on sanitary grounds, it is unfit for such a purpose."

Further,

> "The bakehouse is to be kept free from effluvia from drain, privy, or other nuisance; not to be over-crowded, and to be ventilated so as to render harmless any gases, dust, &c., that may be generated in course of manufacturing processes. In case of injurious dust the Inspector may require fan to be used."

The next rule of the Factory Act is one treating of quite a different matter—

> "A place on the same level with the bakehouse, and forming part of the same building, may not be used as a sleeping place, unless it is effectually separated from the bakehouse by a partition extending from the floor to the ceiling, and unless it has an external glazed window of at least nine superficial feet in area, of which at least four and a half superficial feet are made to open for ventilation."

This applies to a condition of things now but rarely met with: for though bakers' apprentices of the past may have had, in some instances, to make a bed of a sack in the bakeroom itself, yet now, with the disappearance of the system itself of apprenticeship, its abuses by unscrupulous masters will have disappeared with it.

510. Safety.—Still following the lines of the Factory Act, the next question is that of safety; and here again very explicit instructions are given for the baker's guidance:—

> "Every hoist or teagle, and every fly-wheel directly connected with the steam or other mechanical power, whether in the engine room or not, and every part of a steam engine and water wheel, is to be securely fenced."
>
> "All parts of the mill-gearing and all dangerous parts of the machinery are either to be securely fenced, or to be in such a position, or of such construction, as to be equally safe to every person as they would be if securely fenced."
>
> "Mill-gearing comprehends every shaft, wheel, drum, or pulley, by which the motion of the first driving power is communicated to any machine appertaining to a manufacturing process."
>
> "Machinery includes any driving strap or band."

These provisions are so plain that little or no explanatory comment is needed. Most of the bakery mill-gearing where machinery is employed is fixed overhead, so that it is perfectly safe. Where belts pass through the floor, or come down from the overhead shafting to the machine, adequate fencing must be provided.

The engine or other source of mechanical power in the bakery will usually have a separate room provided for it, and so is itself protected, and its moving parts are adequately shut off from contact with any of the bakehouse workers. In may be noticed in passing that the Factory Act provides for the fencing in of the fly-wheel of an engine, "whether in the engine room or not." When a gas engine is employed, this regulation becomes a source of positive danger. As is doubtless known to the great majority of readers, gas engines are started by pulling around the fly-wheel by hand until the first explosion occurs. A wheel with temporary fencings is more dangerous than one unfenced ; for, as a matter of fact, the fence is as often as not left out of position, and any dependence placed on it for security may lead to false confidence and consequent accident. If, on the other hand, the fence is a fixture, then in pulling round the fly-wheel there is danger of getting entangled between it and the fencing. Fortunately most of the inspectors under the Factory Act approach with a liberal and practical spirit the laws they have to administer.

Probably one of the most dangerous appliances which ever enters into a bakery is the power-lift for moving goods, and sometimes persons, from one floor to another. Lifts of this kind, although mechanical in their nature, are integral parts of the building and its permanent fixtures, and so come before us at this stage for review. The lift of raising capacity of say 15 to 20 cwt. consists of a cage about probably 6 feet square, and runs up and down a well the whole height of the building. Where hydraulic power is provided, the cage usually is supported on the top of a long piston rod, for which a pit has to be sunk under the lowest part of the cage travel. In cases where a lift is driven by an engine, the driving gear is most frequently overhead, and the roof trusses or girders must be sufficiently strong to carry same. The great source of danger is that of people falling down the well, or attempting to get in and out of the cage while in motion. The former source of danger can be easily met, particularly on the higher floors, by fixing an automatic gate to the lift, so that when the cage is not at the top floor there shall be a gate shutting the opening. When the cage comes up, it itself removes this gate, and replaces it when it descends.

511. Working Requirements—Compactness.—In natural sequence there next come forward for consideration the requirements of the baker in using the building, as these must vitally affect the design. Among these one of the first to occur is that of compactness ; bakeries are not wanted to be long and straggling, or with the work going on in half-a-dozen places at the one time when one would suffice. There is the inevitable loss of time resulting from inadequate supervision, and also that necessarily following from ovens, machinery, tables, &c., being too far away from each other.

In the next place matters must be so arranged that all approaches and exits are under control, so that the delivery of flour and raw material, and also the packing up and dispatch of bread and finished goods, may be easily and efficiently checked. Where at all practicable, all means of egress and ingress should be through the one main entrance, or, if through different entrances, the whole of these should be under control from the office. Where this is impossible, either such extra doors must be locked, or else arrangements must be made for a responsible man being placed in charge. The expense of loss, or checking loss, is such that it well repays to provide what is practically one main entrance to the bakery.

In the case of a retail trade, there must be ready means of delivering stuff from the bakehouse to the shop. This necessitates, in the case of bakery and shop being on the same level, a direct passage from one to the other. With a bakery either under or over the shop level, the best plan is a simply constructed lift.

512. Ventilation.—Efficient ventilation is compulsory under the Factory Act, but apart from that the necessities of the case would lead every baker to ensure his ventilation being as perfect as possible. With all hot work the comfort and health of the operatives require abundance of fresh and pure air. The ventilation of a bakery is fraught with some difficulty, as it is extremely important that there be no draughts nor sudden chills through the admission of large quantities of cold air in a short space of time. Ventilation is usually effected by what are known as convection currents, the scientific explanation of which has been given in the introductory chapter. Briefly, air expands as it gets hot, and consequently is lighter, bulk for bulk, than when cold. As a result, hot air floats upwards, and cold descends to take its place. From this it follows that in rooms where gas is burning, or where there is any source of heat, the upper part of the room is distinctly the hotter. If air-flues are led upwards from the upper portion of a room used as a bakery, the hot air will escape from these, while cold air will stream in to take its place at the lower levels. This effect is easily studied in the accompanying figure. Immediately over the ovens is an

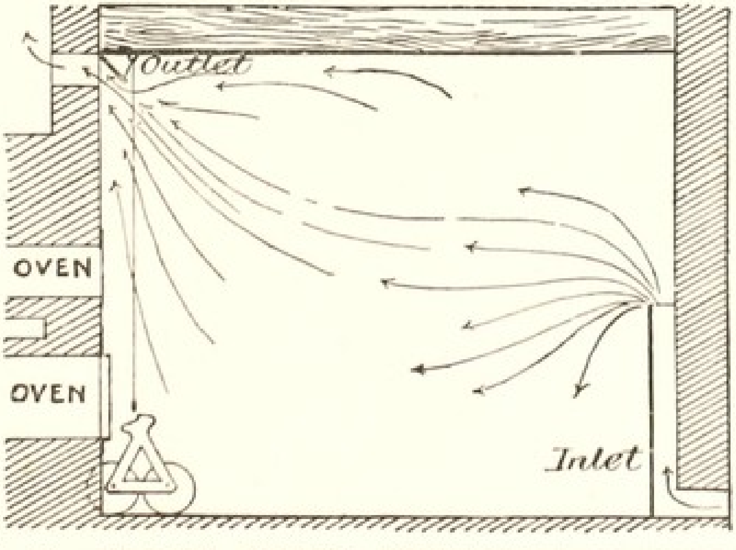


FIG. 43.—DIAGRAM SHOWING VENTILATING AIR-CURRENTS.

uptake to which a sliding door is attached; this is exceedingly simple, and is readily worked by a cord from the floor level. At the sides in various places are inlet pipes: the tops of these are so placed that the cold air does not strike directly on troughs or other vessels containing ferments, sponges, or doughs.

A useful form of ventilating flue is constructed from a compound chimney pipe such as shown in sketch, Figure 44. This pipe is made of earthenware, in lengths of from 12″ to 18″, with spigot and faucet joints like those of an ordinary drain pipe. But on one side of the flue pipe is formed a chamber; this separate chamber or flue is the air flue. The heat of the chimney portion warms the air flue, and so creates a powerful draught through it. Oven chimneys may, as shown, be constructed of such piping: so also in underground bakehouses may the flues or fires in rooms above, the air flue being carried down into the bakery. Windows may be used for ventilating purposes, but it is then a good plan to place a board on the lower side, so as to cut off any direct indraught.

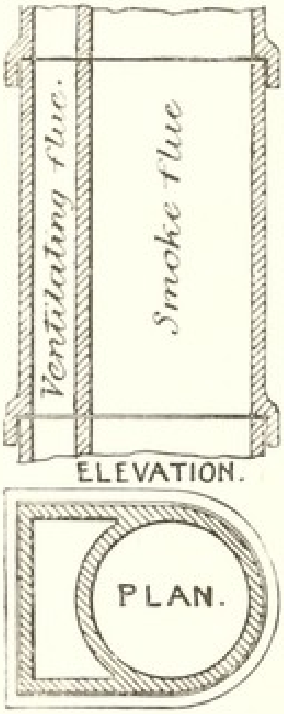


FIG. 44.—VENTILATING CHIMNEY PIPE.

513. Constancy of Temperature.—Sudden changes in temperature are of course largely produced by draughts, but also may be due to the construction and materials used in the actual building of the bakehouse. Lath and plaster are *not* indicated as the most suitable methods of building bakehouse walls. These should be constructed either of stone or brick of sufficient thickness, and if the latter be used a fairly solid brick is an advantage. Brickwork should be cemented on the surface, or other steps taken to ensure its being watertight. The same reasons which militate against thin walls also apply to iron. For light sheds corrugated iron may do very well, but it is not the material for bakery construction. Its ready conductivity of heat causes the bakery to be extremely cold in winter and hot in summer. For the same reasons open iron roofs are to be condemned. To prevent fluctuations in temperature there is nothing like having another room over your bakery, and the common practice of having the flour store above is more than justified by its influence in maintaining an equable temperature in the bakery itself.

514. Arrangements for Ovens.—In may be taken as a cardinal opinion of the author's that ovens should be fired from outside the building wherever possible. In conjunction with this, one has of course to bear in mind the fact that internal firing, or firing in some other way from the front, is much preferred by some bakers; but there are so many reasons why firing, and its concomitant dirt, should be kept out of the room in which bread is being made, that it may well be claimed that these are worth even some little inconvenience in the matter of baking. The fact, however, is that these inconveniences are more imaginary than real, and there are ovens which fire at the back, and yet, so far as practical usefulness and convenience are concerned, do as good work as others with the fire manipulated within the bakehouse proper. This view leads the author to suggest the provision in bakeries of a separate stokehole, with means of access from the bakery, and separate entrances for the bringing of fuel and the carting away of ashes. Ovens may be built within the bakery itself, but where practicable the writer prefers to have them outside, with a lean-to or other roof covering over the ovens themselves only. This separate building can then receive independent ventilation, so as to avoid undue heating by the oven of the bakery itself. Where there is a row of ovens, their faces and doors should be flush with, or form part of, one wall, and this wall should be carried of course right up to the ceiling. This should be done even if the ovens are within the main building, and have the upper rooms extending over them. Such a wall has also of course to bear the superincumbent weight, and therefore it is well so to arrange it that independent pillars or columns should be formed between each oven to carry the weight above. The general work may be faced up uniform with these, or the ovens may be slightly recessed, so as to give a somewhat improved architectural effect, but in either case ovens and building should be separate and distinct from each other.

The design of the bakehouse must depend somewhat on the nature of ovens selected. These resolve themselves, so far as British practice is concerned, into two types, the ordinary oven loaded with a peel, and which is an almost square rectangle in horizontal section, and the drawplate oven, which is narrow and elongated. The particular shape of this latter variety is determined by the width of plate over which men can set bread by hand. Practically this is limited to six feet. which can be readily stretched by reaching from either side. There is one particular in which the drawplate oven affects the style of bakehouse, and that is in the case of a plot of land facing, say, a leading thoroughfare, where a narrow frontage is all that can be had, but where comparatively great depth is obtainable. The narrow form of oven works in well in such cases as these.

515. Machinery.—The arrangements in this matter must depend largely on the space at command, and its shape and other characters. The engine should have a separate room provided for it, and this holds good with especial force in the case of gas engines, where comparatively small quantities of dust and dirt, by finding their way between the valve surfaces, may readily do extreme damage. This is not a matter of great difficulty, because in even a small bakehouse the engine may be screened off with a glass and woodwork partition.

Naturally, in arranging machinery and bakery, provision will be made for running materials about as little as possible. Flour storerooms are generally and properly at the top of the bakery, and the flour is at once raised there when brought into the building. Then flour and dough drops by gravity downwards from floor to floor during all subsequent operations thereon.

516. Typical Bakery Designs.—Having dealt with general principles, an effort will next be made to show how these principles may be embodied in everyday work. For that purpose the following descriptions, illustrated by plates following page 432, are given. It should be explained that most of these illustrations are drawn from plans executed by the author in the course of actual practice, and represent in their broad outlines of design bakeries at present in successful operation.

It must be remembered that these are not to be taken as complete working drawings; many little details of construction are omitted, because they do not affect the general principle of the design. Of course should one wish to carry them into practice, it would simply be a matter of routine work to supply the various building details, and also to prepare architectural elevations of the exterior of the building.

517. Single Peel Oven Bakehouse.—On Plate VII., Figures A, A, there is shown a small bakehouse fitted with one peel oven, which may be single or double decker. The outside width is 18 feet 6 inches, windows all in front, and depth 30 feet. As just mentioned, the oven may be a single one, but a double oven has the advantage of supplying a most useful auxiliary oven at very little extra cost for erection, and none for fuel while at work. The firing arrangement is at the side, giving a separate stokehole, fitted with coke bunker. The assumption is that the oven is accessible at the back; in fact, that no facilities for either light or entrance are obtainable from anywhere but the front. Beyond showing a trough at one side, no attempt has been made to introduce fixtures and utensils; the places of these will at once suggest themselves to the baker in looking over the plan. In the left-hand corner of the bakehouse is arranged a staircase leading to the flour store above. Here is shown in outline the position of a sifting machine, through which flour may be delivered into the trough below. The extreme usefulness of this is self-evident, and the machine is readily worked by hand. The oven portion of the building is covered by a lean-to roof, bringing it up simply one storey high. A large amount of work could easily be done in a bakehouse of this type. The lower oven might be very well used for baking, say, three batches of bread and another batch in the upper oven on ordinary days; extra of course on Saturdays. This would easily provide for a trade of, say, twenty-five sacks per week; which is probably as much as is usually convenient to do in a one-oven bakehouse. So far as the oven alone is concerned, this output might be doubled. Then, following the bread in the upper oven would come such small goods as require a medium-heated oven, and after them cakes, and finally rich block cakes. Following the bread in the lower oven might be baked such goods as require an oven heated to a bread-baking temperature; after which it should be closed, and not allowed to drop below bread-baking heat for the day. Careful management should thus give one constant oven for high temperature work, and another to be used for general work at lower temperatures. The introduction of proper drainage and sanitary appliances would render this bakehouse, small as it is, perfect, from a hygienic point of view—so perfect, at least, as handmaking appliances will permit.

518. Bakehouse for two Peel Ovens.—The next plan on the same Plate (VII.), Figures B, B, is one of a larger bakehouse, in which both front and side light is obtainable. It is shown fitted with a pair of peel ovens, which, again, would preferably be double-deckers; having the two of them, one of the ovens might be fitted with an upper oven arranged as a steam-retaining sloped oven for glazed or Vienna bread. The suggestion here is that the ovens shall be fired at back, and accordingly a stokehole extends the whole length of the back; opening from the passage to the stokehole is a door leading to a small yard, in which are built lavatory and men's offices. In order to protect workmen this passage is roofed over, but left open on side nearest the yard. The bakery has a table in the centre, containing a trough underneath, and again over this is a sifting machine, as before suggested. To the right hand of the bakery is a small office, and behind it a pastry room. Over the bakery is the flour store, arranged as in the previous sketch. A bakehouse such as this would have capacity for a large trade; with properly selected ovens there would be no difficulty in turning out a hundred sacks per week, and also the corresponding amount of small goods and confectionery trade. Of course, the amount of bakehouse space would in such a case be increased with advantage, or the space might be altered in shape to meet exigencies of site. No provision has been made here for machinery, but of course such could easily be adapted to same if desired. Bread-rooms and other conveniences might very well be attached to the bakery in front, or side opposite ovens.

519. Single Drawplate Oven Bakery.—In the third, figures C, C, same Plate (VII.), a plan is given of a bakehouse fitted with a drawplate oven, over which may also with advantage be built an upper peel oven. This arrangement lends itself well to a site where there is a very narrow frontage and plenty of depth. The present sketch has been prepared on this assumption, and shows a bakery standing on a piece of ground 15 feet 4 inches in width. This might be still further diminished by lessening the width of the passage round the stokehole, which in the plan is three feet wide. By resorting to the plan of having the oven fired within the bakehouse, the total width might still further be reduced to 10 feet inside and 12 feet 4 inches external width. Or even in this case the oven might be fired at the back by arranging a spiral staircase or step-ladder down into the stokehole from over the oven through the flour store above. Such very narrow sites are not, however, likely to often occur, and the staircase arrangement is not recommended. As drawn, it is assumed that no light is available from the sides, and accordingly small windows are placed over the ovens into the bakehouse. This plan shows in diagram form the position of doughing, flour-blending, and sifting machinery arranged in the bakehouse, and also parts of the same plant overhead. The engine-room is in front of the bakery, and beyond that is the bread-room. A bakery such as this forms an interesting and fairly complete instalment. With this plant, especially where the drawplate has over it a peel oven, an extensive and varied trade may be done, although the machine plant laid down could very well turn out sufficient stuff to warrant the erection of another oven beside that shown, making of course the bakehouse correspondingly wider. With increased width re-arrangement of space would permit the depth to be reduced.

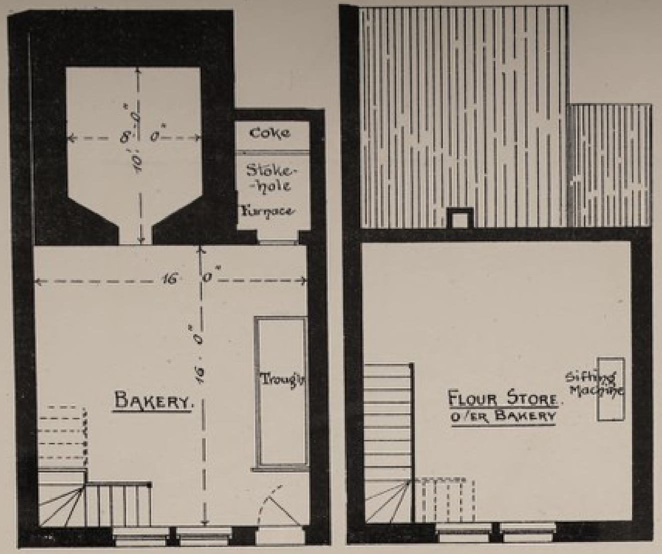
520. Shop and Overhead Bakery.—The designs given on Plate VIII. take into consideration a business which is supposed to be a main street of a good neighbourhood, where the exigencies of the circumstances demand both bakehouse and shop to be in close proximity. It is assumed that the only access to the premises is from the front or street side, there only being at the back a limited amount of air and lighting space, which cannot be utilised in any way in connection with the manufacturing operations of the business.

Regarding the shop itself much must of necessity be left to the nature of the business and the individual taste of the proprietor. It goes without saying that window space is required for the display of goods; this is provided by two windows, each of about ten feet in length. On the one side is a counter, and the other is fitted with a table, which may also, if wished, be easily used for counter purposes. Toward the back of the shop some small refreshment tables are placed, which may, if desired, be employed for the consumption of tea and coffee. Descending from the back of the shop is a staircase leading to lavatories and retiring-rooms in the basement. These are indicated by dotted lines on the ground-floor plan. A passage from the bottom of the staircase leads to one set of lavatories and w.c.'s on the left hand. Another similar set are reached through the room shown under part of the bread-room. This basement room, with the appertaining conveniences, could, if wished, be retained for the staff, the others being reserved for the accommodation of customers, and both kept separate and distinct from each other. If wished, this basement could be used also, or instead, for the preparation of light refreshments to be sent up by a small lift which might be fixed by the top of the stairs.

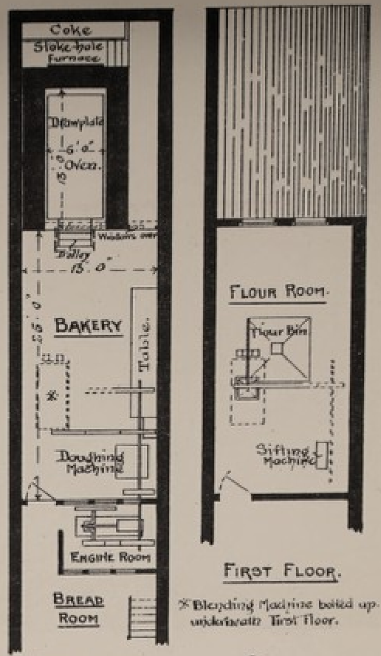
It being assumed that the only approach to the building is from the front, means of ingress and egress have been provided by a side passage on the right hand of the shop; this goes right through to the back of the building, and has doors leading into the bread-delivery room and the office.

As an alternative to the bad plan of a cellar bakehouse, the bakery part of the premises is shown overhead: a feature which is in common with the now frequent plan of having hotel kitchens, &c., at the top of the building. Let us first rapidly run through the general arrangements of the bakery. As already explained, the shop is on the ground floor, with lavatories in back part of basement, opening out in area behind. At the rear of the shop is the bread cooling and delivery room. On the first floor is the bakery, containing the ovens and moulding tables. Machinery and engine are arranged on the second floor, while the flour stores are on the third floor.

A more detailed examination of the arrangements may be made by following the flour from its entry into the place to its departure as bread. Being situated on a main and busy thoroughfare, all flour will have to be delivered either early in the morning or preferably late in



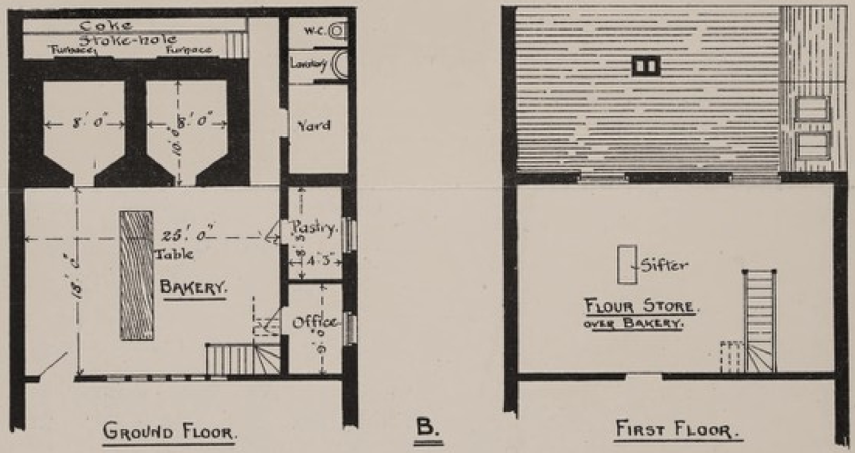
GROUND FLOOR. **A.** FIRST FLOOR.



GROUND FLOOR. FIRST FLOOR.

* Blending Machine bolted up underneath First floor.

C.

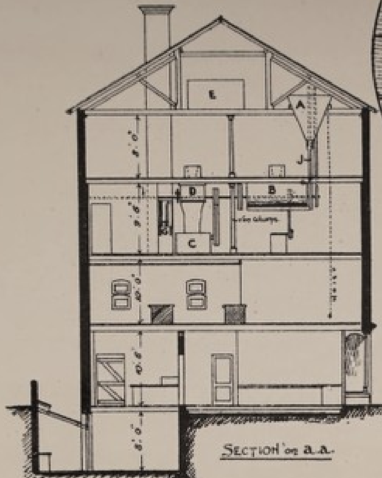


GROUND FLOOR. **B.** FIRST FLOOR.

PLANS OF VARIOUS BAKEHOUSES.

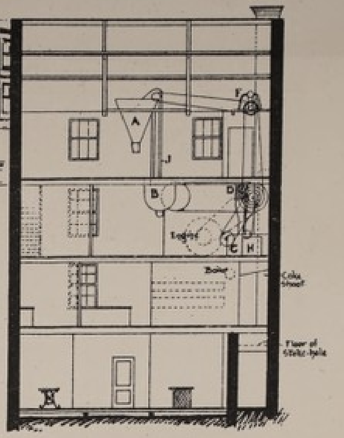
Designed by William Jago.

A. FOR ONE PEEL OVEN.
B. FOR TWO PEEL OVENS.
C. FOR ONE DRAWPLATE OVEN.



SECTION on a.a.

SKETCH ELEVATION.

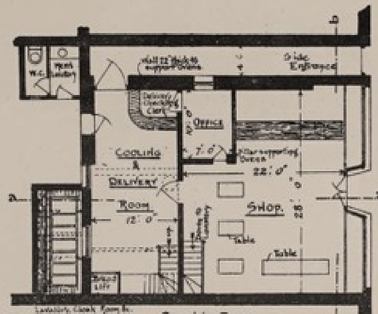


SECTION on b.b.

References.

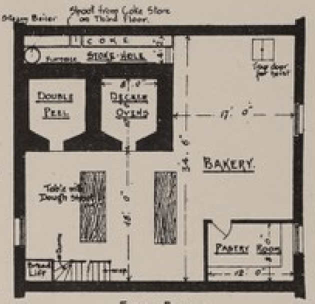
- A. Blended flour Bin.
- B. Blending Machine.
- C. Doughing Machine.
- D. Sifting Machine.
- E. Water Tank.
- F. Hoist.
- G. Attemperating Tank.
- H. Whisking Machine.
- J. Elevator.

PLAN OF
A
BAKER'S SHOP.
with
OVERHEAD
BAKERY.



Lavatory, Cloak Room &c. shown by dotted lines

GROUND FLOOR.

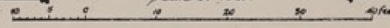


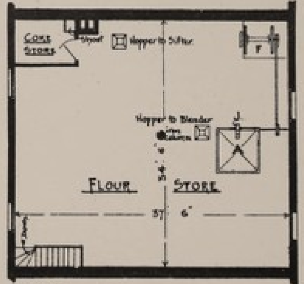
FIRST FLOOR.

SECOND FLOOR.

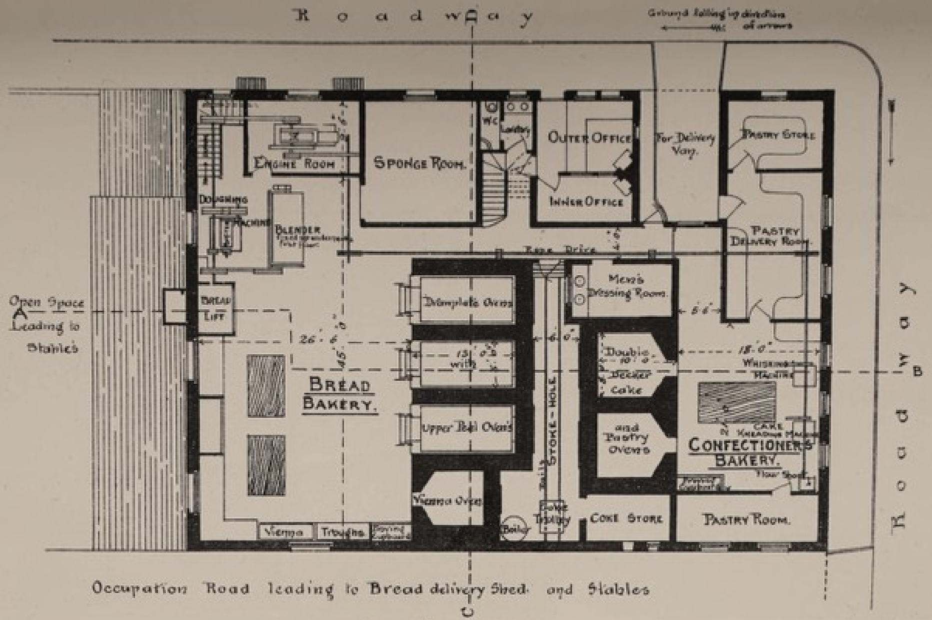
Designed by
William Jago,
BAKING ENGINEER,
LONDON & BRIGHTON.

Scale of Feet.

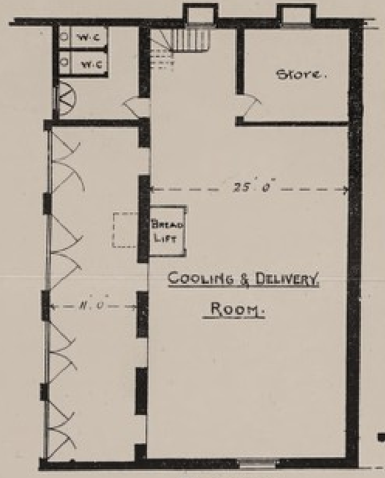




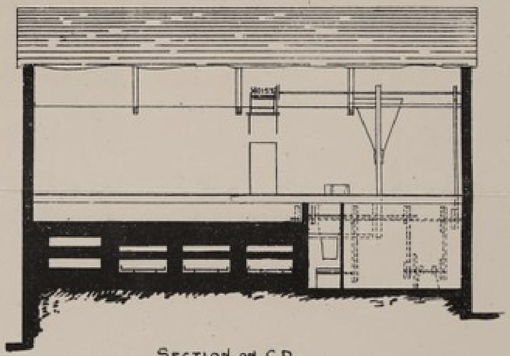
THIRD FLOOR.



GROUND FLOOR.



BASEMENT



SECTION ON C.D.

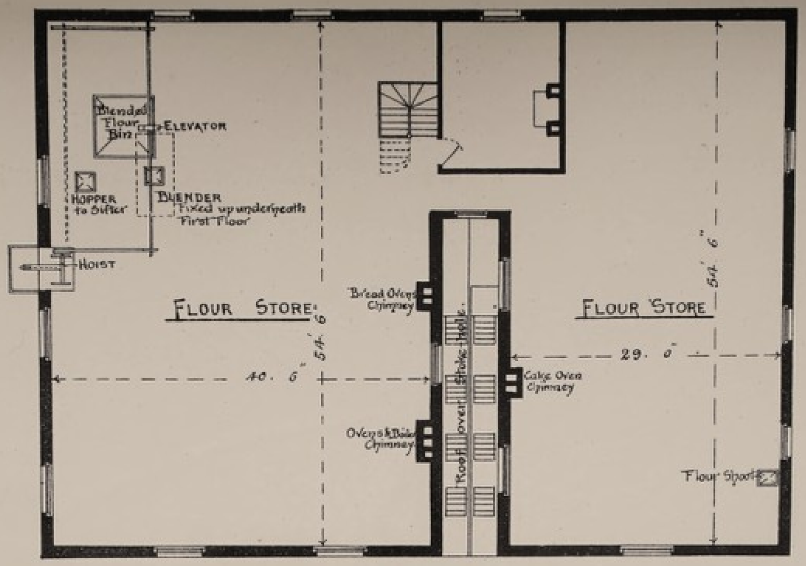
WHOLESALE BREAD and CAKE FACTORY.

Designed by William Jago.

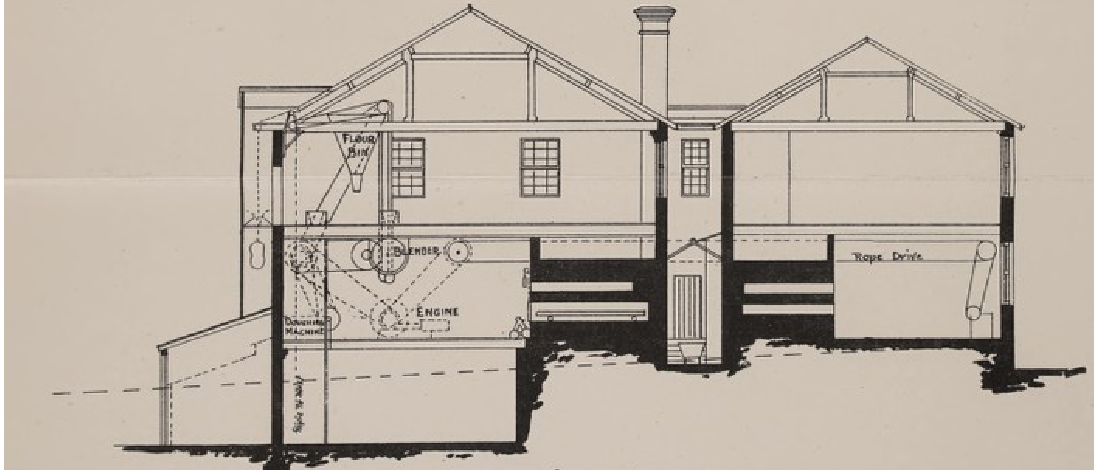
Scale of feet.

feet 10 5 0 10 20 30 40 50 feet.

PLATE X.



FIRST FLOOR PLAN.



SECTION on A.B.

WHOLESALE BREAD and CAKE FACTORY.

Designed by William Jago.

the evening when the shop business is over. The flour would be backed against the side entrance and drawn up at once to the third floor by the sack hoist some three or four feet in from the door. The hoist itself is fixed overhead in the flour-room, and draws the sacks up through trap doors on each landing; in this way flour or other material may readily be brought from a van at the side entrance to any desired floor. Flour-blending machinery will be fixed underneath the third floor, and arranged so as to be worked from the flour store. Sacks of flour in any desired proportion are emptied through the "hopper to blender," and the mixture drawn up once more to the "blended flour bin" fixed overhead on the third floor; from this it is drawn off as required. The hopper, through which the flour passes to the sifter, is also on this floor, the sifter itself being bolted up underneath the joints, as shown on the section, through first floor. From the sifter the flour passes into the doughing machine. The sifted flour, together with water from the attemperating tank and yeast or ferment, as the case may be, is converted by means of the kneading machine into dough. For ferments and sponges a room has been provided in one corner of the machinery room, where they may be kept at an equable temperature and free from draughts. The size of this room may, of course, be varied to suit particular requirements. A whisking machine is shown fixed here for sponge-cake making, &c. Between the doughing machine and the trap door a line of light machines for various bakehouse purposes could readily be placed; or with ovens, as shown in the drawing, such machines could easily be erected on the floor below. The doughs are allowed, after being made, to stay in this room until ready, and are then cut out of the troughs and discharged through a hopper on to the moulding table on the floor beneath. The machinery as shown on this floor is driven by a gas engine fixed in the one corner, from which runs a line of shafting along the partition wall driving most of the various machines from this floor, except the hoist and flour elevator, which are overhead.

Dropping in the next place to the first floor, there are the moulding tables and also ovens. Although, as is well known, the author is an advocate of draw-plate ovens, he has here shown a series of ovens fitted for use with the peel, to give them a turn, so to speak. Of course draw-plate ovens could be arranged for instead, if necessary. The ovens shown are double-deckers, fired from the back. If any very large trade were being done in cakes, it would be well to make the ovens treble instead of double deckers, using the top ovens as solid low-temperature ovens. The stokehole of these ovens runs over the side passage on to the floor below. Two ovens are shown, but space is allowed for putting a third oven beside the others at any future time if wished. The fuel for these ovens is coke, and this, on being brought as usual to the bakery in sacks, is hoisted direct to the third floor and taken into the coke store-room. From here each day sufficient for the twenty-four hours consumption is emptied down the coke shoot into the stokehole behind the ovens. The ashes are completely raked out once a day from the ashpits and put into a portable sanitary closed bin. This is sent down bodily by the sack hoist, and handed over to the dustman on the occasion of his daily visit. At the far end of the stokehole is fixed a small vertical boiler for the production of steam for general purposes. The flue from these ovens is carried into a chimney stack built against the partition wall. The ovens themselves are supported at the back by a strong wall between the shop and side passage; the front is carried on girders supported on the main back outside wall of the building, and on pillars arranged in the corners of the office. For pastry-making purposes a small room is shown in the corner furthest from the ovens. The baked bread is packed in portable racks and taken downstairs by means of a simple gravity lift into the cooling and delivery room below.

From the cooling-room one would naturally like to be able to load barrows and carts at the back, but this, according to the conditions, is impossible. Arrangements have therefore been made for delivering through the side door. A delivery clerk checks the bread as it goes out. It is assumed that the passage is too narrow for bread barrows to pass each other in it, but the bread may be loaded on running waggons just two feet in width, and these could pass each other in the passage. This passage could be used at night for the purpose of keeping barrows, as some six or eight could readily be stowed away in it. A door leads direct from the cooling-room into the shop. Through this all shop goods would be brought, and, if found absolutely necessary, bread barrows could also be filled this way in the early hours of the morning, in addition to the use of the side entrance. On this floor is placed the office, which, as situated, controls the shop, the side passage, cooling-room, and delivery clerk's desk. From the cooling-room, through a door leading into the backyard, are reached the workmen's lavatory and w.c. With sufficient space at the rear this accommodation might well be enlarged.

Such, in brief, is an outlined idea of a bakery and shop fitted for a large and high-class family business in a first-rate locality. The exigencies and nature of the business, together with the actual size and proportions of the premises, must all affect the precise nature of arrangements in each individual case. Such plans as are here given can only touch on the general principles involved in the arrangements, which in themselves lend themselves readily to considerable modification.

521. Wholesale Bread and Cake Factory.—The drawings on Plates IX. and X. are those of a wholesale bread and cake factory. The designs were prepared to meet certain requirements arising out of the nature of the site. The assumption is that the building is to be placed on a corner plot, and on a sloping piece of ground. Looking at the ground plan, the top right-hand corner, where the room marked pastry stores is situated, is the highest part of the ground. The road slopes downward in both directions from this point to the other corners, the opposite diagonal corner being on the lowest point of the ground. It may be assumed that the north and south of the building lie in the same direction as an ordinary map; that is, that the north is on the top. The result of the general arrangement is that an extra floor is gained on the western side of the building. Consequently the occupation or private road leading along the south reaches the van sheds, stabling, &c., which with the bread-delivering room are a storey below the ground floor proper of the bakery, and yet are level with the stable-yard and road leading thereto.

The next point arrived at was that both bread and cake bakeries should be within the same building, each fairly accessible from the offices, and yet as distinct as possible from each other. To meet this want the bread bakery was placed in the western portion of the building, and the cake and confectionery departments in the eastern wing. Bearing these general requirements in mind, the ovens were made the starting point of the design. It was of course an essential in a modern bakery worthy of the name that all fires, and their concomitant dust and ashes, should be kept without the bakery proper. The ovens were accordingly arranged to fire at the back, and the two sets of ovens for bread and cakes respectively open at the back into the same stokehole. Close to the south end of the firing space we have a coke store-room, into which coke is easily shot from the private road. To take the coke to the ovens a small truck is provided, running on rails fixed to the centre of the stokehole. This arrangement enables the stoker to fill his truck at the one end and feed each oven furnace in succession with the minimum of trouble in conveying his fuel. Opposite the coke store on the east of the "furnace lane" is arranged the Vienna oven, and this being less in depth than the other bread ovens, but fixed flush with them in front, leaves a recess in the stokehole. This is utilised as a convenient situation for a small vertical boiler to supply steam for proving cupboards, Vienna oven, and other general bakehouse requirements. The stokehole is covered with a sloping glass roof, to which ventilating lights are attached. Entrance to this department is gained by a door at its northern end, which is readily accessible from either bread or cake bakery.

The actual selection of ovens will depend on the taste and judgment of the baker, but in the plans it is assumed that the bread bakery is supplied with decker ovens, having the lower oven arranged with a drawplate, and the upper one fitted for use with a peel. The confectioner's bakery is shown with double-decker peel ovens. This part of the design could easily be modified so as to fit the bakery throughout with either peel or drawplate ovens, according to the wishes of the owner.

It may now be as well to study separately, and a little more closely, the arrangements of both bread and cake bakeries. For the bread bakery we cannot do better than follow the flour from its entering the building to leaving it as a finished loaf. The flour will enter the premises through the occupation road, and the waggons will back underneath the hoist shown on the west wall of the building. Here is a covered shed by which the flour is protected while unloading. The hoist itself is worked from the upper floor, and is shown on a small platform fixed over the door—this is best seen in the sectional elevation. From the hoist the running chain runs over a pulley fixed in the top of the "lucombe" or covered shaft, through which the flour is drawn from the waggon beneath. The sacks are hoisted through a pair of trap-doors and then stacked away in the flour store. It will be seen that far more room than usual is provided for flour storage; this is done with the conviction that large users of flour will find it preferable to hold and buy flour in correspondingly large parcels rather than buy forward, allowing the miller or flour factor to send in instalments. With large purchases forward, and a rising market, it is at times difficult to insure the later deliveries being absolutely up to the mark. For the ordinary run of business fairly large stocks of flour more than pay for warehousing room and the interest on capital lying temporarily idle in flour stock. This flour store will be of course made sufficiently strong to carry the weight required on it.

The flour being in the place, the next step is to mix or blend such varieties as are required for the various purposes of the bakery. For this purpose a blending plant is shown, consisting of a blending machine bolted underneath the first floor, and arranged with a belt and cup conveyor, by which the flour is elevated to a storage bin fixed overhead in the flour store-room. From this it is weighed off into batch quantities, and these are stored until required. The whole of the blending arrangements are thus effected on the one floor, and so come easily in sight of the man in charge. This floor has also a room shown in it which may be used as a flour-testing room, retiring room, or other desired purpose. Additional rooms could easily be arranged in this floor, if desired, along the north wall of the building. In passing, it may be suggested that in constructing the floor itself of this storey, the part over the ovens at least should be formed of fire-proof material or cement concrete. Whether of stone or concrete or wood, flour is all the better for being raised a little from the floor itself, so as to permit the passage underneath of a current of air.

Through a hopper in the first floor the flour passes into a sifter arranged underneath the boarding, and from thence into the doughing machine placed underneath. This will be a convenient place to speak of the arrangements for supply of power. For this purpose a gas engine is provided, which is erected in an engine-room on the north side of the bakery. The main weight of the engine is carried by the specially thickened wall of the store room beneath, which is so designed as to come under the driving shaft of the engine. The main belt is carried up to the overhead shafting close to the building's north wall, and so is kept quite out of the way.

For the sponges, when made, a room is provided adjoining the engine-room, and marked on the plan as "sponge room." In all very large bakeries there is a difficulty in maintaining an equable temperature, and especially in winter time there is danger of sponges getting chilled by a rapid fall in temperature, or by what amounts to the same thing, a draught through the building. When ready the sponges are once more returned to the machine, and with the addition of more flour and water are converted into dough. The dough at the proper time is thrown out and got ready for the oven, baked, and then removed by means of the "bread-lift" to the bread-cooling room below. The bread-lift involves rather a contradiction in terms, because the bread is all dropped through it, and not lifted. Bread is best removed to this by means of proper racks just fitting the lift, which should be so counterpoised as to rise of itself when there is only an empty rack in it, and to descend of its own accord when it contains a rack filled with bread. Arranged thus the lift requires no power to drive it.

From the cooling-room the bread is checked out into delivery vans, which are backed against the various doors opening into the covered shed. A store-room is provided on the basement floor; it is as far away as possible from the heat of the ovens, and may be used for keeping yeast, and also any large stock of butter or other fats for confectionery and cake purposes. Opening out from the basement are urinals and closets for the workmen's use. These are kept well separate from the bakehouse, and, while under shelter, abundant ventilation is provided through the roof. The men's lavatories are quite distinct, and are arranged in the men's dressing-room alongside of the cake ovens. This room is ventilated by windows opening into the air space along the stokehole roof.

Attention must next be directed to the cake bakery. The ovens shown are double-decker peel ovens; one of these might advantageously be a three-decker, thus providing an additional solid low temperature oven for very rich cakes, while over the other a drying oven might be fixed. Proving cupboards, &c., and other accessories of the confectioner's art, will naturally find a place here. Provision is made by means of a light run of shafting for the driving of cake-mixing and other confectioner's machinery. It was a somewhat awkward point to provide for the power necessary for this shafting, but this object is effected by means of a light cotton rope driven from the engine in the bread bakery. The driving rope runs over supporting pulleys placed at intervals of its length. A pastry-room is arranged at the south-east corner of the building. The flour required for cake-making is shot down through a hopper from the floor above.

The offices are situated in the centre of the north side of the factory, and command both bread and cake bakeries. Adjoining the office is a covered recess for loading cake vans. The north-east corner has a room which is intended as a pastry store-room. From the bakery all cakes, &c., are delivered into this room, from which they are again checked out into the vans. Eggs and such other stores as are convenient may be unloaded in this same van recess, and served out as wanted from the room marked "pastry store."

Heavy cake stores, as sugar, could be kept above on the upper floor, and delivered into the bakery through a trap-hatch. If desired, a cake-mixing room, with its necessary machinery, might easily be built in the flour store above, directly over the cake bakery. Mixed cake doughs could then be made upstairs, and sent below to bake. Either a lift to take a cake rack could be provided between the two floors, or the doughs lowered down through the trap.

The preceding may be taken as examples of designs in which it is endeavoured to carry into practice the principles laid down in the earlier part of this chapter. Their adaptation to individual requirements is simply a matter of ordinary professional routine.

CHAPTER XIX.

THE MACHINE BAKERY AND ITS MANAGEMENT.

522. Sanitary Considerations.—The operations of kneading and working dough involve severe manual labour in a heated atmosphere: it is impossible to conduct these processes without more or less contamination of the bread with emanations from the skin of the workers. In the best conducted bakeries this evil is reduced to a minimum by insistence on scrupulous cleanliness on the part of the workmen; still, even the utmost care cannot entirely abolish the evil. For the strongest of sanitary reasons, both on behalf of the public and of the workmen, operations on dough demand mechanical appliances, rather than manual labour. So forcible are these reasons, that the expense of kneading machinery and its convenience, compared with ordinary manual processes, become merely secondary considerations.

523. Bakehouse Machinery.—In describing this, some classification will be necessary; it is therefore proposed to commence with an account of the various sources of motive power, such as steam, gas, and other engines. Following on this, in natural sequence the means of distributing power, embodied under the general term of "gearing," engages attention. It is then proposed to take the flour as it enters the bakery and follow its history through each mechanical appliance employed, discussing and describing each in detail. In this latter connexion, hoists, blending, sifting, kneading, and other machinery, as well as ovens, will be included.

524. Motive Power.—One of the great objects of machinery being to save workmen from severe manual labour, there are comparatively few machines which are profitably worked by hand, a man rightly being by far the most expensive form of mere force-exerting capacity. For flour-sifting purposes machines may be obtained which work well by hand power, the reason being that comparatively little force is requisite to drive these machines. Various kneading machines are also supplied which may be driven by hand; but it is more than doubtful whether any hand machine can make a mass of dough with the total expenditure of less force, measured in foot-lbs., than can the baker working direct on the dough. The worker's task may be lightened by slowing down speed by means of gearing, but in such cases the compensation is made by the greater demands on time. Nevertheless, such machines, assuming them to be properly designed and made, have all the advantages of those driven by power in the way of enhanced cleanliness.

In cases where steam power is available, that of course forms a useful and convenient mode of driving. Thus, if the bakery adjoins some other building, such as a flour mill, it is economical and convenient (from the baker's point of view) to take his power from a steam-engine there running, *provided it is always available when he wants it.* Or if he can similarly gain access to a boiler and draw off high-pressure steam whenever required, it will be well to fix a small steam-engine and run it as a source of power. These conditions are, however, rare; and certainly the laying down of a steam-plant, consisting of boiler and engine, is bad economy for the ordinary baker's requirements. The keeping up a supply of steam requires considerable time and attention, and also skill and experience in handling boilers; while neglect may cause serious damage, or even, in extreme cases, actual explosion. For these reasons steam engines are comparatively little employed in bakeries.

What, then, is wanted is a source of power that can be started at a minute or two's notice by a man not necessarily trained as an engine driver, and which can be as quickly stopped, the expense of the source of power being arrested simultaneously. Further, the motor should not be, even in case of neglect, of a nature such as would lead it to be a source of danger to the employees or the building. These requirements are met most fully by both gas and oil engines, detailed descriptions of which follow.

525. Gas Engines.—It is of course a well-known fact that appropriate mixtures of gas and air, on being lighted, explode with considerable violence, and generate in so doing a large amount of energy. For some time it has been one of the aims of engineers to use the energy thus developed as a direct source of power in a suitable motor. The successful accomplishment of this problem is witnessed to by the number of gas engines at present on the market. Among these the writer has selected for purposes of illustration and description the engines of the "Trusty" Engine Company, manufactured by Messrs. Weyman and Hitchcock, Limited, of Cheltenham. A special reason for so doing is that Mr. F. D. George, baker and confectioner, of Cheltenham, is one of the directors, and in that capacity has devoted considerable attention to the design of the engine in so far as it more particularly affects bakers. For example, he has insisted on the utmost simplicity, and especially on attention in construction to the provision of means for preventing injury to working parts of the engine by access of flour dust conveyed by the atmosphere. It is certainly, in simplicity of construction and excellence of workmanship and design, admirably adapted for use in bakeries.

A small figure is here given of what may be taken as the typical form of these engines, while further details may be gathered from a study of Plate XI., in which an oil engine is illustrated. As the two are in many respects identical, the one plate and set of lettering serves equally for both. It will be gathered from the figure that the main shaft, fly-wheel, crank and connecting-rod, are similar in general arrangement to those of a steam engine. Space is economised by the

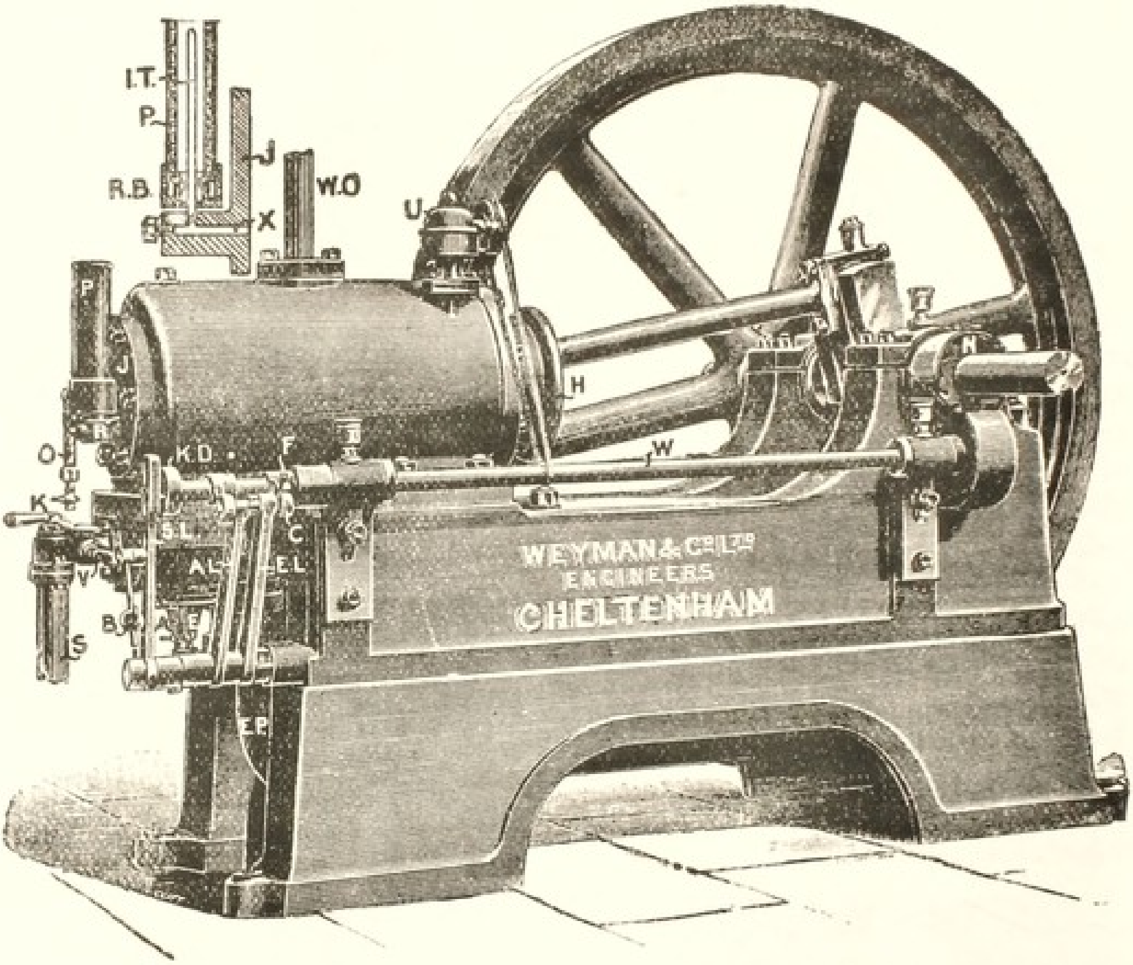


FIG. 45.—"TRUSTY" GAS ENGINE, VALVE GEAR SIDE.

fact that a trunk piston is fitted within the cylinder, the connecting-rod end being caused to work on a pin within this hollow trunk. This arrangement is rendered possible by the fact that a gas engine of this kind is single-acting; that is, the motive force is only applied on the one side of the piston, in this case the bottom of the trunk. Valves are provided by which regulated quantities of air and of gas are admitted within the cylinder. The air and gas are drawn in as the piston makes its outward stroke, and are compressed during the return of the piston. This compression serves first the useful purpose of economising gas, as a mixture too weak to explode at ordinary pressures does so on being compressed. The act of compression helps also to "cushion" the piston, and thus prevent undue shock to the engine. When the piston is just at the bottom of the stroke the gaseous mixture explodes, and so forces the piston out of the cylinder. The outward stroke being made, the fly-wheel brings the piston back again, and the exhaust valve is opened during this return stroke to permit the contents of the cylinder, consisting of the exploded gases, to escape through the exhaust pipe into the atmosphere. The engine makes a half revolution after the completion of the return stroke before any further gas is taken in, and there is then a fresh explosion, and a repetition of the cycle of events. This engine is said to be of the four-cycle type, because there is only the one gas impulse during four strokes, *i.e.*, two outward and two return strokes.

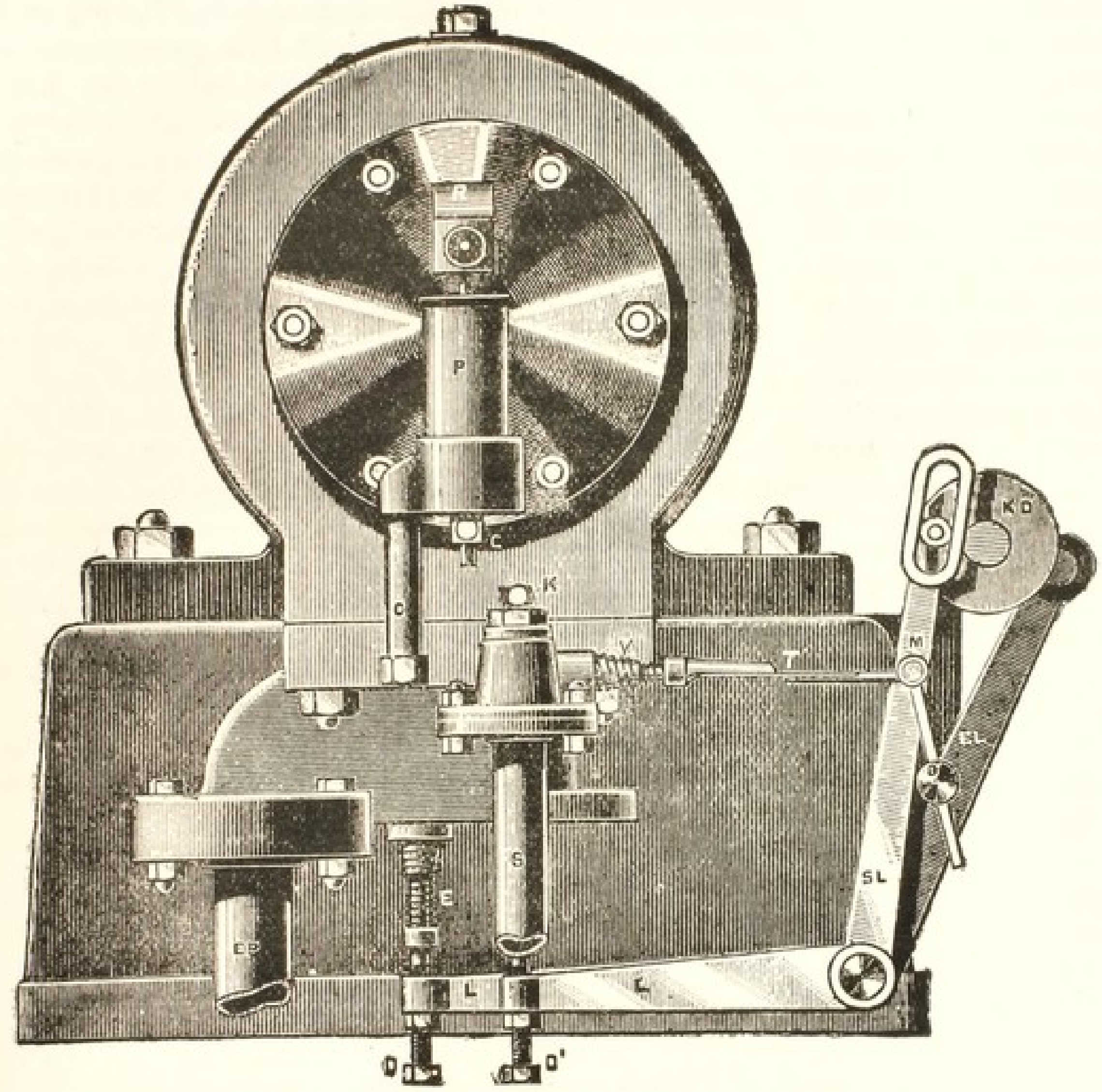


FIG. 46.—"TRUSTY" GAS ENGINE, END VIEW.

Having explained the principle on which the engine works, a more detailed account of its working parts may now be given. Figure 46, which shows the end view, and also Figure 45, as well as Plate XI., are all lettered alike, so that the same description applies. On the main shaft at N is fixed worm gearing, by means of which the cam shaft, W, is actuated. This carries first, nearest the worm gearing, a cam, by which the roller, C, of the exhaust valve lever, E L, is moved. Another cam works the air valve lever, A L. The two valves are best seen on the end view of the engine, and are marked exhaust valve, E, and air valve, A. A crank disc, K D, is mounted on the end of the shaft, and by means of this is actuated the gas lever, S L. To this lever is attached a trip piece, T, which operates against the stem of the valve, V, by which the admission of the supply of gas to the cylinder through the gas-pipe, S, is controlled. To provide for the ignition of the explosive mixture within the cylinder, an exceedingly simple form of apparatus is provided. At the back of the cylinder, at P, is fixed a chimney or jacket, which surrounds the ignition tube, I T, both of which are shown separately in section to the left of Figure 45. A hole, X, passes through the cylinder cover in the projection, R, and communicates direct with the interior of the cylinder. The chimney, P, lifts off, and the ignition tube is seen screwed into the end of this passage, X: a ring burner, R B, surrounds and heats the ignition tube, while the heat is retained by the asbestos-lined chimney. When, therefore, a charge of mixed air and gas is compressed in the cylinder, a portion is forced into this red-hot ignition tube, and then takes fire. The combustion passes through the passage, X, and communicates itself to the main body of gas in the cylinder. A governor, B, is carried on the lever, S L, and this at M is attached to the hit-and-miss arrangement at T, by which the gas valve, V, is actuated. When the engine is running at the correct speed, the governor causes the trip pieces at T to hit each other, and so admit gas as often as is required. Should the load be thrown off, the engine tends to quicken her speed, and at once the governor causes at T the pieces to miss each other, and so a stroke is made without any gas being admitted. If, on the other hand, an extra load tends to slow down the engine, gas is admitted at each outward stroke until sufficient power is being generated to again carry the engine forward at her proper speed. These adjustments take place purely automatically, and practically without any perceptible alteration of the speed of the engine. From running idle up to the maximum load the engine is capable of working with, the governor arranges the number of admissions of gas so as to maintain an uniform and definite speed.

Before attempting to use a gas engine, read carefully through the printed card of directions always supplied with it. First of all, every part of the engine should be thoroughly clean, and must be kept in that condition. See that all working parts are properly oiled, and that lubricators are in good order and choked nowhere. Lift off the lid of the little dome-covered vessel at U and see that it is full of oil: in this there is a little feeding wire, worked by the belt from the cam shaft, by which the piston is continually fed with oil. See that this works all right. At times the driving belt may get slack and stick; take care that this does not occur, as very little running without oil will do most serious damage to the piston, which works inside the cylinder-liner, H. Turn on the gas through the pipe, O, and light the ring-burner: this is a bunsen, and must burn with a non-luminous blue flame, which must be regulated so as not to appear above the top of the chimney. Take care that the bunsen does not light back; if it should do so, turn the gas out, wait a few seconds, and re-light. It is well to turn the gas full on before placing the light to the burner. In from three to five minutes the ignition tube should be at a bright red heat. See that the main driving belt of the engine is on the loose pulley, and before turning on the gas give the fly-wheel a pull round to see that everything is clear. It doing this it will be noticed that, as the piston is nearly finishing its back stroke, a gradually increasing resistance is felt. This is due to the compression of air within the cylinder, and in order to relieve it, take out the milled-head pin, F, and move the roller of the exhaust lever, E L, to the left, and replace the pin to keep it in its place. In this way part of the compression is relieved by keeping the exhaust valve partially open. Turn on the gas to the engine by opening the stop-cock, K, and pull round the fly-wheel, standing on the outside for that purpose. The revolution of the engine causes the piston to draw into the cylinder the requisite supplies of air and gas, through the valves opened at the right time for that purpose, and the return of the piston compresses the explosive mixture, forcing it partly up into the ignition tube, where, as explained, it takes fire, and thus ignites the charge within the cylinder. The engine then gets its first impulse, and at once starts working: as soon as it has got up its speed, return the exhaust lever roller to its proper place to the right, and fix it by means of the pin. To stop the engine, first throw the driving belt on to the loose pulley, then move the exhaust lever roller over to the starting position, left-hand side, and then turn off the gas at the stop cock, K. Next turn out the gas in the ignition chimney. When the engine has come to a standstill, turn it round until the piston is at the bottom of its stroke.

The ignition tube of these engines is now made of a special alloy, and should stand from six to twelve months' constant work before requiring to be replaced. The directions for maintaining the engine in working order, as given on the engine room card, need not be inserted here. Among accessories to a gas-engine there are, first, an india-rubber gas bag, which is fixed between the engine and the gas-main. The object of this is to provide a reservoir of gas so as to prevent the drawing in of gas by the engine from causing a fluctuation in the general gas supply. The exhaust pipe, E P, conveys the spent gases away to the outside of the building, or other convenient place for their discharge. Within the foundation plate of the engine is fixed a silencing box, which almost completely muffles the sound of the inrush of air. In cases where almost absolute silence is necessary, as, for example, when gas engines are fixed in hospitals, an additional silencer may be arranged for the exhaust. This may consist of a cylinder of cast-iron, about two feet in length by a foot diameter. The cylinder is fixed vertically, and the exhaust pipe led in through the centre of the bottom. About three inches up a grid is arranged, and above this the box is filled, to within two inches from the top, with clean pebbles from 1½ to 2 inches in diameter. The exit pipe is bolted or screwed on to the cylinder cover, and carried, if necessary, right above the eaves of the roof. Or, if wished, a very effective mechanical silencer can be supplied with the engine. Whenever a long exhaust pipe and silencer is attached to an engine, there is always a danger of their getting full of water, as a condensation product of the spent gases from the cylinder. A drain cock should therefore be inserted at the lowest point, and from time to time the condensed water drawn off. In order to keep the cylinder cool, it is water jacketed, and this jacket connected by circulating pipes to a tank of sufficient size. The tank must be fixed at as high a level as possible, and the water outlet pipe from the engine, W O, must slope upwards throughout its whole length. The return pipe fixed under the cylinder is not visible in either of the figures. When other arrangements permit, it is a good plan to have the water tank on a floor above; good circulation is then easily obtained. The cylinder jacket should not get hotter than can be just borne by the hand. The outlet pipe should be much warmer than the inlet one: if this is not so, the circulation is obstructed. This may, perhaps, be due to the tank not being full, and so the upper end of the outlet pipe from the engine above the level of the water: in this case immediately fill up the tank. Properly speaking, the tank should be provided with a ball-cock by which it is kept permanently filled. A cause of stoppage peculiar to bakehouses is sometimes found in the fact that flour dust settling in the water induces a fungoid growth over its surface: this spreads down and stops up the end of the circulating pipe. The remedy of course is to thoroughly clean it. There should be a full way stop-cock in the lower circulation or inlet pipe, by which the water of the tank can be turned off the engine in case it becomes necessary to discerinect the cylinder for any repairs.

At times an engine refuses to start, a fact which may be due to various causes. Should there be any such difficulty, see first that the gas has been turned on everywhere, and that the burner of the ignition chimney is alight, and the ignition tube at a bright red heat: there may be some air in the gas-pipes, a few turns of the engine removes this, and it should then start working without difficulty. See that the governor is not stuck anywhere, and that it opens the gas valve each time. If none of these are the cause of the trouble, give each of the valves a twist round on its seat to see that there is no dirt or grit underneath. See that the spiral springs attached to the valves bring them back on their seats after being lifted: they occasionally may stick back and leave the pipe open. These points having been seen to, turn the engine, and notice whether or not any explosion occurs: the absence of such may be due to the gas and air not being admitted in proper proportions: open or shut, more or less, the main gas cock, K, until this defect is got over. Practically, the only other cause of non-explosion is the want of compression in the cylinder by which the gases are forced into the ignition tube. Place the roller on the exhaust lever into the working position (to the right), and pull the engine round; notice whether, as the bottom of the stroke is reached, the resistance of the compressed gases is normal. If not, the exhaust valve is leaking, and requires cleaning or regrinding.

Prior, however, to an engine getting in a condition in which it will not start working, there is a stage in which it works very badly. Instead of, with an average load, taking gas once in from two to four revolutions, gas is being always taken, as each stroke the governor causes the gas valve to be opened. This may be due to excess, or the reverse, of gas: make a careful trial, giving a little more or a little gas, until, with the constant load, the minimum number of explosions are caused. If this does not remedy the matter, listen to the engine carefully and note whether the explosion is clear and sharp: if followed by a peculiar whistling noise, the gas is escaping through a leaky valve, that at fault being usually the exhaust. It should be taken out and cleaned and reground.

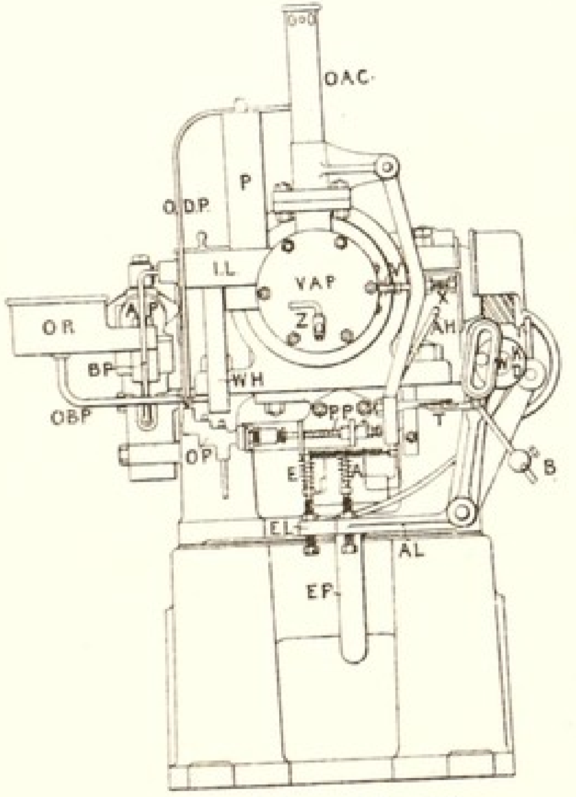
Such are a few of the points to be remembered in connexion with the working of gas engines, attention to which should be of considerable service to bakers who are in charge of same.

There are many localities where coal gas is unobtainable, and

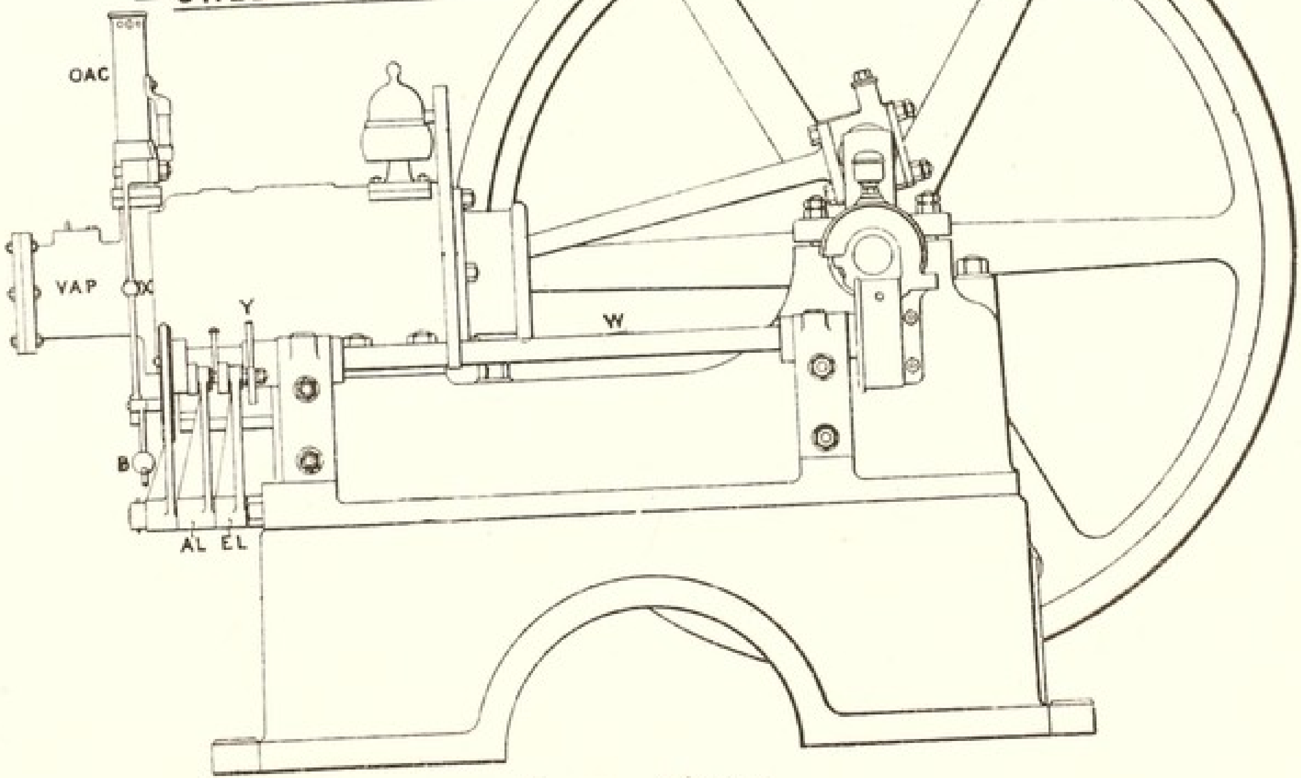
TRUSTY OIL ENGINE.

WEYMAN & Cº LTD ENGINEERS.

CHELTENHAM.



END VIEW.



SIDE VIEW.

A.	AIR VALVE.
AH.	AIR HANDLE.
AL.	AIR LEVER.
AP.	AIR PUMP.
B.	COVENOR & LEVER.
BP.	BLAST PIPE.
E.	EXHAUST VALVE.
EL.	EXHAUST LEVER.
EP.	AIR PIPE.
IL.	ICNITION LAMP.
OP.	OIL PUMP.
OR.	OIL RESERVOIR.
OAC.	OIL & AIR CHIMNEY.
OBP.	OIL PIPE.
ODP.	OIL DELIVERY PIPE.
P.	ICNITION CHIMNEY.
PP.	PUMP PLUNCER.
T.	HIT & MISS CEAR.
X.	ADJUSTING SCREW.
V.	VAPOR VALVE.
VAP.	VAPORISER.
W.	CAM SHAFT.
WH.	WICK HOLDER.
Y.	STOPPINC HANDLE.
Z.	DRAW OFF COCK.

consequently gas engines are an impossibility unless gas from some other source be obtained. To meet this want the "Dowson Gas-Making Apparatus" has been designed. The plant is essentially one for the production of carbon monoxide and hydrogen by forcing steam through bright red-hot coke. The resultant mixture of gases, though not adapted for illuminating purposes, serves well for gas engine fuel. The gas may be used for running the Trusty Gas Engine in just the same manner as coal-gas.

526. Oil Engines.—For bakers' purposes, where gas cannot be obtained, the petroleum or "oil"-engine is an admirable substitute. At a moderate temperature petroleum boils and produces an inflammable vapour which may be used, in precisely the same way as gas, as the motive power of an engine. Messrs. Weyman and Hitchcock, Limited, have devised a remarkably simple and efficient oil engine, which they name the "Trusty," and which is illustrated in Figure 47, and also in Plate XI.˙ The lettering of the plate is for the same parts the same as that in Figures 45 and 46.

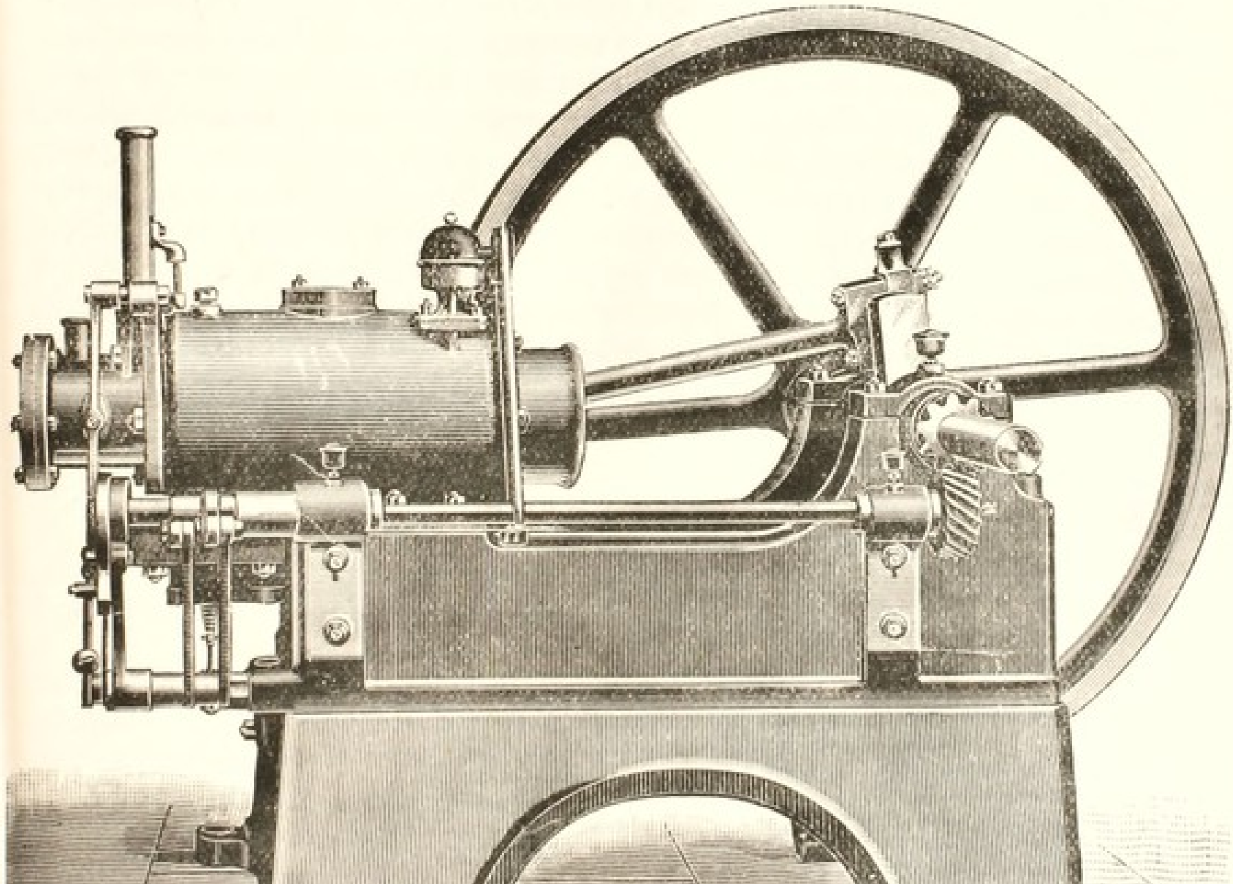


FIG. 47.—"TRUSTY" OIL ENGINE.

Having to work with petroleum vapour instead of gas, the first and essential part of the oil engine is the vapouriser. This is a simple jacket, VAP, attached to the cylinder cover of the engine in which the oil is first heated. The vapouriser of the oil engine has to perform practically all the functions of the gas works, the raw material being oil instead of coal. The petroleum having once been converted into vapour, the working of the oil engine is simply that of the gas engine. So absolutely is this the case that the vapouriser of the "Trusty" oil engine may be detached, and gas connected on to the cylinder, when the working may be conducted as usual with the gas engine. Or, conversely, a gas engine may have a vapouriser, and other necessary petroleum fittings attached to it, and becomes an oil engine.

Explaining first in detail the oil treating parts, there is an oil reservoir, O R, in which a supply of oil is placed. From this, by means of the pump, O P. oil is drawn over into the vapouriser, V A P. When the engine is running, the heat of combustion within the cylinder suffices to maintain the vapouriser at a sufficiently high temperature to vapourise the oil as required. Starting with the engine cold, a powerful petroleum lamp is provided by which the initial heat of the vapouriser is obtained, this lamp being placed for the purpose beneath the vapouriser. It is of importance that the vapouriser be, while working, at the right temperature, for if too cold, sufficient vapour is not generated, while, when too hot, the oil suffers decomposition, and is split up into fixed gases, which, upon combustion within the cylinder, throw down tarry products. The pump, O P, is worked by the same lever as that which actuates the gas valve, and is so adjusted that each stroke of the pump raises sufficient oil for one explosion within the cylinder. The result is that the governor not only regulates the number of explosions, but also simultaneously governs the quantity of oil supplied to the engine. By means of an over-flow pipe, any oil which escapes volatilisation returns to the oil reservoir. The ignition chimney, P, is fixed to the left of the vapouriser, and is heated by the lamp, I L, of which W H is the wick-holder. Provision being thus made for the supply of oil to heat the ignition tube, and of oil-gas through valve V to the cylinder, the engine works in the same manner as has previously been described for the gas engine.

Starting with the engine cold, see that all is perfectly clean, and working parts well oiled, as for gas engine, also that the water supply to the cylinder jacket is right. Twist the valves to see that they work freely, and that they are properly on their seats. Move each of the valve levers, and notice particularly that the valves do not stick, but are promptly brought back by means of their springs. Turn the fly-wheel round, and see if the compression is all right.

The Starting Lamp.—This is a pressure lamp, in which a fine jet of petroleum is forced by air pressure into the flame of a burning wick. Partly fill the lamp, and pour also a little oil direct on the wick: light same, and after about a minute get up pressure in the lamp reservoir by means of the pump attached for that purpose, turning the cock off while so doing. Then slowly open this cock until the flame burns steadily and regularly. This lamp is then placed under the small tube beneath the vapouriser for about ten minutes, in which time the vapouriser should have got sufficiently hot. About three minutes before the engine is required to start, light the ignition lamp, I L.

Starting.—Pump a small quantity of oil into the vapouriser by means of the handle on the oil pump, O P. Shut, or nearly shut, the air supply handle, A H (when shut, this handle is upright). Shift over the roller on the exhaust lever, E L, as in the gas engine, holding it in the position to the left by the milled-head pin, F. Lay hold of the fly-wheel, and give the engine one or two sharp turns, when it should take an explosion and start: return the exhaust lever roller to its working position. The engine being started, the air pump, A P, will cause a blast of air across the flame opposite the hole in the ignition chimney, P. This blast can be regulated by the tap on the air pipe, and will in two or three minutes heat the ignition tube to a red heat. The starting lamp is then taken away and extinguished.

A very important point in starting the engine is the adjustment of the air supply by means of handle, A H, which opens and shuts the throttle valve in the air pipe. At the start very little air is required, while as the vapouriser gets to the right heat, the amount should be increased. Sometimes a little more oil being pumped up will help the starting; but, on the other hand, too much oil will prevent the engine going off. This is a matter easily learned by practice, but a very good guide to the condition of things within the cylinder is obtained by watching the exhaust. If clouds of vapour are issuing, there is too much oil or too little air, or the parts are not warm enough on starting. If the charges do not ignite, the cause is probably the same, or the ignition tube may not be hot enough. When the engine is working with a fair or heavy load, the exhaust should be invisible, or only just visible, with a blue tinge; with a small load, the exhaust is a bluish white; and with no load is almost always white. When the exhaust is black and sooty, the oil is being burnt in the cylinder, and although the engine may work in this condition, sooty deposits will take place, and the vapouriser will have to be taken off, and it and the valves and air passages thoroughly cleaned every two or three weeks. Oil burning in the cylinder is generally due to oil being supplied in excess with too little air.

Hints.—Should the vapouriser become too cold, sufficient vapour is not given off, and the engine takes its charge without any result, no combustion occurring, and no impulse being given to the piston. This sometimes tends to very loud explosions in the exhaust pipe. The unfired charge in the exhaust may be fired by the next exploded charge; but more frequently, if not enough vapour is made, the charge, being weak, is fired very late, and continues burning in the cylinder until the next charge is drawn in, when the incoming charge takes fire, and what is called a premature explosion takes place, a rumbling sound being heard in the air box or underneath the engine. When too much vapour is admitted, the charge has too little air to take fire, and so passes over unignited into the exhaust pipe, where it gets weakened down by additional air, and is ignited with loud explosion by the next charge fired. These minor inconveniences need only to be known to at once apply the remedy: it therefore well repays the user of each engine to study its behaviour, and in a short time learn to fully control the proportionate supplies of air and oil gas, so as to get perfectly smooth and regular working.

Occasionally the ignition tube of an engine is liable to become choked by carbon deposited within ; the remedy is to unscrew the tube and clean it out.

Whenever the cooling water in the cylinder jacket gets too hot, and the exhaust gases are drawn by any means back into the cylinder, or the vapouriser gets so hot as to form fixed gases, a sticky formation takes place on the cylinder walls, which gradually glues the piston to the cylinder. A little soap and water put on while the engine is working will remove this. It may be taken as a general rule that oil engines require the circulating water to be kept cooler than with gas engines, and therefore it becomes especially important to see that the circulating arrangements are perfect. There should be no sharp angles or descending pieces in the outflow pipe, and the cooling tank should be fixed as high as possible, preferably, as before suggested, on a floor above.

Efficiency.—Beaumont has made a series of important trials of the efficiency of this engine. He finds that it works with petroleum oils of practically any kind, such as are supplied for lamp and other purposes. The vapouriser gave no trouble, and no deposit whatever occurred within it ; there was perfect combustion within the cylinder, with no deposit there ; and a practically invisible exhaust when working with a full load, the exhaust gases being dry and free from oil in any form.

Tests were made both by the indicator and with a friction or brake dynamometer. The running of the engine was very regular, and when at half power the speed was within 0·4 per cent. that at full power. The oil used in the trials was Royal Daylight, costing in quantities about 4d. per gallon. As a result of the trials, it was ascertained that the cost of working a 6-horse power engine with oil at 4d. gallon, on full power load, is about one-third of a penny per indicated horse power per hour. Beaumont concludes his report by remarking that " these trials confirm others previously made, and show the great economy now achieved by a very simple form of oil engine, and one which is easily managed without a skilled attendant."

With the advent of such simple and satisfactory oil engines, the problem of the supply of power to bakeries in districts where there is no gas may be looked on as solved. This is particularly so with an engine like the Trusty, which can at any future time be converted into a gas engine in case of gas being available and preferred to oil.

527. Gearing.—Under this heading is included all appliances by which power is transmitted from the engine or other prime mover to the various machines. A moment's consideration shows that the power of the engine is engaged in causing rotary motion of the main shaft ; further, that all machines are actuated or driven by causing the shaft or spindle by which the power first enters the machine also to rotate. Consequently all gearing is practically composed of devices, having as their object the transmission of rotary motion.

Shafting.—The first requisite in gearing consists of the shaft, which must be of sufficient thickness, and turned absolutely circular, and of uniform diameter throughout its length. The shafting is supported on bearings or pedestals, which are carried in various ways according to the structure of the building. Provided the floor joists above are sufficiently strong and rigid, the pedestals may be fixed on "hangers" bolted up to the joists. These hangers may be single or J-shaped, or double. The former arrangement permits the shafting to be more easily removed; but the double hanger is by far the more rigid. If shafting be carried by hangers attached to wooden joists, especially in a new building, it becomes necessary to examine and readjust it after being up a few weeks, as with settlement of the walls there is almost sure to be a drop somewhere. At times shafting is instead carried on wall brackets, which possess the merit of greater rigidity; but in order to carry the shafting sufficiently far from the wall to admit of pulleys of the largest size requisite, it is necessary to use rather long brackets. Many of the machines in a bakery are comparatively slow running, heavy power-absorbing machines, which throw a great strain on the shafting at the points from which the power is taken. Such shafting should therefore be carried in long and very accurately turned bearings. It is not too much to recommend that for this purpose all bearings be made four times the length of the diameter of the shafting. Lateral motion of the shaft is prevented by having collars on the shaft, which are fixed against the faces of some of the bearings; preferably these collars are welded on the shaft itself, so as to be immovable. When made to slide along the shaft, they are fixed by means of set screws; there should be a well marked "countersink" in the shaft to take the end of the set screws, of which there should be two on each collar. Set screws with projecting heads are objectionable, as they are liable to catch in the clothing of a workman oiling the adjacent bearing. In every length of shafting there should, if possible, be one bearing which is fixed direct to the wall by means of a wall-box properly built in. The shaft collars should work against a wall-box bearing. If it so happens that it is impossible to obtain a fixing to the wall, then one of the hangers or brackets should be stayed so as to be absolutely rigid in the line of direction of the shafting, and the collar-carrying bearing or pedestal fixed on this.

With true shafting and sufficient bearing surface, the first problem in erection is to arrange that the shaft shall be absolutely horizontal throughout its whole length, and also parallel to the main wall or other desired line of direction of the building. The pedestals and supports must not be too far apart, and should be so arranged as to carry the shaft as closely as possible to the places where pulleys for heavy drives are fixed. The arranging of all this is largely the work of the engineer by whom the plant is designed, but it often devolves upon the baker to see that this condition of things is maintained. The shafting should show no signs of "sagging," nor should there be any up and down movement in it when running. Whether or not it is horizontal may readily be determined by means of a plumb line. Suspend a leaden plummet from the upper edge of one of the largest pulleys on the shaft, and notice whether the cord just exactly touches both top and bottom edges of the pulley—if the edge of the pulley is vertical, then the shafting is horizontal. It is very necessary to see that the shafting continues true, as otherwise the various belts are likely to run off the pulleys. If either end of the shaft has dropped, it may be due to nuts shaking loose on the hangers—see that these are all tightened up, and, if necessary, raise one of the pedestals by packing it underneath with a thin piece of hard wood.

The speed at which shafting is driven must depend somewhat on that of the machines to be driven from it. For most bakery purposes a speed of from 100 to 120 revolutions per minute is a very convenient rate.

Pulleys.—It is unnecessary to describe the shape of these, as everyone must be familiar with their use for the purpose of carrying a belt on the outside face. Pulleys are turned either flat, that is, of uniform diameter throughout their whole width, or "rounded," in which case the diameter in the centre is rather more than at the edges. A rounded pulley causes the running belt to keep in the centre, since belts always tend to climb to the greatest diameter of a pulley. Pulleys may either be cast in one piece, or made in halves and bolted together around the shaft. In the former case the pulley must be slid over the end of the shaft and pushed up to its place, an operation which necessitates the dismantling of the shaft, and possibly other pulleys in event of it being required to put a new one on. The whole pulleys are usually fixed on the shaft by means of a "key," a groove is cut longitudinally through the hole in the pulley, and either a corresponding groove is cut in the shaft, or else a "flat" is filed. The former is to be preferred for heavy drives, while the latter suffices for light machines. The split pulley is for most purposes far the more convenient. A new pulley may be placed on any part of the shaft without any disturbance whatever of pre-existing arrangements. A very convenient form of these pulleys is one in which the two halves are placed around the shaft and bolted together. A kind of bush is arranged to run inside the hole of the pulley, this has a roughened interior surface so as to bite on the shaft—the outside is cut with a screw slightly larger at one end than the other—the pulley is screwed on to this bush over the small end, and the further it is screwed up the tighter its grip. It must be arranged so that its drive is such that the work thrown on the pulley tightens it on the bush. These pulleys are readily adjusted and work very well.

The engine is usually connected to the main shaft by means of a belt working on a pair of "fast and loose" pulleys. Care must be taken with the engine (and all machines) that the pulleys are "lineable" with each other, that is, a cord stretched along the edges of the pulleys should touch the pair of edges of both pulleys when tried first on one side, and then on the other (assuming of course that the pulleys are of equal width). Whatever the width of the engine pulley; on the main shaft are two pulleys of just half the width each, one of which, the fast, is keyed on, and the other with a long bearing runs loose, being held in its place by a collar on the outside. The size of the shaft pulleys must be determined by the rate of speed of the engine, size of its driving pulley, and speed at which it is desired that the shaft shall run. It is useful to bear in mind in this connexion that of two shafts coupled up with a belt, their speed is in inverse proportion to the diameter of the pulleys on each. Thus, supposing the engine shaft to be making 200 revolutions per minute, and its pulley to be 24 inches in diameter, and that the main shaft is required to run at 120 revolutions, then

As 120 : 200 :: 24 : 40 = diameter of pulleys on main shaft.

Knowing any three of the above data, the fourth is easily calculated by an ordinary proportion, as shown.

In transmitting power generally, it is well to use large pulleys, thus the relative speed of two shafts will be the same whether they carry 10 and 15-inch pulleys, or 20 and 30-inch pulleys respectively; but the strain on the belt in the latter case will only be half that in the former. The steam and flour dust in a bakery combine to render the adhesion between the surface of the pulley and that of the belt less than the normal, consequently it is well to have an ample margin of pulley capacity. This is obtained by using as large and wide pulleys as convenient.

Belting.—Belts are commonly made of leather, either in single or double thicknesses, according to the strain to be carried. When the belt runs round the pulleys in the ordinary way, with the belt open, the direction of revolution of the two shafts is the same. When the belt is crossed in the middle, the one shaft runs in the opposite direction to the other. The joint in belts may be made by lacing, in which case the edges of the belt should be paired down in order to make a "scarfed" joint, otherwise there is a disagreeable jump when the laced part is passing over a pulley. In arranging the belt, care should be taken that the lacing is so done that the thin end of the joint leaves the pulley last, otherwise it may get turned over by the pulley, and the lacing broken. A moment's reference to a running belt will make this clear—considering solely the *inside* of the jointed belt, there is one end which shows; now the lacing part should travel *before* this end when the belt is running; in other words, on the inside of the belt the end should be drawn *after* the running belt, and not pushed in front. With very thick (*i.e.*, double) laced belts, the overlapping joint requires to be made very carefully, or the jolt on the machinery will be seriously felt, particularly as in a bakery the drives are usually short. In such cases a butt joint with a piece on the top is advantageously employed. The two ends of the belt are cut square and placed together, and a piece placed on the top, and laced to the two belt ends. A smoothly running belt is thus obtained. Other devices are now frequently employed instead of laces for belts: very convenient among these are what are known as Harris' Belt Fasteners. These consist of rectangular plates of malleable cast iron, with on the one side rows of teeth or nails cast on. With smaller belts, it is a very simple matter to bring the ends of the belt together so as to form a "butt" joint, and then hammer on the fastener with a hammer. For even the heaviest thickness belts, joints can well be made with these fasteners, provided some sufficiently heavy for the belt are obtained. The teeth on the fastener should be a sixteenth of an inch less in length than the thickness of the belt. When the width of the belt is four inches and upwards, two fasteners should always be employed, each being a little less than half the width of the belt. In making a joint in a new belt, it should be remembered that the belt stretches very considerably: it is therefore safe in a belt, say 20 feet in length, to cut it, to start with, six inches shorter than it can be drawn around the pulleys by hand. The ends of the belt should be marked off exactly square with a carpenter's square, and cut perfectly clean, and at right angles to the thickness of the belting. First of all, see that the belt is properly round the pulleys and shaft which are to be connected. Then turn the belt so that the inside lies uppermost, and place it down on a heavy weight. Lay the fasteners down on the weight with the teeth upwards, and place the ends of the belt in exactly their right places on it. Get some assistance to hold the belt in exactly the right position, and, with a heavy hammer, drive the leather down on to the teeth of the fasteners. With the joint properly made, there is no danger of the fastener tearing out.

In designing machines, it is well to arrange that the belt runs at a fairly high rate of speed, and that it is of ample width for the work it has to do. The rule for the baker using the machine is to have the belt as slack as possible, provided it drives the machine without slipping. Where it is practicable to do so, the drive of the belt should be of a good length, as nearly horizontal as possible, and with the slack side of the belt, when running, on the uppermost edges of the pulleys.

If a belt commences to slip, the probable reason is that it has become slack through stretching. To remedy this, tighten the belt: this may be done, when laced, by taking it up a hole. In the case of fasteners, as before referred to, it is well to cut the fasteners right off on each side, and strip the short pieces off the teeth, and make a completely new joint. Unfortunately, at times, there are machines in which, however tight the belt, a tendency to slip exists. To increase the grip of these some dressing is frequently employed. For a momentary slipping a little powdered resin strewed on the inside of the belt is a ready and efficient cure. When a belt has grown hard and slippery, an occasional dressing of oil is an advantage. This, however, must be put on and allowed to dry in, as at first an oiled belt refuses to grip at all. Oil in which a little resin has been dissolved very considerably increases the gripping power of a belt, and does not seem to cause any injury to the leather. Treacle is sometimes applied to belts in order to prevent slipping: this, however, is only mentioned in order to give it the most severe condemnation. While it gives a temporary gripping power, the belt is rapidly destroyed, and soon becomes absolutely rotten.

When fast and loose pulleys are employed, the belt is transferred from one to the other by means of an iron fork; this should be arranged near to one of the pulleys, and always so that the belt runs from the fork to the pulley.

Rope Gearing.—In place of belts, rope is now at times employed. In these cases the rope runs in a V-shaped groove in the pulleys. The same rules as to relative speed, crossed or open belts, apply to rope drives as to leather belts. Rope possesses an advantage that it can be bent in any direction, and thus a drive may be taken round corners when power has to be transmitted in other than a direction at right angles to the line of shafting. With a very long rope drive, the rope should be carried at intervals of its length on "jockey" pulleys. An example of this is shown in Plate IX., where such a drive is employed for actuating the machinery on the confectionery side.

Lubricating.—It is essential for the proper running of not only gearing, but also of all other machinery, that all parts where there is friction be kept thoroughly lubricated. On the upper parts of all bearings there are commonly holes through which oil can be poured. It is very rarely now, however, that this primitive form of lubrication is alone depended on, there being used certain forms of lubricator which have as their object the continuous, and more or less automatic, lubrication of each bearing.

Two forms of lubricator may be described. One of these is the oil lubricator. This consists of a small glass flask or bottle, fitted with a wooden plug, which is also tapered on the outside, and in this way fitted to the oil-hole of the bearing. Through the plug is a hole, in which is put a piece of stout iron wire just slack enough to move freely by its own weight. The vessel is filled with oil, the plug inserted, and then inverted, and put in the hole of the bearing. The wire drops down through on to the top of the revolving shaft, and very slowly the oil finds its way down it, and so lubricates the bearing. When properly worked, this is an efficient lubricator ; a glance shows whether any oil remains in it : as soon as empty it should of course be refilled. It is not well, however, to trust too completely to the part of the glass still containing oil : from time to time it should be taken out and examined to see that the oil passage is not stopped. Periodically, the upper part or cap of the bearing should be removed, and the oil channels, which are cut in branching directions from the oil hole, cleared out, so as to ensure proper distribution of the oil.

Another form of lubricator is that known as Stauffer's, and consists of a small cast-metal box or cylinder, screwing down over a piston, cut with a fine gas thread. The piston portion is screwed at the other end to fit in the bearing which has been tapped to take it : a small hole is bored through the whole of this, leading from the interior of the cylinder right into the bearing. In use, the cylinder is filled with a special semi-solid grease or lubricant, and screwed on to the piston ; with each turn of the screw a little of the lubricant is forced into the bearing, until at last the piston screws right up to the far end of the cylinder, and the lubricator is empty. It then simply requires to be unscrewed and refilled. When lubricators of this kind are adopted, they possess the advantage of great cleanliness, but require to be looked after, and some once or twice a day have a slight turn given them so as to run a little grease in. The great difficulty is that they are liable to be overlooked and forgotten, when the shaft may run dry. For loose pulleys they are an exceedingly convenient form of lubricating, as the lubricant can be forced up where it would be impossible to pour oil.

528. Flour Hoisting.—For previously explained reasons, flour is usually stored at the top of a building, therefore some means of raising it becomes necessary. One of the simplest machines for this purpose is the sack-hoist figured below. In some bakeries the flour, when brought from the mill or stores, is simply backed against the outer wall of the bakery in a waggon. A stout pulley is suspended above a door on the uppermost floor by means of a projecting arm, so that a chain hanging from it may draw up a sack without the latter scraping the wall in its passage. The draw chain passes over the pulley and away to the hoist, Figure 48, when it is attached to the iron barrel.

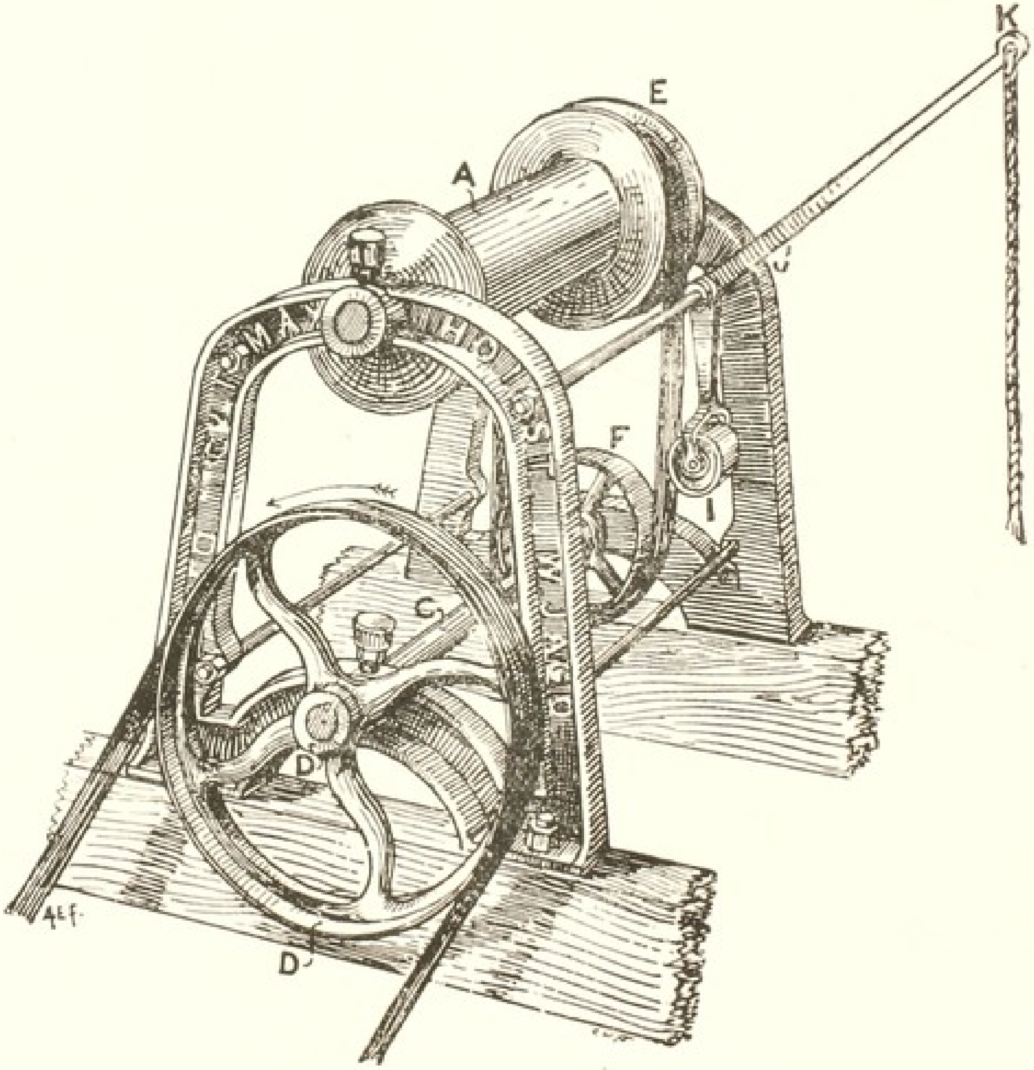


FIG. 48.—JAGO'S CLIMAX HOIST.

An inspection of the figure shows in a moment the manner in which this machine is driven. The framework not only carries this barrel, A, but also a running shaft and pulleys, C D. The outer pulley at D is connected by its belt to the main driving shaft, and is always running when the machinery is in motion. On the other end of C D, and also on the barrel, A, are a pair of pulleys, E and F: around these a belt passes, which is, however, too slack to convey any motion from the running shaft to the barrel. On the slack or non-driving side of the belt there is attached a running or jockey pulley at the end of a lever, I J K; if the end, K, of this lever be depressed, the pulley, I, is forced against the belt, takes up the slack, and sets the barrel in motion, thus raising the sack. In practice a rope is attached to the eye, K, and passes right away as far down the building as may be desired, in order to set the hoist in motion. The weight of the pulley, I, is sufficient when at rest to keep it away from the belt, which consequently remains perfectly slack. As soon as the cord is tightened the hoist starts; and when the sack is raised, on slackening the cord, the sack may be drawn in to the store, and the chain lowered for another sack. By means of a hoist of this kind flour may also be lowered: it is only necessary to raise it gently by a slight pull on the cord, and then slacken until first the sack is stationary, and then slowly descends. The hoist, as designed, has all its parts absolutely interchangeable: thus, the jockey pulley lever may be placed on either side, permitting the hoist to be driven in either direction, or the machine itself may be turned upside down, and bolted up underneath the joints, instead of being placed upon them. In this latter case the barrel, A, and the driving shaft, C D, are interchanged, as in all cases the driving shaft must be underneath.

A preferable arrangement to hoisting flour outside the building is, if possible, to bring the van under cover, and let the sacks pass up through double trap-doors as they ascend. These doors are somewhat noisy as they fall after the passage of the sack, but they are an absolute safeguard against the accident of the raised sack falling once more to the bottom. In cases where the flour must be raised outside the building, it is well to have a covered-in raising shaft or "lucombe," with a double trap-door at the top through which the flour is lifted, and then allowed to descend on the upper surface of the dropped doors. This arrangement is shown in Plate X.

529. Flour-Blending Machinery.—With the acceptation of the principle that the baker blends his various flours, it becomes necessary to decide on what form of machinery is best adapted for that purpose in the bakers' hands. There are a number of devices more or less successfully employed by the miller, which are not likely to give efficient results in the hands of the baker. The principle of many of these is to have a screw (what is technically known as a "worm") conveyer running in a horizontal pipe or trough: from various hoppers flour is allowed to pour into this, and as the flour is wound along, an efficient mixing of what enters the worm is the result. The difficulty is the regulation of the flow of flour from these hoppers: for this purpose various valvular contrivances are employed, with sliding shoes below, and other devices for ensuring the accurate control of the rate of egress of the flour. But different kinds of flour flow at different rates, owing to the hardness or softness of the flour, the fineness or coarseness of its granulations; so that, with the machine set to deliver one kind of flour at a certain speed, it is difficult to guarantee that it will do the same with flour of another kind. Further, the management of devices of this kind requires a type of skill and experience belonging rather to the miller than the baker. Also, in a mill, this is at once the most convenient way of blending flour, because during the course of manufacture it is continually flowing along pipes in various directions, to and from different machines, and only gets weighed when in the finished state at the close of manufacturing operations. With the baker, however, all this is different: he buys his flour, and has it ready to hand in 140 or 280 lb. packages, and can therefore at once without any difficulty get the exact quantity he requires of each for his blend. If he wishes to make a blend of two parts of A. flour to three parts of B. flour, he must, with a series of hoppers set to deliver at the same speed, pour a sack or a bag into each of five hoppers; or, if he prefers, can arrange two hoppers so that one delivers half as quickly again as the other, putting the B. flour into the one with the more rapid delivery. But in either case he will have discharged his flour into the blending apparatus from previously weighed packages. Now, in a mill the great object of these graduated delivery arrangements is to take a stream of flour, and as accurately as possible, without weighing, measure it off by volume into a mixing apparatus. But the baker has no need for all this, because, as before said, his flour is already weighed: therefore in his case an infinitely simpler arrangement is one which will

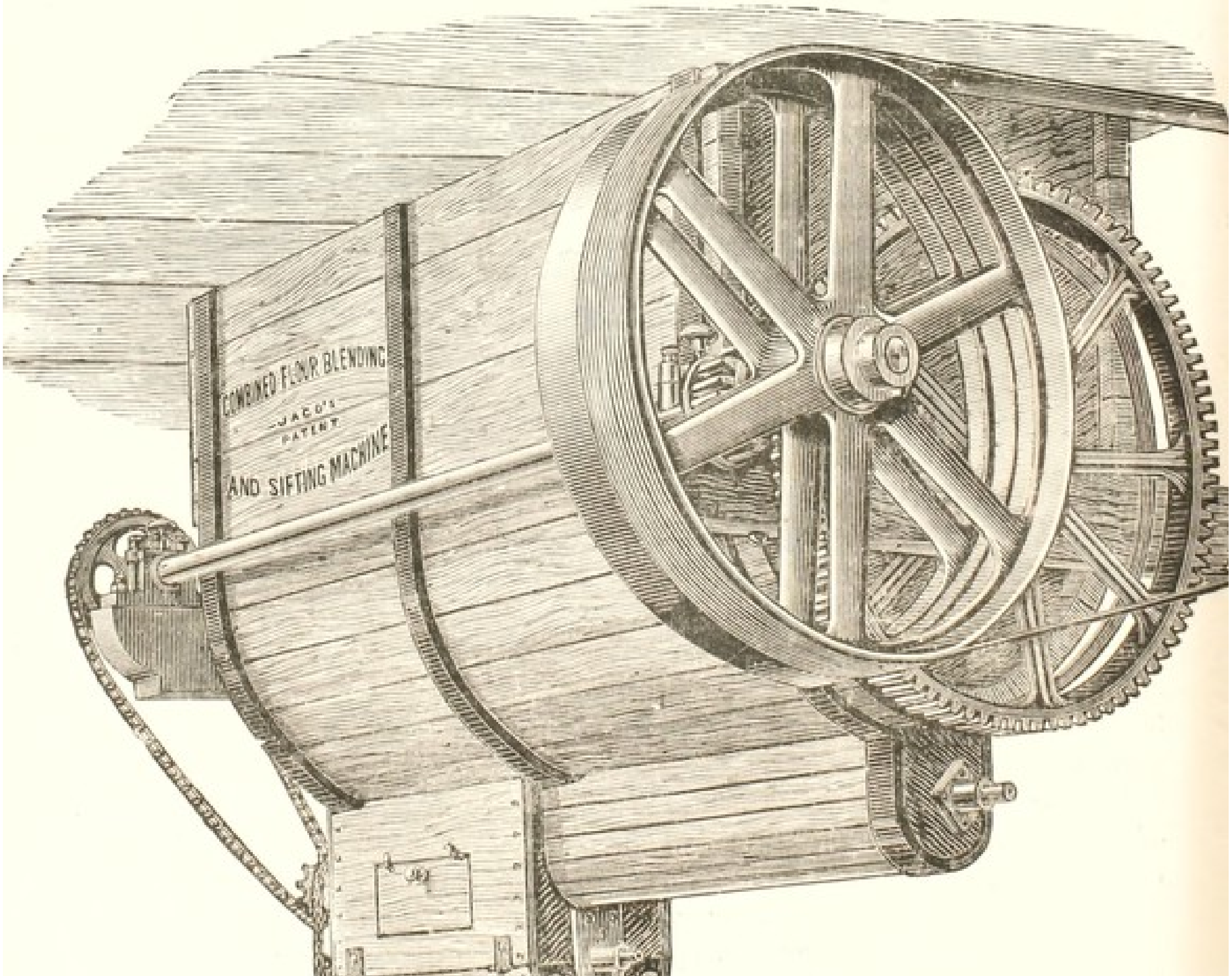


FIG. 49.—JAGO'S CLIMAX COMBINED FLOUR-BLENDING AND SIFTING MACHINE.

permit him to discharge all his varieties of flour into one and the same hopper. He can then add, up to the capacity of his machine, any number of bags or sacks in any proportion whatever he pleases. To meet these requirements most fully, the Climax Flour-Blending Machinery was devised. The machine itself consists essentially of a trough, which is built up throughout of wood, as being far better fitted to hold flour than metal; the bottom of this trough is semi-cylindrical, and as closely adapted as possible to the movement of a revolving mixing blade of special shape. This blade is so constructed as to turn the flour over as gently as possible, drawing it in from the circumference toward the centre, and at the same time giving it a certain amount of motion from end to end of the machine. These combined movements in a very few minutes mix as much as ten sacks (2800 lbs.) of flour in the larger machines. The driving pulley and gearing by which the mixing blade is actuated are shown at the right-hand end of the machine. Underneath the mixing trough, and running its entire length, is a gridiron valve, which consists of a series of apertures cut through a metal slide: underneath this is a fixed plate with a similar series of apertures, and when the upper plate or valve is drawn into one position the apertures

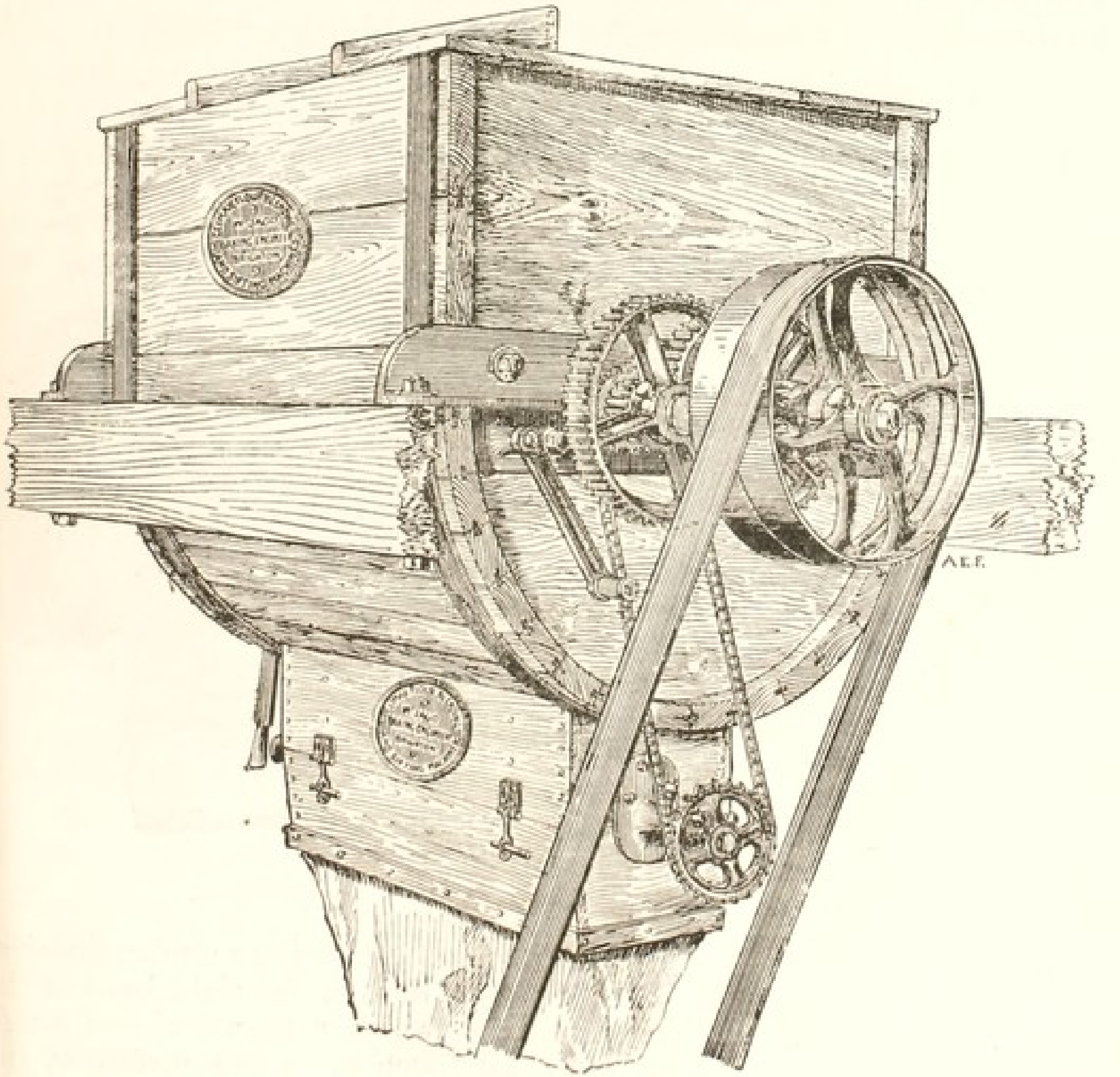


FIG. 50.—SMALLER SIZE CLIMAX FLOUR-BLENDING AND SIFTING MACHINE.

in both correspond, and so the flour falls through. When the valve is pushed the other way the apertures of the one coincide with the spaces of the other, and so the machine is closed to the escape of flour. This valve is actuated from the outside by a lever fixed in any convenient position. Underneath the valve runs a spiral conveyer, by means of which the flour is conveyed to either end of the machine as wished, and thence to a sifting machine, or to any other machine or receptacle as desired. While running through this conveyer the flour gets a second mixing. The whole of the machine is self-contained, and is worked by one driving belt.

In Figure 50 a smaller machine is shown: this is intended for small bakeries, and has a maximum capacity of three sacks. The construction is such that the machine occupies very little space, and takes only a light belt drive. In addition to use in the small bakery, it is well adapted for the blending and making of self-raising flours and baking powders.

530. Flour-Sifting Machinery.—An illustration is given in the preceding figures, Nos. 49 and 50, of a sifting machine, which is fixed in any convenient position underneath the blender. Figure 51 is an illustration of a similar machine arranged to drive separately. The machine consists essentially of a wooden frame carrying a semi-cylindrical sieve, the end of which is shown in dotted lines at the right hand of the figure. Above this is fixed an axle, on which runs a series of longitudinal brushes, so arranged as to just touch the upper surface of the sieve. The flour is poured in at the top of the machine, and by means

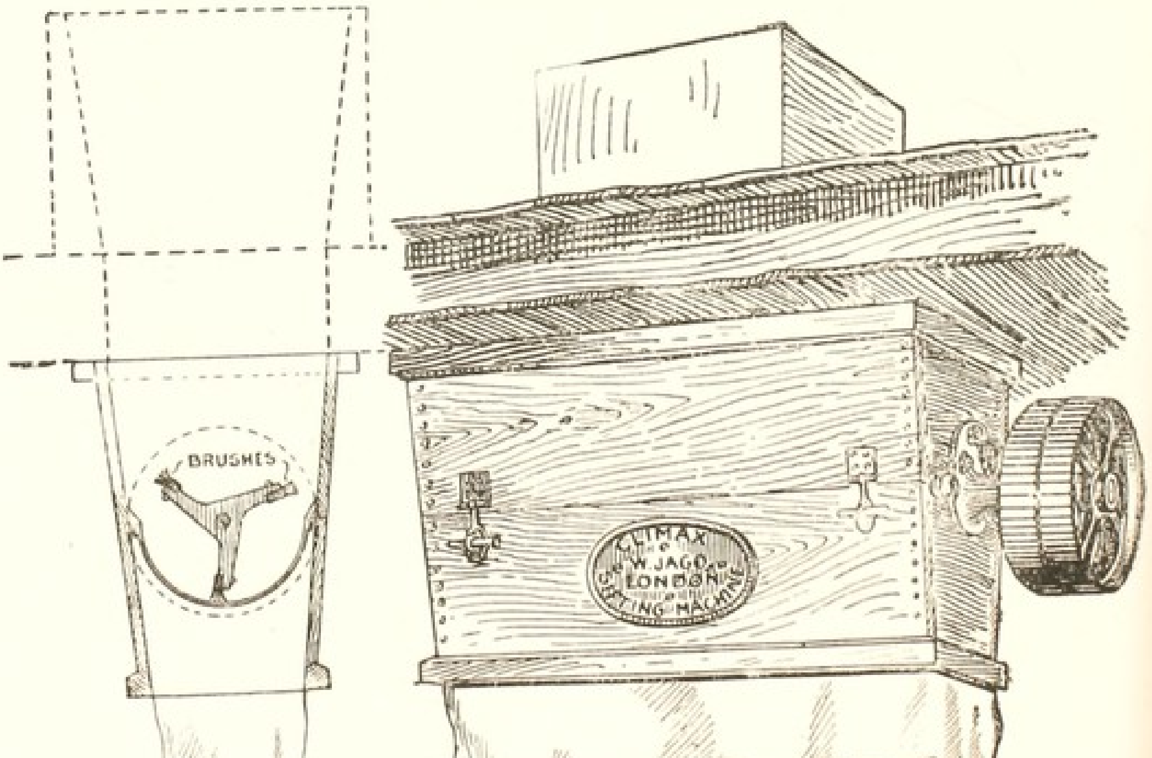


FIG. 51.—JAGO'S CLIMAX FLOUR-SIFTING MACHINE.

of the revolving brushes is gently brushed through the meshes of the sieve. One of these machines easily and efficiently sifts flour at the rate of one sack per minute. The framework of the machine below the brushes is hinged both at the back and front in such a manner that the bottom portion containing the sieve may be opened from either side, and any fluff or other separated matter removed. In the same way one sieve can be taken out and instantaneously replaced by another of different mesh. The spindle, to which the brushes are attached, is carried in bushes fastened to the sides of the framework, with bolts working in slotted holes, so that the brush may be adjusted with exactness to the sieve. The brushes themselves are fixed on radial arms, and are also provided with an adjustment by which they may easily be shifted backward or forward so as to bring them nearer to, or further from, the surface of the sieve. A sleeve is attached to the lower part in order to convey the sifted flour to a bin, or the doughing machine, as may be wished.

There are differences of opinion as to whether the sifting of flour should precede or follow the blending. The advocates of the former course argue that, if there is anything in the flour which ought to be removed, it is bad policy to first rub it up and into the flour before taking it out. That is to say, the purification of the flour should be effected at the earliest possible stage of its manipulation. A good deal may be said for this view, for although *ordinary* flour contamination, such as sack fluff and loose particles, can do no harm to the flour during blending, yet there are other rare but occasional accidental impurities which it is highly inadvisable thus to rub into the flour. On the contrary side, it takes longer to introduce the flour into the blending machinery if it first has to go through a sifting machine. In this case it would have to be fed into the hopper of the sifter a part of a sack at a time, while otherwise it is at once dropped in. If the sifting and blending machines are combined, as in the above figures, the valve, on being opened, permits the flour to gradually enter the sifter, and sifting thus goes on while the man in charge is bringing up more flour, or untying and preparing the sacks for the next charge of the machine. Whether the flour be sifted or not before it is blended, there is no doubt it ought to be sifted direct into the doughing machine or trough if it should have been re-sacked. One of the objects of sifting is to break down the flour into a fine powder, and thoroughly ærate it immediately before its mixture with water to make dough. In the case of the combined machine it is so designed as to be made either to sift the flour *after* blending as shown in the figure, or *before* it enters the mixing trough of the blending machine. Either arrangement is therefore possible according to the wish of the purchaser.

531. General Arrangement of Blending and Sifting Plant.—This will naturally depend somewhat on the size of the bakery plant, and the amount of space at disposal for blending machinery. When there is sufficient head room on the ground floor, it is a good plan to fix the blender entirely beneath the floor, as no space is then occupied on the floor above except that necessary for the hopper leading into the machine. The larger machine is shown fixed in this way. Where the head room is insufficient, the whole machine may be allowed to come up through the floor as shown with the smaller blender. This is entirely a matter of arrangement depending on the particular premises. If the arrangement of the combined machine is reversed, then the blender would be underneath the flour, with the sifting gear fixed in the hopper above. This combined machine is found particularly useful in hand-work bakeries—the sleeve at the bottom can be held over each trough below in succession, and each morning the sifted and blended flour for the coming day's work let down into the troughs. Or, if wished, the flour from such a machine may be sacked off and stored for future use.

In machine bakeries a somewhat more extensive plant is more convenient: one of these is shown in Plate VIII. of the overhead bakery. It is advantageous to be able to conduct the whole of the blending operation on one floor, which in this case is the third one. The flour is raised here by the hoist and stored. In order to blend, the necessary bags or sacks for the mixture are wheeled up to the hopper of the blender. The gridiron valve, actuated in this case from the upper floor, is closed, and the blender set in motion. The whole of the flour is then put in as rapidly as possible, care being taken to see that none of the external sack dirt also enters. In about five minutes after the addition of the last sack the mixture is complete. The next task is the again raising to the same floor the blended flour: for this purpose there is attached to the end of the conveying worm underneath a "cup and belt elevator, by which the flour is once more lifted to the floor above, and discharged into the blended flour bin. The worm conveyor, and also the elevator, must be set in motion, *after which* the gridiron valve must be carefully opened so as to allow just as much flour to come out as the elevator will carry; by this means the blended flour is again rapidly conveyed to the floor above. This blended flour bin is fitted with a draw-off valve and sleeve below, so arranged as to weigh off the blended flour into sacks. It is recommended that such weights be taken as exactly make oven batches, or aliquot parts of such batches. Where the ovens do not exactly hold a sack or simple fraction of a sack, it is just as simple when thus weighing off flour to take the necessary oven batch quantity as any other. The blended flour for each variety of bread, and also sponges and doughs, should then be stacked and allowed to lie some days before use.

The hopper leading to sifting machine is fixed on the same floor, and when sponging or doughing, the requisite flour is let down the hopper and thus into the machine.

532. Water Measuring and Attemperating.—It is occasionally advocated that the water for each batch be weighed, instead of measured, so that the variations in volume due to alterations of temperature may not affect the actual mass of water delivered. The water for sponging and doughing does not, however, usually vary much in temperature, and consequently the theoretic correction from differences of expansion is so little that in practice it is absolutely inappreciable.

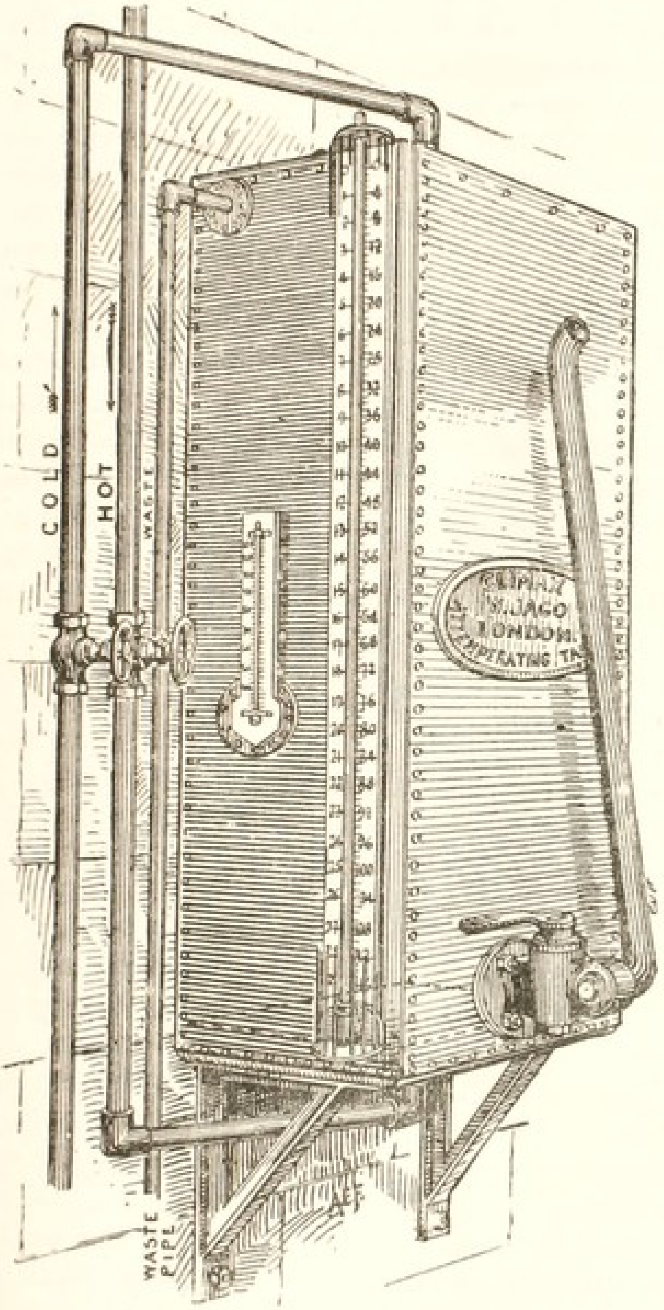


FIG. 52.—JAGO'S CLIMAX WATER ATTEMPERATING AND MEASURING TANK.

With a properly constructed measuring tank, water can be measured, not only very quickly, but also very accurately. For this purpose the upright tank introduced by the author should be employed. A convenient size tank for ordinary purposes is one holding 120 quarts or 30 gallons, this being sufficient to make two sacks of flour into an average dough. (Where from the nature of the bread more water is taken, it is well to have a tank made specially larger.) A tank of this capacity will be about 4 ft. in height, by 1 ft. 6 in. by 1 ft. 2 in. at the base. The tank is conveniently fixed by means of a bracket and clamps to the wall. On the side is shown a guage graduated into quarts and gallons, the figures for the one being to the left and the other to the right, and the zero of each scale at the top. In front of this guage is a glass tube, connected at the bottom with the interior of the tank, so that the water stands at the same level within them both. An elbow thermometer is also fixed in the side, with its bulb projecting into the water space about one third of the height of the tank from the bottom: this thermometer must be marked plainly in single degrees, from say 50° to 120° F., and should have a small bulb blown at the top of the mercury column, so as to provide for the possible filling of the tank with boiling water. About two inches from the top of the tank a small overflow pipe is arranged, and this should be so adjusted that when the overflow has just ceased, the surface of the water should correspond with the zero of the measuring scale. A large and quick delivery cock is attached to the lower end of the tank, carrying a swing arm (which may work either horizontally or vertically, whichever is most convenient), so as to deliver the water into the doughing machine. The height of the kneader determines that of the tank itself, which should be fixed as low as possible, while providing for its emptying into the machine. The cold-water supply should be led into the top of the tank, while at the bottom the hot-water supply should be fixed, the object of this particular arrangement being that each shall rapidly permeate the whole mass by gravity, the hot water ascending, and the cold descending when added. A grid plate bored with small holes should be arranged inside the tank, and about two inches from the bottom. It is well to fix to the wall a small step, with handle above, so that from it the level of the top of the guage can easily be seen. When attaching the pipes, the overflow should be brought down to discharge over an open head attached to the wall, so that the flow of water through it can be observed by the workman in charge. The cocks regulating the hot and cold water supply should also be fixed side by side against the wall, at a convenient height for the hand, and so that they can be manipulated at the same time as the thermometer and measuring guage are being watched. In using the tank, run in both hot and cold water until full, and water just commences to run from the overflow, regulating the proportions so as to get the temperature slightly below that required, rather than higher. After a very little practice this is easily managed. Wait until the thermometer becomes stationary, by which time the overflow will have emptied the tank to the zero mark. Note the reading of the thermometer, and if too low, let in a very little more hot water; while if too hot, add cold water in requisite quantity: again wait until the thermometer becomes stationary, during which time the excess of water will have run out through the overflow pipe. In practice this is a rapid operation, as knowing the speed of flow of water through each of the two supplies, and their approximate temperature, the quantity taken of each can be adjusted to a nicety.

Starting from the zero, supposing that, for example, 57 quarts have to be taken, turn the swing arm of the delivery cock of the tank into the doughing machine, and run in water till the 57 mark is reached on the guage, and the 57 quarts will have been delivered. One batch having been made, suppose that 60 quarts are required for the next: note the reading of the guage, and simply add on the quantity required to be taken, in this case $57 + 60 = 117$; run water in to the 117 mark, and the operation is performed. With a scale of this kind, even when one starts from any other point than the zero, the operation of adding the quantity required to the first reading is so simple and easy, that it is to be recommended in actual use as preferable to any scale which is adjusted to its own zero by the surface of the water before the measurement of quantity drawn off is made.

In deciding at what temperature the water has to be taken for sponging or doughing, it must not be forgotten that the temperature of the flour is a most important factor. This should be taken every day, and allowance made accordingly. From paragraph 9, Chapter I., it is seen that the specific heat of flour is about 0·4, and that consequently in a mixture of equal parts of flour and water, if the flour were found to be 2·5 degrees colder than the water, the water would have to be taken at 1 degree hotter to restore the temperature of the mixed dough to the same figure. But in doughs the quantity of water is nothing like so much, being usually about half the weight of the flour, therefore for a variation of 2·5 degrees in the flour there must be a variation of 2 degrees in the opposite direction in the water.

533. Doughing Machinery.—All doughing machines consist essentially of a trough, usually made of iron, in which the flour and water are placed. One or more sets of blades revolve in this trough, and in so doing knead the flour and water into dough.

The machine selected by the author, in his installations of baking machinery, as being that which at present, in his opinion, is best suited to the requirements of the baker, is the kneading and mixing machine invented by Pfleiderer, and made and sold by Werner, Pfleiderer, & Perkins, Limited, London. For this reason it is chosen for description in these pages. The design is very simple and, at the same time, efficient, while in construction the machine is exceedingly durable.

The reader is in the first place referred to Figure 53, in which the arrangements of the blades in the trough is well shown. This figure is drawn from a small working model of the Pfleiderer machine, such as the author uses in doughing experiments with the strength burette and the viscometer for the purpose of testing flour. Attention is called to the two revolving kneaders, the actions of which are separate and parallel to each other. These kneaders are geared together by means of toothed wheels: an essential point about these wheels is that they have different numbers of teeth, and so the two shafts revolve at unequal rates.

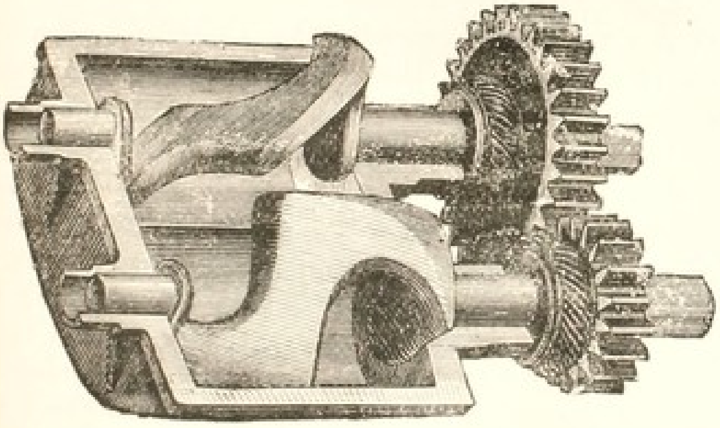


FIG. 53.—WORKING MODEL OF PFLEIDERER'S DOUGH MIXER.

In order to show the blades more clearly, the upper part of the trough has been removed. This particular machine is worked by a hook handle placed on the square end of either of the axes.

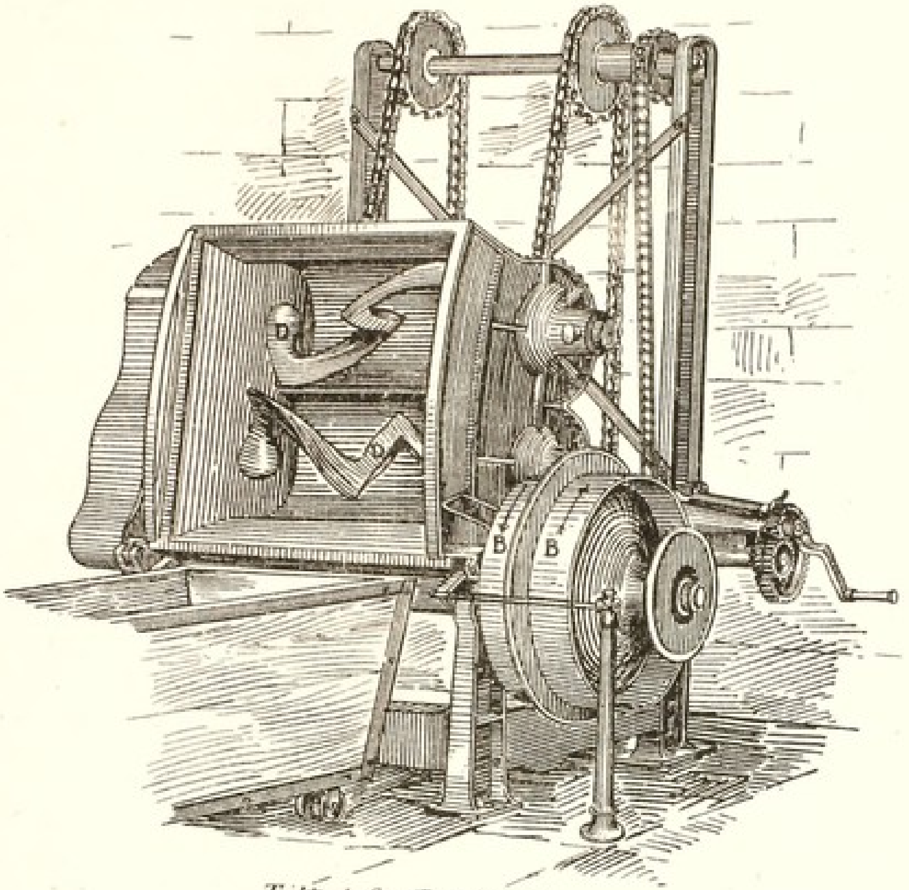
Turning next to the machines of sufficiently large dimensions for bakehouse use, an illustration of one of these is given in Plate XII., both in the kneading position, and also uptilted so as to turn out the finished dough into a trough that may be placed in order to receive it. At the right-hand side of the machine are two pulleys, B B; one of these is driven by an open, the other by a crossed belt, from the same driving shaft. By putting either one or the other of these pulleys into gear, the machine may be caused to revolve in either direction.

The starting, stopping, or reversing of this machine is effected in an exceedingly simple manner. On the same shaft as the pulleys, B B, is a hand-wheel with a smooth rim. The machine is so devised that it precisely obeys all the motions of this wheel; thus, when the machine is at rest, if the hand-wheel be turned either way, the machine immediately follows suit by revolving in the same direction. When the machine is in motion, if the hand-wheel be stopped by grasping the rim, the machine also stops. The tilting of the machine for the discharge of dough is effected by means of an endless chain and small winch worked by hand, which is shown in the illustration of the machine in tilted position. The tilting does not interfere with the working, as the blades may still be caused to revolve in either direction, with the machine uptilted. At the back are shown two weights, P P, by which the machine is balanced, rendering it extremely easy to turn it over when desired at the close of the doughing operation. One special feature of this form of the machine is its being set very low. It will be seen that when in the working position, the top of the trough is barely breast high.

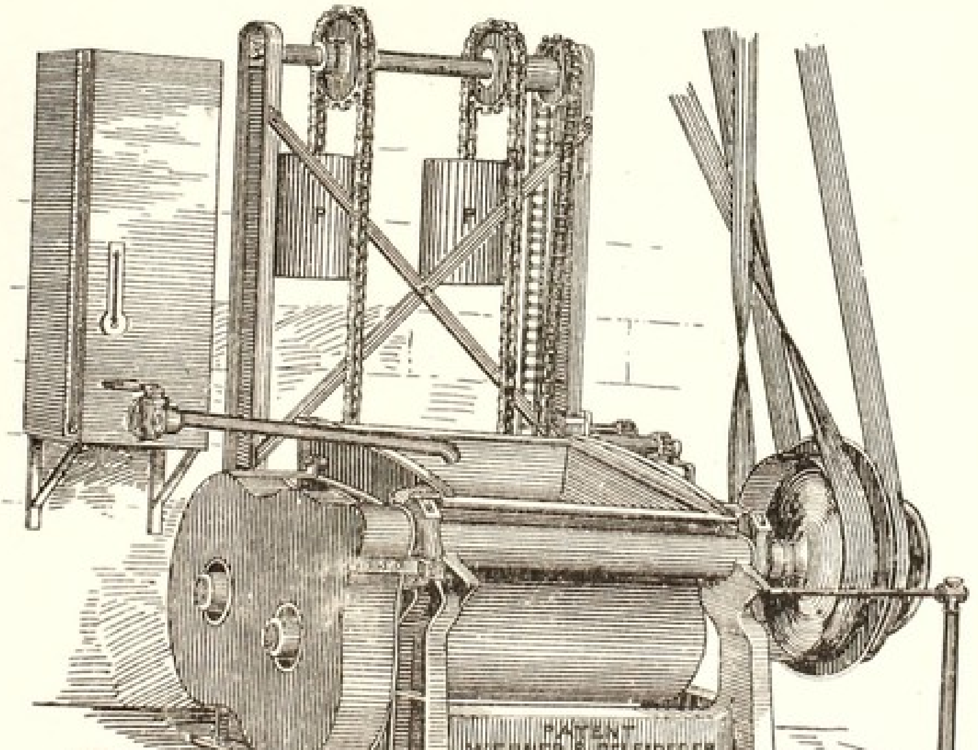
In the figure of the machine when tilted the position of the blades, D D, is clearly shown: in general configuration they resemble those of the smaller machine in Figure 53. The foregoing brief description, together with a study of the engravings, will render clear the more important points of construction of these machines.

An endeavour must now be made to describe the kneading results produced by the movement of the blades, the machine being charged with flour and water; this is a matter of some difficulty. The machine is first started in motion, the direction being such that the blades in the course of their movement approach each other at the top of the revolution. It should be mentioned that the trough of the machine is so shaped that the blades in the course of their revolution scrape it quite clean, no lodgment for the dough being permitted in any part. The blades bring the flour and water continually from the sides of the trough toward the centre, and there mix them together; they then pass down through the centre, and at the bottom of the trough are separated into two portions; one of each is again brought to the surface by each blade traversing the circumference of the trough in its passage. Following the one portion only, it is, with the completion of the revolution, brought once more to the position where the two blades meet; but as the one blade is revolving more quickly than the other, the two portions which were separated as the blades descended do not again come in contact; each one is mixed with a fresh portion of the dough. This differential motion is one of the most important features of the machine, and effects the thorough mixing of flour and water with great rapidity. A very few turns of the machine changes the loose flour into tough plastic masses of dough; the action of mixing at that stage resolves itself into the pressing together of the portions of dough, cutting it asunder in fresh places and again reuniting. After some little time it is well to reverse the motion of the machine for a few revolutions. As soon as the kneading is completed, the machine is turned over in the position shown in the lower figure on the plate; the mechanical arrangements are so adjusted that this operation does not interfere in the slightest with the revolution of the blades. These should then be

PLATE XII.



Tilted for Discharge.



In Kneading Position.

WERNER & PFLEIDERER'S UNIVERSAL KNEADING MACHINE.

reversed, when they discharge the dough with the greatest readiness. Great care and thought have been exercised in devising the shape and arrangement given to these blades. The object is to secure the most efficient possible mixing with the least possible cutting and dividing of the dough. The bearings of the shafts are so constructed as to absolutely prevent any oil or lubricating material entering the dough. While the machine is admirably fitted for thoroughly kneading and mixing dough, its peculiar construction enables it to discharge the finished dough with the greatest readiness, and so thoroughly that there is not the slightest waste.

In addition to the double-bladed machine just described, the manufacturers also offer a "single blade" machine, which is illustrated in Figure 54. The principal difference is in the fact that there is but one blade, instead of two. The machine cannot compare with the latter in point of efficiency or rapidity, but still is a useful and serviceable machine, giving satisfaction where low prime cost is an essential object.

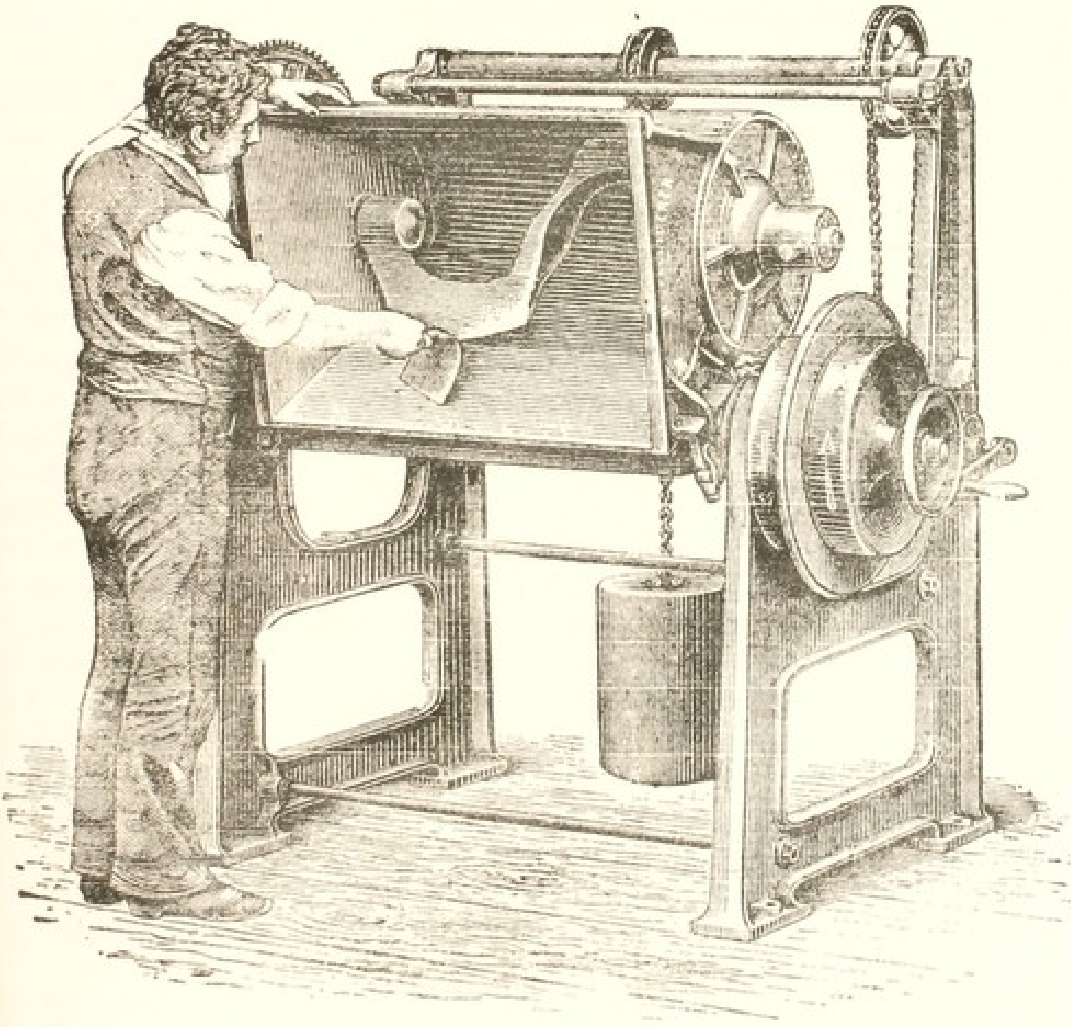


FIG. 54.—PFLEIDERER'S SINGLE-BLADE DOUGHING MACHINE.

In using the doughing machine, the following course is recommended :—As a preliminary to first employing a doughing machine, take the temperature of some water carefully, and pour sufficient into the trough of the machine to make a batch of dough. Start the machine in motion, and after a few turns take the temperature of the water in the trough of the machine itself, and note the extent to which it has cooled. This is usually only very little, within one or two degrees F.: in making first batches each day with a cold machine, use water to that extent hotter, in order to compensate for the cooling which the machine may exert. There is no necessity to make a similar correction for the following batches.

In the majority of instances there will be a sifting machine above the doughing machine: the author prefers to fit a wooden cover to the machine itself, holding it down in place by special clamps while the machine is working. This cover makes a tight joint on the machine by means of felt or indiarubber packing, and is suspended from the ceiling by ropes and balance-weights, so as to be easily raised and lowered. The sifting machine is connected to this cover by means of a linen sleeve. This arrangement largely prevents the scattering of flour dust, as sifted flour falls very lightly, and, unless prevented, partly escapes in falling into the machine, thus causing loss, and at the same time prejudicially affecting the atmosphere of the bakehouse.

Sponging.—The proper quantity of attemperated water should first be put into the machine, retaining sufficient in a convenient measure or bowl in which to break down the yeast. This is then poured into the machine, and any salt that may be required also added. The cover is next clamped down, the machine set in motion, and the requisite quantity of sponging flour, previously weighed off, is poured down through the sifting machine. As soon as the whole of the flour is down, the cover is raised and the mixing watched. As the sponge is in many cases a very small charge for the machine, it is well to tilt the machine forward, so that the sponge is mixed by the front blade only. The machine should be stopped for a few moments, while any fragments adhering to the back blade are scraped off, and forward to the main portion in front. Using one blade only, it should be set in motion, so that the top of the blade moves toward the front of the machine. The kneading or "stirring" of the sponge being complete, the machine is reversed and uptilted, when the sponge is discharged into a trough arranged for its reception. It is recommended that sponges for machine doughs be made slightly stiffer than is the custom for hand work. As an alternative mode of working, the flour may first be let into the machine, and the water subsequently added. This method has the advantage of the machine being left in a drier state.

Doughing.—The sponge being "ready," and doughing time arrived, the trough containing the sponge is wheeled up in position in front of the machine. By means of a scraper it is detached from the sides of the trough, and then divided into some four or six pieces by transverse cuts with a knife. A pair of workmen taking these pieces, one on each side, very quickly transfer the whole sponge into the machine. The doughing water, in measured quantity from the tank, and the salt are now added; and the machine set in motion, preferably with the blades revolving in the outer direction. The cover is clamped down, and the weighed doughing flour let down through the sifting machine. When all is down, the cover may be raised and the kneading watched. At this stage the direction of the blades should be reversed, and most of the kneading done on the inward movement. An occasional reversal is of service, because of its effect in accelerating the mixing action on the dough. Kneading should be continued until the flour and water are well incorporated, but not necessarily until the dough is perfectly "clear" and smooth. Machine-made doughs "clear" themselves remarkably after being made, and it is well to err on the side of under- rather than over-kneading. At the finish the blades must be moving toward each other: the machine is uptilted, and the dough readily and completely discharged.

It will be noticed that no directions are given for first "breaking down" the sponge before the addition of the doughing flour—the reason for this is, that, with an efficient machine, such a course is absolutely unnecessary. The flour, sponge, and water, when added altogether, are rapidly incorporated into a perfectly uniform dough without any preliminary breaking down whatever.

It is recommended that at the close of each day's work the machine be thoroughly scalded out with hot water, wiped clean, and tilted up until perfectly dry. No old dough should be allowed to remain in it, and it must be perfectly sweet and clean.

534. Ovens.—The requirements in bread-making are that an air-tight chamber shall be provided, which is equably heated all over, and whose heat shall be under control. It is further necessary that the oven be cleanly in action, and that it shall bake bread with the minimum loss of weight, each loaf being thoroughly cooked through (or "soaked"), and with the desired proportion of top and bottom crust. In addition it is required that the ovens be well built, economical in fuel, and easily handled.

In the older forms of oven the heat was obtained by burning wood or other fuel within the baking chamber of the oven itself. A later development was that in which a furnace is placed on the one side of the door, and a flue on the other, both being on the front of the oven. The heated gases of the furnace strike backward through the oven, and return to the flue on the other side of the door. The fire is lit, and the oven thus heated, after which it is allowed to "lie down" for a longer or shorter time, so that equalisation of heat shall occur. The furnace and flue being shut, the bread may be put in the oven, and is baked by the stored heat within the oven walls. On one batch being baked, the oven is again heated by once more sending the products of combustion through it. The essential feature of ovens of this type is that the heating and baking alternate, and the fire products find their way into the oven itself. The necessity of having the furnace by the door of the oven requires that the fire, and its concomitant coal, dust and ashes, must be within the bakehouse itself: thus perforce introducing most undesirable features.

In other forms of oven the heat is conveyed into the baking chamber by means of steam-pipes. These consist of stout iron or mild steel tubes, partly filled with water, and then hermetically sealed by welding up the ends. These pipes are so arranged that their principal part is in the baking chamber, but their ends project into a furnace, which is usually at the back of the oven. The water in the pipes is converted into steam, and this being under high pressure acquires a sufficiently elevated temperature to raise the interior of the oven to baking heat.

In another form of oven the source of heat consists of a furnace, which may be arranged at any part of the oven; from this the heat is conveyed by flues around the bottom and top of the oven, and thence to the chimney. In these ovens the source and all products of heat are kept separate from the baking chamber, while the fire and stokehole are altogether apart from the bakehouse.

535. Climax Ovens.—Some time ago the author patented a variety of oven to which he has given the name of **The Climax**, the construction of which depends on having the baking chamber surrounded by flues conveying hot air from the furnace. The principle of the oven may be gathered from the diagrammatic section, Figure 55, showing the general arrangement of flues.

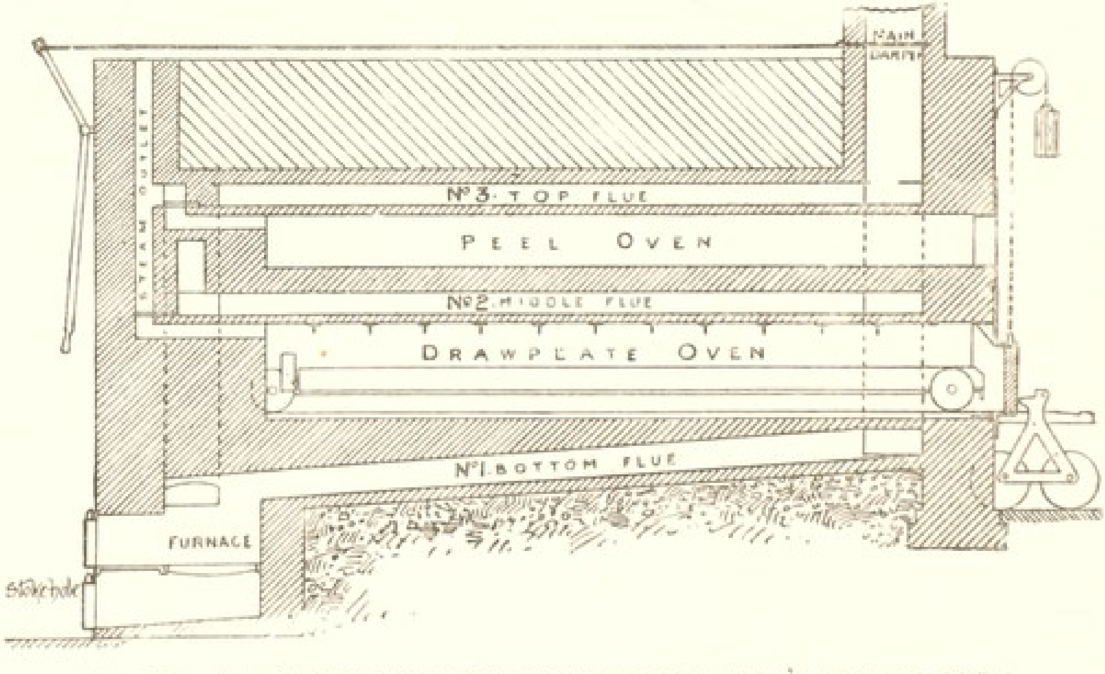
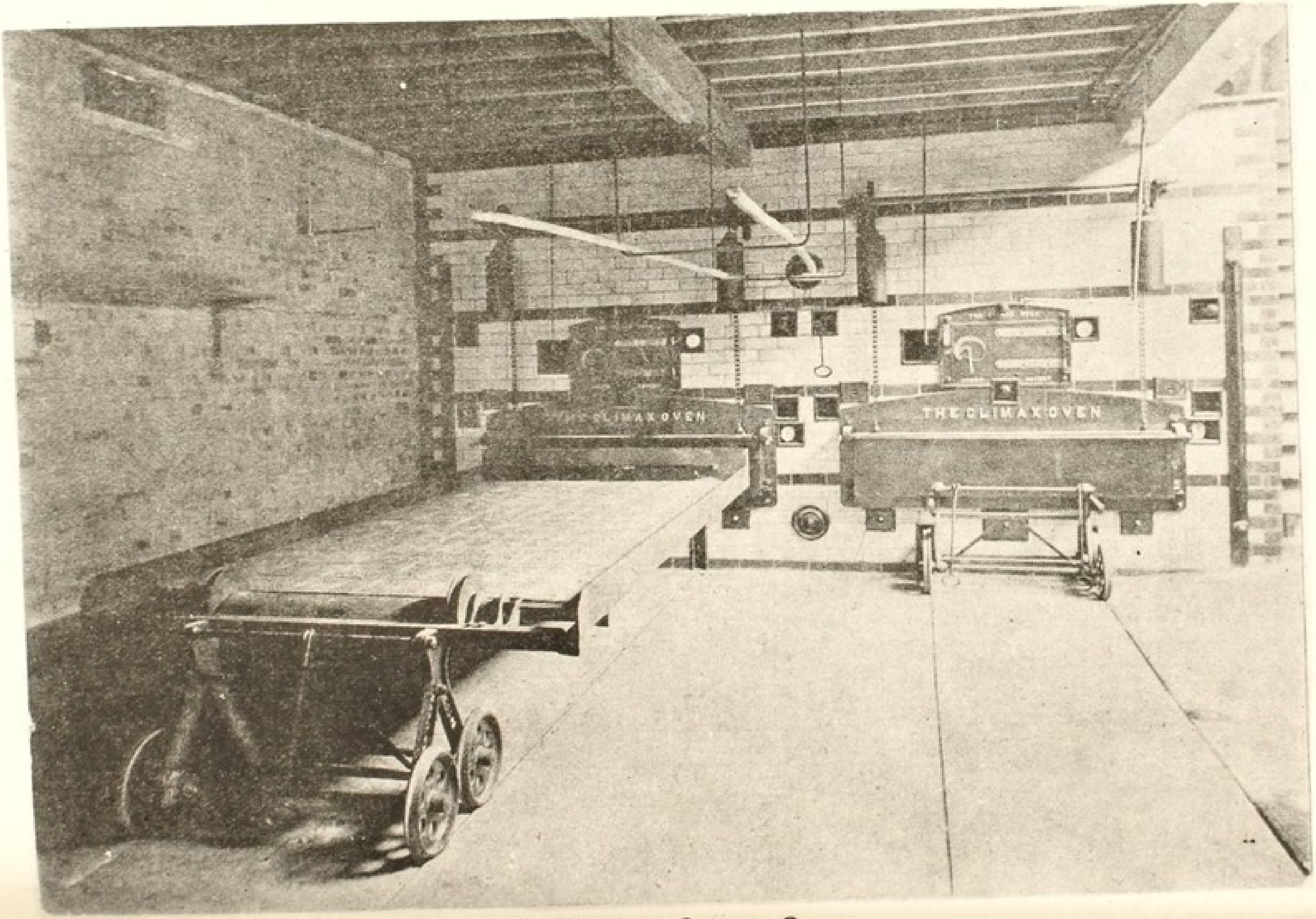


FIG. 55.—DIAGRAMMATIC SECTION THROUGH JAGO'S CLIMAX OVEN.

The furnace may be either at the back (as shown in figure), side, or front, but, as previously urged, should whenever possible be kept outside the bakehouse. The figure shows two ovens placed over each other, and arranged in such a manner that the flues heat them both. If desired, a third oven may be built above the second, and the heat distributed to the whole three. The heat of the furnace first passes through flue No. 1, underneath bottom oven, and subsequently through flues Nos. 2 and 3, thus heating both the top (crown) and bottom (sole) of each oven of the series. Their arrangement is subsequently described in detail.

Construction and Materials.—The oven is solidly built of the very best materials, with walls two feet in thickness, thus ensuring retention and "solidity" of heat, and securing economy of fuel. The furnaces

PLATE XIII.



COMBINATION CLIMAX OVENS.

and all lower flues are built throughout of fire-brick, cemented together by fire-resisting cement. The soles of the ovens are constructed of a special variety of stone, retaining the heat well, and yet not burning the lower crust of the bread. As there is a flue between the crown of one oven and the sole of that above, the crown is built of thin fire-clay tiles, with all joints rebated and cemented together. This construction permits the passage of heat readily into the oven, but still without that danger of burning resulting from the employment of iron. From the materials used, the baking chamber has the whole of its internal surfaces of either brick or stone, thus ensuring a remarkably steady radiation of heat, such as will ensure efficient baking without burning. The oven is very economical in floor space, all the furnace and flues being contained, if necessary, within the area of the oven itself and its two-feet walls. Where practicable, it is well to have a greater thickness of wall at the back, but, if desired, all forms of the oven may be made only two feet deeper and four feet wider than the actual oven space provided for baking.

Flues and Dampers.—The success or otherwise of an oven such as the Climax depends on the proportions of the flues and thickness of the brickwork between them and the baking chamber. This in the oven being described has been carefully worked out experimentally, so as to ensure even and equable heating in each oven. With the heat passing successively, as before described, through each flue, Nos. 1, 2, and 3, each oven is regularly heated, that at the bottom of course being somewhat the hotter. All flues are perfectly straight from front to back, and so planned that, without any trouble, they are immediately accessible for inspection or cleaning through properly placed soot-boxes. There are, in addition, auxiliary passages, by which a portion of the heat may be allowed to pass direct to the upper parts of the series of ovens, control over them being obtained by the use of dampers, which may be opened or shut. The object of these is to provide for the further heating of the upper ovens when desired, independently of the bottom one.

Continuous Baking.—The arrangement of flues exterior to the baking chamber permits the firing to be done independently of the baking, so that by maintaining a small steady fire, batch after batch may be baked indefinitely. By a proper proportioning of the flues, the utmost limit of profitable economy of fuel is secured: that is to say, as little fuel as possible is burned consistently with regular baking. It must not be forgotten that it is easy to allow the heat more ready access into the oven by the employment of thinner soles and thin iron crowns, for example, but beyond a certain point any problematic saving of fuel by adopting such a course is more than compensated by irregularity in baking, and probable burned or unbaked bread.

"*Decker*" *Ovens.*—It has been already explained that these ovens may be built in series one over another: when so arranged they are termed two or three-decker ovens, the phrase evidently being of naval origin. Several advantages accrue from this arrangement of ovens; first of all, there is a gain in space, as more oven accommodation is obtained on the same floor space. Further, the upper ovens of such a series are heated by the waste heat of the lower, and thus a great economy of fuel results. The object in such ovens is to utilise the whole of the heat of the fuel, only such amount being allowed to remain in the waste gases when they find their way into the chimney as is required for the purposes of efficient draught. Other advantages will be evident when subsequently dealing with the mode of working these ovens.

Peel Ovens.—This term is descriptive of the manner in which the oven is loaded with bread and other goods and afterward emptied. The older method consisted in having a comparatively small oven door, from eighteen inches to two feet wide, and introducing and withdrawing the bread by means of a species of long-handled spade, called by the baker a "peel." Hence the name of peel ovens. The worst of the peel is that it is a slow method of loading and unloading; with the ordinary workman an average of some fiteen minutes is taken to load or unload an oven holding the bread from a sack of flour by means of a peel. As the loaves first put in must be those withdrawn last, some of the bread will be baked about half an hour longer than the rest, and must, consequently, be over-dried and lessened in weight. This is to a certain extent compensated by having ovens which are so fired as to be cooler at the back than the front.

Oven Lights and Pyrometers.—With the use of a small peel door, it becomes necessary to have some means of artificially lighting the interior of the oven. The old method of so doing consisted in having a swing gas arm, which was turned into the oven when the door was opened. Among later and pleasanter devices is that of having a separate light box built into the brickwork: the front of this consists of a sheet of mica, immediately behind which is the gas light. So arranged, the gas illuminates the interior without itself being within the oven. The light is easily regulated from the outside of the light box, and has conveniently a small bye-pass by which the flame is kept alight the whole time, while the main supply is turned off by pressing a button or turning a tap.

In order to ascertain the temperature of the interior of ovens, they are usually now fitted with a pyrometer or high temperature thermometer. The pyrometer depends in its action on the unequal expansion of the various solids of which it is constructed, and registers the result on its dial, which is built into the face of the oven. A pyrometer measures fairly accurately the baking condition of the oven at one time as compared with another; but must not be too implicitly relied on as an indicator of absolute temperature.

536. Climax Drawplate Oven.—The slow process of loading with the peel has led to the design of oven in which the contents are inserted and withdrawn mechanically. Ovens of this kind were first employed for biscuit baking, such ovens having some form of travelling plate. More recently the travelling plate, called briefly a "drawplate," has been introduced into bread-baking ovens. The Climax oven from its earliest inception has been fitted with a drawplate, and as a matter of fact was designed in this form prior to its employment as a peel oven.

The principle of the drawplate depends essentially on having a sliding plate or tray which is withdrawn from the oven, loaded with bread, and then returned.[1]

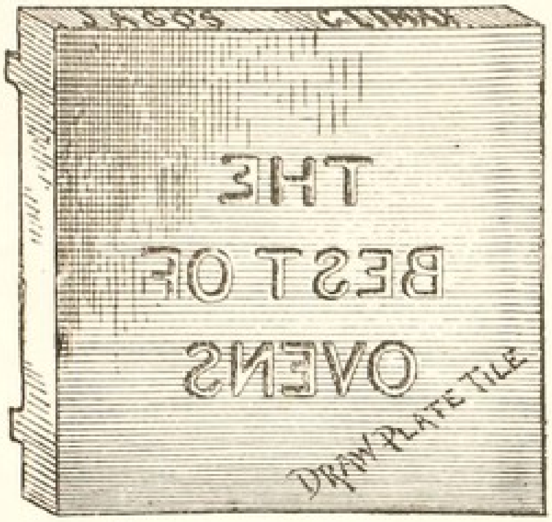


FIG. 56.—CLIMAX OVEN DRAWPLATE TILE.

The drawplate of the Climax is distinguished from all others by not having an iron baking surface. It consists first of a skeleton iron frame mounted on wheels. On this frame are laid, edge to edge, special red baking tiles, so as to form a continuous baking surface. These are cemented in place, and in this way all the disadvantages of baking on iron are entirely obviated, the bread being baked both on the top and bottom with heat evolved from tiled surfaces, by which are afforded all the advantages of a brick oven. These tiles are made of such a size that each just takes a loaf, and on each may be sunk any required name or device, thus automatically marking the bread in a most distinctive manner: a single tile is shown in Figure 56.

Running Arrangements.—It is evident that, considering the weight of a loaded drawplate, it must be well designed and made, in order to run easily. The Climax plate is carried on large wheels about ten inches in diameter, running on rails within the oven, and extending a few inches only outside the oven door. One great objection to drawplates as originally designed was the great space they occupied within the bakehouse, as permanent rails at the same height as those within the oven had to be fitted so as to carry the plate when run out. The Climax drawplate is arranged to run on a small carriage as it leaves the oven, the wheels of which run in counter-sunk rails which are exactly level with the floor. As the plate is pushed into the oven, the carriage is left close to the oven door, and thus when the oven is closed the whole of the space in front is left clear from all obstruction. The general arrangement of the carriage and drawplate is shown in the pair of combination deckers on Plate XIII., but it may be of advantage here to explain somewhat more in detail the working of the carriage. The right hand illustration in Figure 57 shows the oven door closed over the rails, which are projecting in front. The upper part of the carriage, at B, has a recess cast in it, which corresponds with a notch cut in the front-bearing rail of the drawplate. On pulling the plate out of the oven the vertical edge of this front rail, D E, passes over B C, the height of the cut notch being just sufficient to clear B C, while its sides prevent any lateral play of the drawplate on the carriage. As the plate

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[1] The old-fashioned domestic oven fitted with withdrawable baking sheets is a rudimentary drawplate oven.

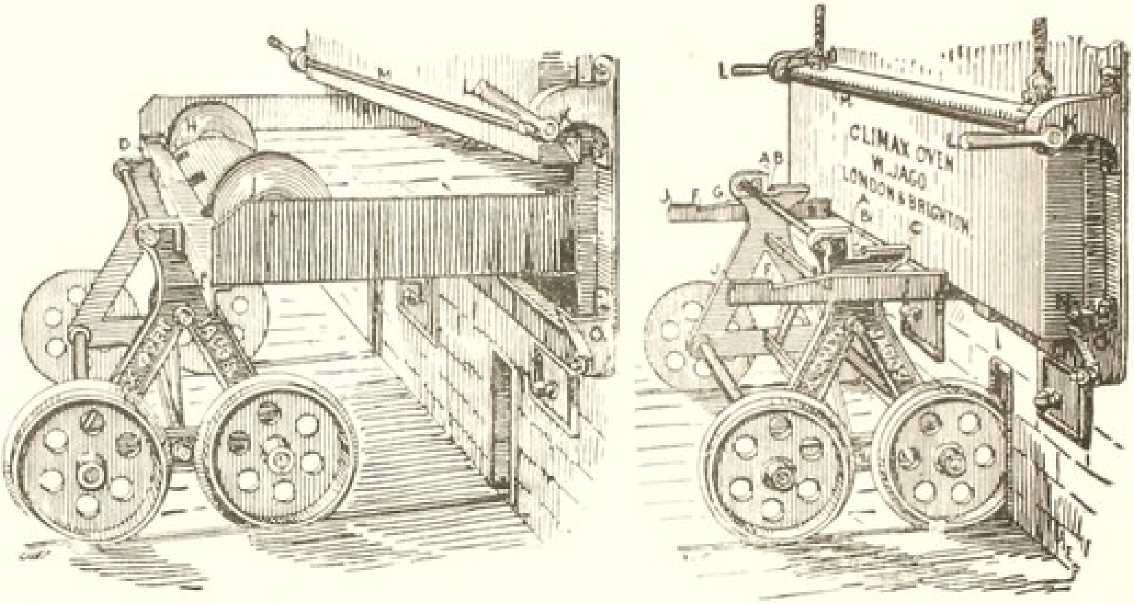


FIG. 57.—CLIMAX DRAWPLATE CARRIAGE.

is drawn further out, the front rail presses against A B, and pushes the carriage before it: when the plate has travelled sufficiently far for its running wheels, H I, to descend into the incline marked F G, on the ends of the rails, the whole plate gradually descends bodily, and the notch in its front rail drops into that marked B of the carriage, and so the two are securely interlocked. The little piece, F J, of the rail is cut sufficiently low to permit the wheels to run over without touching. When the plate is entirely withdrawn, a catch at the back of the plate descends into the recess, F, and effectually stops further forward motion. On repushing the drawplate into the oven, it travels on the carriage until the drawplate wheels pass over J F, and commence the ascent of the incline, F G. The plate rises, and thus has its front rail once more lifted out of the notch, B, on the carriage, from which it is consequently liberated, and travels into the oven. In this manner a perfectly simple but absolutely effective automatic locking and unlocking arrangement is provided between the plate and the carriage. Should any attempt be made to draw the plate without the carriage being in position, the whole would simply run down into the recesses, F G, and be stopped there by the notch, F.

A necessary consequence of the use of the drawplate is that the oven door must be made sufficiently wide to permit its withdrawal. As seen on Plate XIII. the door hangs by chains from an overhead spindle, being counterbalanced by weights on the other ends of the chain. (If wished, these weights may be arranged to run the other side of the front oven wall, and over the oven.) When free, the weights are just sufficient to keep the door open: the shutting arrangements shown in Figure 57. The rod, M K, has a small eccentric at either end; when the handle, L K, hangs vertical, the door is free, and easily slides up and down. On raising L K to the horizontal position, the eccentrics grip the door and hold it firmly at any part of its travel. When the door is closed, a V-shaped lug, N, on its lower edge drops into a corresponding recess on the frame, O, thus holding the lower edge close to the framework. The eccentrics, on being tightened, tend not only to grip the top of the door against the frame, but also to force it as a whole downwards, thus tightening its joint over the whole of the face.

537. Advantages of the Climax Drawplate.—The preceding paragraph describes the essential points of the drawplate; a few words may appropriately be here introduced as to its advantages over all forms of peel oven. In the first place, it can be loaded with great speed. With an oven of sack size it is no uncommon thing to open the oven door, draw the plate, load it, run in the batch, and again close the door in one minute and forty seconds. So, too, the unloading can be performed in equal time. Contrasting this with the time occupied in filling and emptying an oven with a peel, it at once becomes apparent that greater rapidity of baking is attained in this oven than is possible by any other means. Further, the drawplate does not require the services of experienced "setters," and consequently less expensive labour is necessary; while in case of emergency these ovens could be filled by hands absolutely unaccustomed to the baking trade, a matter of impossibility with a peel oven. In the next place, all the bread is in the oven the same period of time, and so absolute equality of baking is attained. In consequence of this there is a much less loss of weight of bread while baking. A most substantial economy is effected in this manner; for it is evident that when some loaves are in the oven twenty minutes to half an hour longer than others they must lose more in weight. The actual amount of the saving in weight attributable to the Climax drawplate has been estimated by a number of users of this oven at a half-ounce per 2-lb. loaf. The best evidence of the quality of the baking is the testimony of those who have seen the oven at work. The bread is characterised by a perfect bloom, and the loaf is bolder and finer than that baked in iron surface ovens (whether crown or sole). Doubtless this is due in part to the fact that the ovens are perfectly steam-tight: this property also enables the oven when desired to produce bread with a very thin crust. On the other hand, there is no difficulty in obtaining bread as crusty as can be wished.

The automatic marking of the name on the bottom of each loaf by means of the drawplate tiles has considerable commercial value as an advertisement.

538. Combination Double-Decker Climax Oven.—This being the type of oven most generally useful, is selected for illustration on Plate XIII. As the name implies, it is a combination of a lower drawplate oven, with a peel oven above. The drawplate stands at a much less height from the floor than the sole of an ordinary peel oven, and so permits the oven above to be arranged at such a height as to be conveniently worked with a peel.

Discussing for a moment the general applicability of these ovens to bakery purposes, it will be well to classify these according to the main class of work done. There is first the factory bakery, where bread is baked in large quantities, to the exclusion of all other kinds of goods. On the other hand, there is the smaller bakery, in which a mixed trade is being done, one and the same set of ovens being required to bake bread, pastry or "small goods," and cakes.

The ovens photographed were an installation ordered for a large wholesale trade confined to bread only: unfortunately, during the preparation of this work for the press, the whole bakery has been destroyed by fire, but the author has just been commissioned to rebuild same precisely as erected in the first instance, thus showing most conclusively their general value and suitability.

Firing.—It will be of service to describe such modifications in the methods of working as the use of special ovens such as these requires. Taking first the case in point, where a large bread trade is being done. Assuming that work is started at 4.0 A.M., it is well to fire the ovens overnight. During the day time the furnaces and ashpits will have been thoroughly cleared out. If practicable, the fires should be started by taking some live (red hot) coke from another furnace, and placing it in that of the oven. Failing this, it is well at the close of working the ovens, after cleaning out the ashpits, to throw in them a few shovelsful of clean coke, and shut the doors on it. The warmth of the ashpit will thoroughly dry the coke, and thus render it much more easily ignited. Make up the fire with a very few sticks (old butter tubs answer admirably) and this dry and warm coke; with a little care the fire lights readily. **In flue ovens coal should never be used: if properly designed, they work efficiently with coke, and coal very speedily chokes the flues, and detrimentally affects the baking properties of the oven.** For a similar reason an oven furnace should not be used for burning egg shells and all the general waste and débris of a bakehouse. When it is insisted on, there is no difficulty in getting the fires lighted and started with coke. A word may be said as to the quality of coke employed for oven firing—the best is the cheapest. Retort coke (*i.e.*, that obtained from the retorts of gas-works) is better than oven-coke (*i.e.*, coke manufactured in coke ovens). A hard, clean, porous coke, in cauliflower lumps, is that best suited for oven firing. It must not be soft or dusty.

The fires being started, the furnaces should be filled with coke, the main damper should be drawn full out and the furnace doors closed, those of the ashpit remaining open. Let the fire in this manner draw up until perfectly bright right through, then partly close the ashpit doors and push in the main damper until there is only just enough draught to cause slow but clear combustion. A very little experience shows the right point for this. In the morning the ovens will be very nearly at baking heat, while the fire will be still alight. Draw out the damper and make up the fire first thing in the morning, so as to supply heat for maintaining the ovens at baking temperature.

Nature of Coke Combustion.—This is of great practical importance in connection with the whole subject of the firing of oven furnaces, and so merits a somewhat careful examination. First of all, coke has the advantage of producing an absolutely smokeless fire, and so all soot deposits and their inconveniences are entirely obviated. On the other hand, the combustion of carbon being the burning of a flameless solid, the heat produced is not only intense, but also very local, so that the furnace itself is very hot, compared with that of flues at some little distance. This requires careful designing, so that due provision shall be made for the ready transmission of this local heat: granted proper arrangements, however, this localisation of heat in no way interferes with the perfectly efficient working of coke fired ovens.

Although coke burns flamelessly, yet one usually sees more or less pale blue flame over the surface of a coke fire. This latter is due to the formation and subsequent combustion of carbon monoxide according to the following equations. The air, in passing up through the red hot coke of the fire, forms carbon monoxide, thus:—

$$\underset{\text{Carbon.}}{2C} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad = \quad \underset{\text{Carbon Monoxide.}}{2CO.}$$

The gas rises to the surface, and there, on meeting with excess of air, undergoes combustion, thus:—

$$\underset{\text{Carbon Monoxide.}}{2CO} \quad + \quad \underset{\text{Oxygen.}}{O_2} \quad = \quad \underset{\text{Carbon Dioxide.}}{2CO_2.}$$

In this way the production of carbon monoxide indirectly causes a flame combustion from coke, and thus produces heat in such a form as to be more readily conveyed away, so far as the flames will reach, from the furnace into the flues. But unless complete combustion of the carbon monoxide occurs, there is a very serious loss of heat. This is readily seen by studying the thermal effect of the burning of carbon and carbon monoxide respectively. One gram of the former evolves during combustion 8080 heat-units, while the same quantity of the latter produces 2634 heat-units. From the equations above given it is readily calculated that 1 gram of carbon produces 2·33 grams of carbon monoxide. And further, this quantity of carbon monoxide must produce in burning

$$2{\cdot}33 \times 2634 = 6146 \text{ H.U.}$$

But as the gram of carbon only evolves 8080 heat-units, we have $8080 - 6146 = 1934$ H.U. produced in the burning of 1 gram of carbon to monoxide.

Summing up—

	Heat Units.
Heat produced by 1 gram of carbon burning to monoxide,	1934
,, ,, ,, the combustion of the carbon monoxide yielded by 1 gram of carbon, ...	6146
Total, ...	8080

Whatever quantity of carbon monoxide therefore escapes combustion, means a loss of over three-quarters of the heat-producing power of the carbon it contains. To prevent this loss, air should gain access to the coke gases after they leave the coke. In practice this end is attained by letting the furnace doors be slightly open—it is possible, however, by having the opening too big, not only to cut off the draught from the fire, but also to absolutely cool the oven by the admission of excess of cold air into the flues. Theoretically, the right thing would be to keep the furnace closely shut, and thus favour the production of carbon monoxide, providing for its combustion, *beyond the fire*, by admitting air on the flue side of the "bridge," or back wall of the furnace. Such an opening would need to be regulated so as to admit the exact quantity of air with the utmost nicety, as too little would mean imperfect combustion, and too much a direct cooling of the oven. The practical difficulties of such an arrangement more than compensate any theoretical advantages.

Not only among those in charge of ovens, but also furnace-men generally, there is a widely spread opinion that the admission of steam between the fire-bars into the fire is greatly advantageous. To such an extent is this view held that fire-bars have been patented and used in boilers, which are made hollow and perforated for the admission of steam upwards into the furnace. From extensive experiments that have been made by large steam users, and which have come under the author's notice, he is assured that a distinct saving of fuel is gained when measured by that most crucial of all tests, a three months' fuel bill. In these tests the only difference made was that steam-admitting bars were substituted for the ordinary solid fire-bars. Furnace men obtain roughly the same effect by placing vessels of water in the ashpit, by the evaporation of which a supply of steam is produced.

The claimed advantages are (1), comparative absence of clinkering, and concurrent longer life of fire-bars; (2), clearer fire, better draught, and consequent more even heating of oven; (3), saving in fuel. The existence or otherwise of these benefits is best determined by individual practical experiment, and will probably vary according to type of oven and character of fuel employed. But, assuming that the number of observers who unite in these opinions are not entirely mistaken, it is well to inquire whether such opinions have any scientific justification.

Clinkering is due to oxidation of the iron of the bars, and subsequent fusion of such oxide into a slag, by combination with siliceous matter from the coke. So far as steam helps to avoid clinkering, it is probably due to its exercising a local cooling effect on the bars. If clinkers are avoided, there is necessarily a clearer fire, and as a necessary consequence a better draught, as the air finds its way through more readily. Good draught tends to prevent the formation of clinkers, and the absence of clinkers helps the draught, so that each of these reacts favourably on the other. A general result is a more even distribution of heat throughout the oven.

The third claim of saving of fuel requires careful examination. It will be best to first deal with the chemical changes produced by the passage of steam over red-hot coke; carbon monoxide and hydrogen are evolved in abundance according to the following equation:—

$$\underset{\text{Carbon.}}{C} + \underset{\text{Water.}}{H_2O} = \underset{\text{Carbon Monoxide.}}{CO} + \underset{\text{Hydrogen.}}{H_2}.$$

Subsequently, with excess of air we have,

$$\underset{\text{Carbon Monoxide.}}{CO} + \underset{\text{Hydrogen.}}{H_2} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Carbon Dioxide.}}{CO_2} + \underset{\text{Water.}}{H_2O}.$$

It will be noticed that the same quantity of steam which passes into the fire escapes as such at the close of the combustion processes; therefore the steam neither increases nor diminishes the number of units of heat produced by the ultimate combustion of the carbon to its dioxide. Any saving can only possibly be due to the combustion being to a much greater extent a gaseous one; and, as has been before explained, gaseous combustion means more ready and even heat transmission, and therefore economy. Absence of clinker and improved draught are in themselves of course indirect sources of economy of fuel. It is a somewhat popular error that a gain due to an absolutely increased amount of heat is effected in this case by the combustion of the hydrogen produced: it must be remembered, however, that precisely the same quantity of heat is required for the dissociation of water into its component gases as is set free by their subsequent combination. Consequently, no outside heat is liberated by this decomposition and re-combination of the constituents of water.

Chimney and Dampers.—The proper manipulation of the draught is a most important point in oven management; and first of all it is necessary to insure that the proper means for obtaining a draught are in existence. To commence with, a hermetically sealed stokehole cannot yield a draught: there must be ample provision for the free admission of air to the furnaces. Further, there must be a sufficiency of chimney to create a brisk current of air through furnace and flues. The cost of erection of a chimney is comparatively little, and unless that already provided is absolutely beyond suspicion, it is the most economical course to build a fresh chimney for a new oven. Such chimney should be of sufficient sectional area, carried well above neighbouring roof-ridges, and preferably built straight up from the back or side walls of the oven itself. Its thickness should be sufficient to prevent water being driven through the substance of the brickwork: for the same reason close-textured bricks should be selected. The sectional area should be maintained throughout the whole length of the chimney; and on no account should the chimney be spoiled by having a small diameter pot placed on its summit. Whatever advantage the greater height of a pot gives is far more than taken away by the diminished sectional area it causes. It is therefore far better to carry up the chimney itself to the requisite height, simply finishing the work in cement, or placing on a plain cast-iron cap.

The position of dampers varies somewhat with each individual oven, but a few hints may be given as to their general management. Taking the combination oven, both ovens to be used for bread, the top oven is required to be as hot as the lower. It is therefore generally found best so to arrange the dampers that all the heat passes under the draw-plate oven, and then has the passage to the middle or No. 2 flue, and also that direct to the top or No. 3 flue, both open. A portion of the heat then passes through both Nos. 2 and 3 flues, and another portion direct to No. 3 flue. This arrangement of dampers when once made rarely requires disturbing, and is very suitable for bread-baking in both ovens.

It will probably be more convenient to continue the description of the use of the ovens for exclusive bread manufacture; work of the dampers for a mixed trade will therefore be referred to subsequently.

Mode of Working Ovens.—Assuming that fires have been made up at 4.0 A.M., as soon as the pyrometer shows any signs of rising, thus demonstrating that the heat of the ovens is solid, close the main damper and furnace and ashpit doors. Should the lower oven have become too hot during the night (a thing which with ordinary care need never occur), the drawplate should be drawn and allowed to cool; this will much diminish the heat of the oven on its return. Allowing the oven door to remain open an inch, and keeping the steam damper which is at the back of the oven open, will draw a current of air through the oven, and cut off undue top-heat. The ovens being at the right temperature, the bread will probably be ready to go in about 6.0 to 6.30. The top oven should first be filled with the peel, and then the drawplate loaded.

The working with the drawplate needs rather different treatment of the bread than does the peel oven. It must be remembered that the whole of the oven load goes in at once: therefore all the bread must be allowed to get a fair degree of "proof" before being put on the plate. For this purpose get all the help available on the bread on the moulding table, and as quickly as possible place the moulded loaves on boards about 7 ft. long by 2 ft. wide. If cottages are being made, the top and bottom of each cottage must be placed on the board side by side. Cover over the bread with a piece of flannel, so as to preserve from "skinning" by contact with cold air, and place these boards in a rack provided for the purpose. (In cold weather it is an advantage to have a curtain which will let down over the front of this rack.) As soon as the whole of the bread has acquired a sufficient amount of proof, the oven plate should be withdrawn, the door shut behind it, and the loading *at once* commenced, and carried through with the utmost celerity. Two hands who act as setters should place themselves one on each side of the plate, commencing at the back, and two others should bring up a board, laying it across the plate. Cottage loaves should have their tops "bashed" on while on the board, and then be placed on the centre of a tile. "Coburgs" or "Brunswicks" should be placed on without being cut, the whole oven load being scored with the knife last thing after loading. While the setters are loading up the bread of one board, the other men should bring up the next board, and take away the empty one, continuing this until the plate is filled. If there are only two men, they must of course fetch and carry bread boards for themselves. The object is to load as quickly as possible, and this should be effected in from one and a half to four minutes, according to the kind of bread and the amount of help available. The back of each plate is provided with a water "upset" (cast-iron water vessel). This, on being filled, cuts off any back or top heat, and at the same time adds materially to the bloom and appearance of the bread. Experience is soon gained as to the right quantity of water to be used, which will depend somewhat on whether the oven is full hot, or only at average temperature. When the bread is about half baked, the fires may be made up, and the oven reheated in readiness for the next batch. Working sharply in the way indicated, the lower oven of bread may very possibly be the first ready, in which case the plate should be withdrawn, unloaded sharply, returned, and the upper one drawn with the peel. By the time the interval of unloading the upper oven is over, the next batch of bread will be approaching readiness. It will be moulded up, and probably the drawplate again filled, after which follows the peel oven. The object of this arrangement is that, if anything, the upper oven does not acquire so high a temperature as the lower one, and therefore it is not well to follow on quite so rapidly with baking in it as is done with the lower drawplate. Where both quartern and half-quartern loaves are being made, it is a good plan to use the upper oven for the former, as the slightly lower temperature suits the longer soaking required for the larger loaves.

Use for Mixed Trade.—Here the arrangements will slightly differ, as provision must not only be made for bread-baking, but also for that of cakes and pastry. It is usually advisable to set the damper so that the heat passes through all three flues in regular succession. In this way the top oven is heated to a somewhat lower temperature than the lower one. A very good plan is to keep the dampers out, as before suggested, for the greater heating of the top oven during the night, and then first thing in the morning to shut off the direct passage to No. 3 flue. This will give a hot top oven suitable for a first batch of bread, simultaneously with the drawplate, after which the top oven becomes cooler, and may be used for baking cakes. With the two ovens thus arranged, the lower one is at a high bread-baking temperature, and may be maintained at that point, while the upper oven is cooled down for other purposes. If the baking of bread and other goods in the upper oven has not lowered its temperature sufficiently, it may be still further cooled by opening the door and also the steam damper; the current of air, which passes through readily, brings down the temperature to any desired point. For many mixed trades the three-decker with yet another upper oven is found useful. This provides for the baking of very low temperature goods, such as bride- and other rich cakes. The third oven is easily reached by means of a step fixed on the drawplate carriage.

Peel Ovens.—These call for no special remark as to use; they follow very closely the lines of ordinary ovens, except that they are continuous. The dampers are generally best left so that the heat finds its way direct to the crown of the lower oven and the upper oven; by this means a sharp top heat, and consequent good bloom on bread and other goods, is obtained.

Vienna Ovens.—Very successful Vienna ovens have been built on the Climax principle. The essential point about these ovens is that they are sloped upwards from the mouth, the object being to ensure the retention of steam, which, being lighter than air, always tends to rise. The slope is so arranged that a peel laid upon the sole just clears the top of the door, as shown by dotted line in Figure 58. When the steam is let in by pipe marked s, it gradually fills the oven, displacing the air until the level of the steam

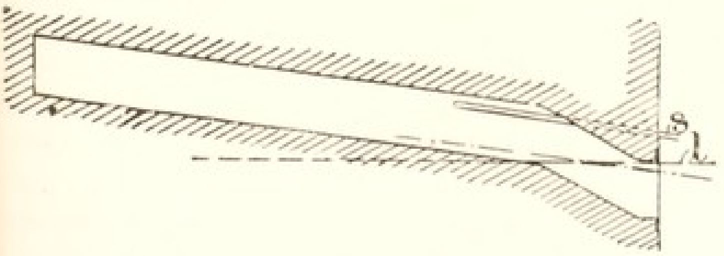


FIG. 58.—DIAGRAMMATIC SECTION OF CLIMAX VIENNA OVEN.

reaches the top of the oven door as shown by the dotted line L. As previously explained, the result of baking in this manner is the production of a glaze on the bread or rolls.

Climax Vienna ovens may be either built separately in one or two decks, or the Vienna oven may be erected as the upper oven of a combination decker.

539. Water Heating.—The most convenient method of providing a hot water supply for bakery purposes is by means of a boiler built into and forming part of the oven structure. A small boiler may be placed in one of the flues in close proximity to the fire, and connected up by means of flow and return pipes to the hot water cistern. This course, however, is not recommended, as it is not advisable to interfere with the brickwork so close to the fires. A much better plan is to place a larger heating boiler on the top of the oven, and carry the oven flue round it after it has left the crown of the top oven. The boiler here is easily accessible, and has the advantage of being heated entirely by waste heat after it has left the oven. The flow and return pipes should be at least 1½ inches bore, and should be connected up in the ordinary manner with a supply cistern at the top of the building. Pipes will be led from this to the attemperating tank and any other hot water draw-offs.

540. Other Baking Appliances.—In a modern bakery there are other mechanical appliances which considerably lessen labour, and enhance cleanliness. Where ferments are used, there are apparatus for washing and cooking the potatoes. There are also portable racks, carriages, and trucks for the conveyance of dough and bread. Description of these scarcely however fall within the scope of the present work.

541. Bakery Registers.—An almost integral part of the economy of a machine bakery, and in fact any bakery of modern pretensions, is a register of particulars of the making of each batch of the day's work. This should be in book form, and affords, when properly kept, a most valuable record of work done, and also gives the means of checking same from day to day. The author has had printed a register in which the following is the heading of the day's work :—

BAKEHOUSE REGISTER.		TEMPERATURE.	
		DAY.	NIGHT.
................................189...	Highest ...	......	......
	Lowest ...	......	......

Temperature of bakehouse at time of setting 1st sponge......

There then follow the various column headings, arranged right across two pages of the book, in the following order :—Number and kind. Water (quantity). Temperature. Yeast, kind and quantity. Salt. Flour. Flour temperature. Sponge when set. Temperature when set. When taken. Remarks. Time when taken. Water. Temperature. Salt. Flour. Dough temperature. Oventime. No. of Loaves. Remarks.

Such a register may be amplified, simplified, or modified, according to the requirements of any particular mode of working. The system of testing the temperature of a sponge when set, and when taken, often gives useful information as to its condition. With any uniform method of working, the amount of rise in temperature is very nearly a constant quantity. When the rise is excessively low, the sponge is likely to have been starved or the yeast weak; if, on the other hand, there is an abnormally high rise, the fermentation will have been too vigorous, and have proceeded beyond its proper limit. In either case a useful diagnosis of the condition of the sponge is afforded at a time when it is possible to take steps toward remedying either evil.

CHAPTER XX.

ANALYTIC APPARATUS.

542. Commercial Testing and Chemical Analysis of Wheats and Flours.—The remaining portion of this work will be devoted to practical directions for testing and examining wheats, flours, and breads. As a matter of convenience, the various analytic operations are divided into two classes: first, those which are more readily performed, and which afford information having the most immediate bearing on the actual value of wheats and flours; and second, those determinations which are more purely chemical in their nature. The operations of the first class are comprised under the heading of "Commercial Testing of Wheats and Flours;" their nature is such that they may be performed personally either by the miller or baker. The second series of tests requires rather more chemical knowledge and experience: they consequently appeal more particularly to the students of milling and baking who have had the advantage of a course of chemical training in a properly appointed laboratory. The matter of the succeeding chapters has already in another form been largely used by such students of the author's as their practical text-book in the laboratory. It is also hoped that a knowledge of how the operations of chemical analysis are conducted will be of interest to other readers who may not have the time or opportunity of themselves going personally over the practical work. The chief reason why millers and bakers should understand analytic methods is not that they will continually be practising them in after life, but that they will often wish to make themselves acquainted with the results obtained by scientists and their deductions therefrom. These results can only be fully understood and their exact bearing appreciated by those who are familiar with the methods by means of which the results are attained.

A description of the laboratory, and of the principal analytic apparatus used in weighing and measuring, will now be given as an introduction to analysis.

543. The Laboratory.—For the benefit of any millers and bakers who may wish to fit up a laboratory for themselves, the following few hints as to utilising a room for the purpose are here inserted. If any work is to be done beyond the roughest experiments, a balance and microscope will be requisite; these delicate instruments must be kept free from dust, and so cannot be exposed to the ordinary atmosphere of the mill; they should therefore be placed in either a private office or study, and covered over when not in use. For the other purposes of a chemical laboratory, almost any room, or part of a room, can be made to answer. A working bench or table should be fitted in as good a light as possible, at a convenient height. Gas, when obtainable, should be laid on to this bench by means of a pipe terminating in a nozzle, over which a piece of india rubber tubing can be slipped. There should be near at hand a drain, over which is fixed a tap, with a good water supply. This tap should also have a small side tap, with nozzle for india-rubber tubing, in order to lead water into any apparatus in which it is required. These are almost the whole of the necessary fixings. There must of course be a few shelves on which bottles and the various apparatus may be kept. With time and money to spare, many additional fittings might be suggested. These can, if wished, be added afterward.

544. The Analytical Balance.—It is presumed that the student will have, before attempting the following work, made himself familiar with the simpler chemical apparatus, by their actual use in the laboratory. Quantitative analysis, as its name implies, is that species of analysis by means of which the quantity or amount of each ingredient in any particular body is determined. For purposes of analysis, quantity is measured and expressed either by weight or by volume. Accordingly, the chemist first of all requires some accurate means of determining with exactness both weight and volume.

For purposes of weighing, an accurate balance and set of weights are necessary. Of these there should be in a laboratory at least three of different degrees of sensibility. Taking the most delicate first, let us describe what may be termed the "analytic balance proper." This instrument requires to be made with the utmost care and accuracy—the figure given is an illustration of an analytical balance known as the "Sartorius" balance. The speciality of this particular variety is that the beam is very short; it is claimed for it that, as a result, the delicacy of the balance is increased, while the time in which a weighing is performed is lessened. The writer has had one of these balances in use for some time, and is able to speak well of them from practical experience.

On referring to figure 59 it will be noticed that the balance is enclosed in a case; the bottom of this consists of a stout slab of glass, fixed on levelling screws. The front, back, and sides of the case are glazed; and all open, the front and back by sliding up, the two sides on hinges, as doors. The beam is suspended on a pillar, which in turn is screwed down to the bottom of the case. The beam carries at its centre a knife-edge made of agate; this rests on a plane of the same material; on each end of the beam there are similar knife-edges, and from these depend the scale pans. When the balance is not in use, the beam, instead of bearing its weight on the knife-edge, rests on a sort of cradle; so, too, the end hooks carrying the pans are likewise supported by the cradle. Underneath each pan there is also a small support on which the pans rest until it is required to set the balance in action. In the centre of the front of the balance, and immediately underneath the glass base, is fixed a large brass milled head; this, on being slowly turned by the operator, first lowers the supports from beneath the pans, then drops one portion of the cradle, and so suspends each scale pan from the terminal knife-edges of the beam, and next lowers the central knife-edge on to its agate plane, and permits the balance to swing. On turning the milled head back again, the opposite of these movements takes place in reverse order, and each knife-edge is gently

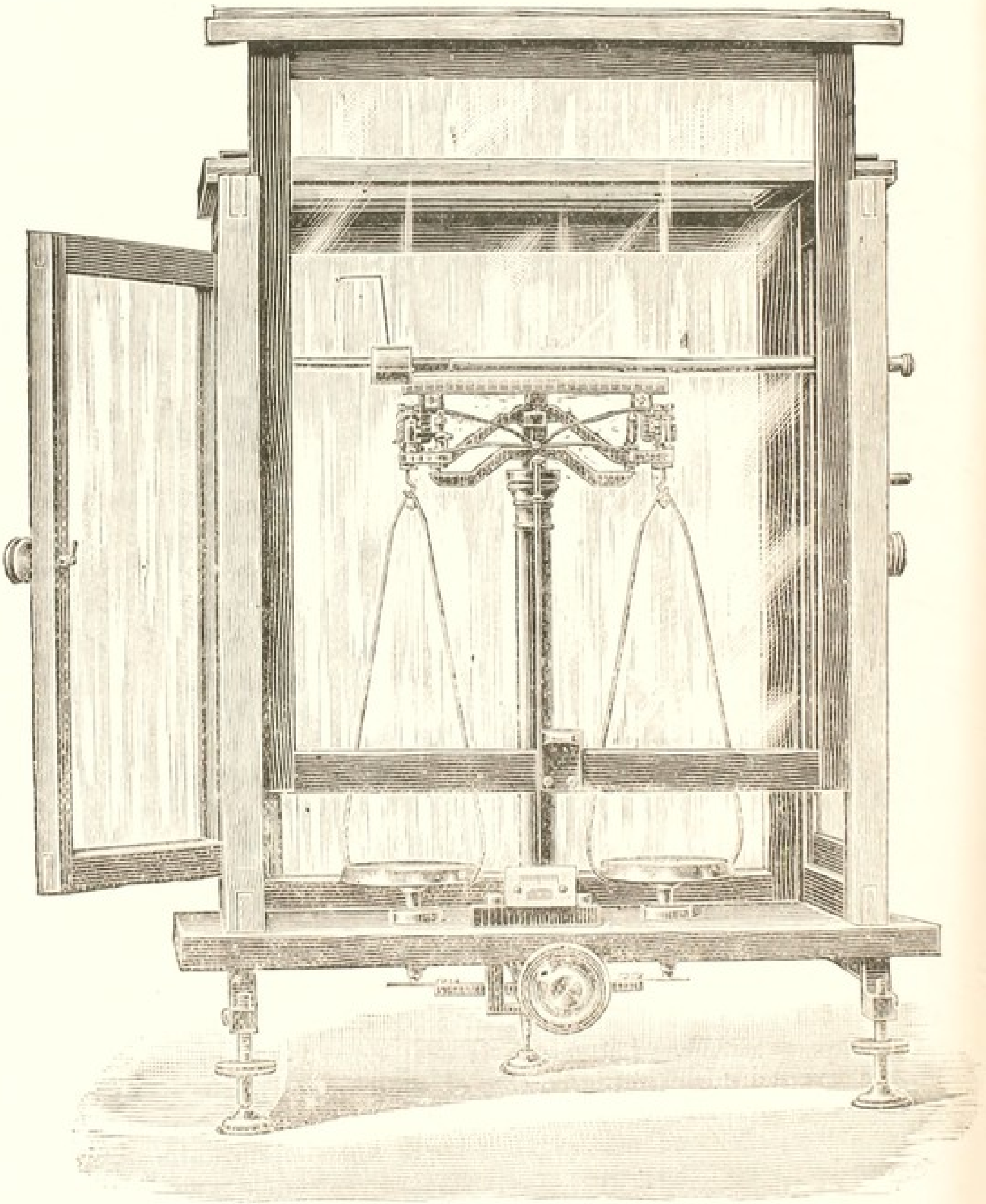


FIG. 59.—SHORT BEAMED ANALYTICAL BALANCE.

lifted from the agate plane. The object of this is to prevent wear of the edges by their being continually in contact, particularly as a balance would soon be seriously injured by the jarring caused to knife-edges and planes by putting on and removing weights while these were in contact. It must be borne in mind, as a golden rule of weighing, that **nothing must be added to or removed from either pan of the balance when the instrument is in motion.** In order to show the movement of the beam, there is a long index finger descending from its centre and moving in front of an ivory scale at the bottom of the pillar. A description of the mechanism employed to effect these various movements is unnecessary, as they can readily be understood by a few minutes' careful inspection of the instrument itself. Some other attachments of the balance will be better understood when we come to describe the operation of weighing. If a student is working in a laboratory under the direction of a teacher, he will find balances there, and already properly adjusted ; in case that he happens to have purchased one for his private use, all the adjustments will have been made by the maker, and should not be interfered with by him unless he is thoroughly acquainted with the mechanism of a balance. It should always be borne in mind that a balance must on no account be altered or re-adjusted except by some responsible person ; there may be several persons working with the balance, and the one, by altering it, and possibly setting it wrong, may upset the work of all the others. Suppose a student has procured a balance for his own private use, let him place it in its permanent position, which should be on a stout bench or table in a dry room, and at a height convenient for weighing when sitting down. The light should, if possible, be from a window behind the balance; that is, the balance should be so placed that the operator is facing the light, which should not be glaring, while it should be good. A light coming from a high window behind the operator also answers, but a strong light from either side is not suitable for weighing. The first thing to do is to get the pillar of the balance vertical. In the Sartorius balance, a plummet hangs from the back of the pillar, immediately over a corresponding index point on the base ; the two levelling screws in front of the balance must be turned in one direction or the other until the plummet is directly over the index point ; the base of the balance will then be horizontal. In the next place carefully dust the beam and the pans with a camel's hair brush. Then turn the milled head which actuates the balance, and allow the beam to vibrate ; it will most likely swing one way or the other immediatly the beam is liberated, but if not, open the right-hand side door and waft a *very gentle* current of air down on the one pan with the hand. Close the door again, and watch the vibrations of the index finger ; it should be explained that all the sides of the case must be kept closed as much as possible during the operation of weighing. The little ivory scale has its zero in the centre, the divisions count each way from it, and are usually ten in number on each side. Should the balance be correctly adjusted, the index finger will swing the same number of degrees each side of the zero, and after a time, as each vibration becomes shorter, will come to rest over the middle of the scale. Strictly speaking, the distance travelled on each side must be slightly less than that of the other : thus, supposing the index travelled to 9 on the left hand, it would, when the balance is correct, swing slightly less than 9 to the right, say 8·9, and then back to 8·8 on the left. With a good balance this diminution is so little for one or two vibrations that practically we may say that it should swing equally on both sides.

Such a balance as that described is capable of weighing to the tenth of a milligram, with a weight of two hundred grams in the pan. In addition to this instrument a coarser balance is also necessary; this should be capable of carrying a kilogram, and weighing to the hundredth of a gram. Balances of this kind cost from thirty shillings to two pounds, and are similar in principle to that already described.

545. Adjustment of Balance.—In case when testing the balance the index does not swing to the same distance on either side of the zero of the scale, first of all again dust the balance most carefully, and test once more. In the event of this not removing the error, the beam must be re-adjusted; there will be seen two little balls, one on either side of the top of the beam, and running on two slender horizontal screws attached to the beam—on the side which is the lighter, screw the ball very slightly from the centre of the beam, and again test. Repeat this until the two sides of the beam exactly counterpoise each other. When once adjusted, a balance, if kept clean, needs no alteration for a considerable time, providing always that it be carefully and delicately handled. In different makes of balance the modes of adjustment vary. To describe these in full would go far beyond our present scope; the maker will, however, in every case either give directions or see to the proper adjustment of the instrument before it leaves his hands in case of its being a new one. For a very clearly written and most interesting chapter on the mechanical principles and management of the balance, the student is referred to Thorpe's "Quantitative Analysis," published by Longmans & Co.

546. Analytic Weights.—After the balance, the next thing required by the chemical student is an accurate set of weights. As a rule the chemist returns his results in percentages; it is therefore of not very great importance to him, from that point of view, what unit of weight he adopts. In England chemists either use grain weights or else those of the French metric system. When grain weights are employed, the set contains pieces varying from the hundredth of a grain to 1000 grains. From its much greater simplicity, weights of the metric system are now used to a much greater extent than grain weights. Not only is there this advantage of greater simplicity, but, in addition, they are fast becoming the international system for scientific purposes; for this reason, as well, it is highly advisable that all chemists and students of chemistry should learn to work with these weights. Those who have done so will be unanimous in looking forward with pleasurable anticipation to the time when they, or at least some similarly simple modification of our own unit of weight, take the place of our present complicated system of weights and measures. Whatever weights are employed a few very simple factors suffice to convert those of the one denomination into those of the other. In chapter I. is given a table of the most important metric weights and measures, together with their English equivalents.

The set of weights employed for analytical purposes must be of the greatest possible accuracy. They usually range from 50 grams to a milligram. The heavier weights are made of brass and then electro-gilded; the fractions of a gram are made of stout platinum foil. In shape, the brass weights are made slightly conical, and are each fitted with a small handle at the top, by which they must be lifted; for the same purpose each of the platinum weights has the top right-hand corner bent at right angles to the weight. These weights are arranged in a box, each being placed in a separate compartment, those for the gram weights being lined with velvet; the smaller weights are further protected by an accurately fitting cover of glass. For the purpose of lifting the weights a pair of forceps is provided; this has its place in the box. **Analytic weights must on no account be touched with the fingers.** Most sets of analytic weights contain the following pieces arranged in the box in the order shown below:—

50	20	10	10	5	
	1	1	1	2	
0·5	0·2	0·1	0·1	0·05	
0·001 0·001 0·001	0·005	0·01	0·01	0.02	Rider.

The student will require to learn, not only the denomination of each weight, but also its place in the box. He must be quite as well able to read the weights he has placed in the balance pan from the empty spaces as from the weights themselves. As soon as the weights are done with they should always be returned to the box; this should be further protected by being kept in a case made for it of wash-leather. The accuracy of all analysis depends on that of the weights; too great care cannot, therefore, be taken to preserve them from injury.

In giving the denominations of the weights above there is a place marked "Rider;" the nature and use of this particular weight remains to be explained.

The arrangement of the weights, as shown in Figure 60, corresponds with the table just given of their value. Special attention must be directed to the "Rider," which is drawn to its full size at A.

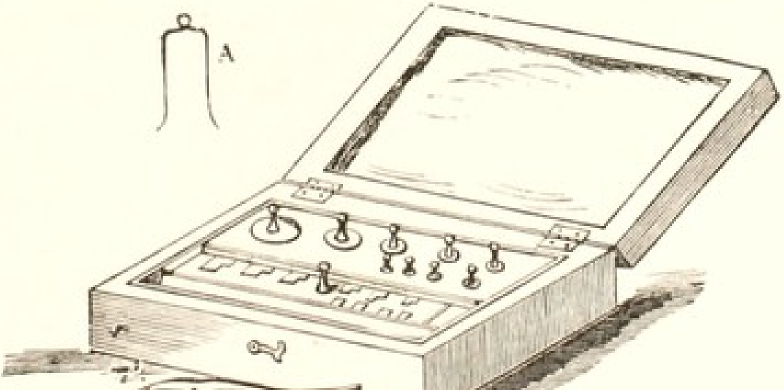


FIG. 60.—BOX OF ANALYTIC WEIGHTS.

The student must now refer again for a moment to the figure of the balance previously given; he will there notice, at the top right-hand corner, a milled head; this actuates a rod, at the other end of which, from a little hook, depends the rider, as shown just over the left-hand pan. From end to end of the beam itself there also runs a graduated scale; this scale is divided into twenty equal parts, the centre is marked zero, and the other graduations numbered 1—10 from the centre towards each end. Each of these units is still further subdivided into 5 or 10 equal parts. This scale is the exact length of the beam, measured from one to the other of the terminal knife-edges. An inspection of the balance itself shows immediately that, by means of the milled head and rod attached thereto, the rider can be placed astride the scale at any part of its length. The weight of the rider is one centigram, consequently, if placed in the pan of the balance, or at 10, the extremity of the scale, the effective weight of the rider is the same as its absolute weight. But if it be placed somewhere intermediate between the centre and end of the beam, its effective weight is between 0 and 1 centigram. The effective weight is governed by the well-known principle of the lever, namely, that the force exerted by any weight is directly proportional to its distance from the fulcrum. As each side of the beam is divided into 10 equal parts, the weight of the rider at each division is the number of tenths it is from the centre: thus, at 5, its weight is equal to $\frac{5}{10}$ of a centigram, or 5 milligrams, and so for each graduation and intermediate fraction. The employment of the rider in actual weighing will be gathered from the next paragraph.

547. Operation of Weighing.—We will suppose that the student has balance and weights in readiness, and requires to obtain the weight of some particular piece of apparatus; this, whatever it is, must be thoroughly cleaned and dried, and then placed on the left-hand pan of the balance. For this purpose the front of the case of the balance may be raised, or if working with a balance with side-doors, that on the left hand may be opened. **Two rules of weighing are: 1st, always place substance in left-hand pan, and weights in the right; 2nd, keep the doors of the balance case closed whenever possible.** Let the weight of the piece of apparatus in question, say a crucible, be 17·8954 grams; we will see how these figures have been arrived at. First take the 20 gram weight from the box by means of the forceps, and place it in the right-hand pan, release the beam from its support by turning the milled head: notice whether the left or right-hand pan of the balance is the heavier. In this case the weight will be too much, and the index finger will swing to the left. Bring the balance to rest by turning the milled head, and take out the 20 gram weight, and replace it by the 10 gram, try whether sufficient—not enough, add 5 grams—still too little, add 2—too little, add 1—too much. Do not forget that every time before a weight is added or removed the beam must be brought to rest on its supports; this is always to be done gently and carefully. After the addition of each weight the beam will have swung over more slowly; with the 18 grams in the pan the swing of the index to the left will have been much slower than any preceding it, showing that the actual weight of the crucible is being closely approached. Return the 1 gram weight to its place in the box, and next try 0·5 gram—not enough, add 0·2—not enough, add 0·1—not enough, add 0·1—too much. Replace the 0·1 and try 0·05—not enough, add 0·02—not enough, add 0·01—not enough, add 0·01—not enough. The weight has now been ascertained within a centigram, because the addition of another centigram would bring the weight up to the 0·1 gram, which has already been tried and found too much. The conclusion of the weighing should now be done with the rider. Place the rider on the 5 on the right-hand end of the beam, lower the supports, cause the beam to vibrate, and shut the door of the case. If necessary, waft with the hand a gentle current of air on to one of the pans in order to set the beam in motion. Count the number of graduations which the index moves on either side of the zero; it will be found to vibrate slightly more to the right than to the left. Next try the rider on the 6th division; this is found too much. Try the rider at intermediate distances until it is found that the beam swings through an equal number of graduations on either side of the zero scale; the weight in each pan is then the same. Let us now see how the weights are to be read; this should be done from the box, reading the empty spaces. In the case in point these are 10 + 5 + 2 = 17. Against "weight of crucible," write this number in the note book. Next read off the decigram weights; there are empty, 0·5 + 0·2 + 0·1 = 0·8; write ·8 after the 17. The centigrams come next, they are 0·05 + 0·02 + 0·01 + 0·01 = 0·09; write 9 after the 8. The milligrams and fractions of a milligram are to read off from the rider; in the present instance the rider stands at 0·0054 grams, 54 must therefore be written after the 9. The whole figure will then read:

"Weight of crucible = 17·8954 grams."

Having thus read the weight from the empty spaces in the box, next take the weights out and check the reading off as they are returned to their places. This double reading greatly reduces the chances of error in recording the weight of the substance. After a little experience in weighing, and thus getting to know the capacity of the particular balance used, the student should test his balance in order to ascertain the value of each graduation of the index scale. To do this put the rider on the 5 milligram mark, cause the beam to vibrate, and notice how far on either side of the zero it swings. Alter the position of the rider until the beam swings from the zero to the 10 on the one side; note the position of the rider. Suppose it to be on the 5, then 10 divisions of the index scale = 5 milligrams, and 1 division = 0·5 milligram. This value will only be approximately the same when the pans are loaded, but still sufficiently near to save time in the weighing. Thus, suppose 3·5 grams have been placed in the pan, and the index vibrate 10 to the right and 8 to the left, there is no need to successively try the 0·2 and other weights down to the 0·01, but the rider may at once be put on the 1 milligram mark, and will be found to be very nearly in its right place. One or two trials will then find the exact weight. The 1 is found in this case by taking half the difference between the vibrations on each side; this will often apply, even though the balance does not swing quite to the ten; thus, the distances indicated might be 9 and 7. The beam should, however, be always caused to swing freely, as it makes a long oscillation in the same time as a short one. It will be noticed that, so far, the right-hand side only of the rider scale has been referred to; the left is also frequently convenient. Supposing that, with the 3·5 grams just mentioned, the index had vibrated the two extra degrees to the left, this would have indicated that the substance weighed about 1 milligram less than 3·5; to put this weight in would require the removal of the 0·5, and the placing of the 0·2, 0·1, 0·1, 0·05, 0·02, 0·01, 0·01, on the pan, and the rider at the 9 milligram mark. The same result is produced by placing the rider on the 1 milligram mark to the left. When the rider is on the left side of the beam, the weight it represents must be *subtracted* from that in the right-hand pan.

The operation of weighing has been described at full length, because it is the foundation of all quantitative analysis; these operations are, however, much shorter in practice than they appear on paper. The genuine chemical student will never forget that his balance should be carefully, intelligently, and even lovingly used.

In addition to the two balances and set of weights already described, the student will need another set of weights, ranging from 10 milligrams to 200 grams.

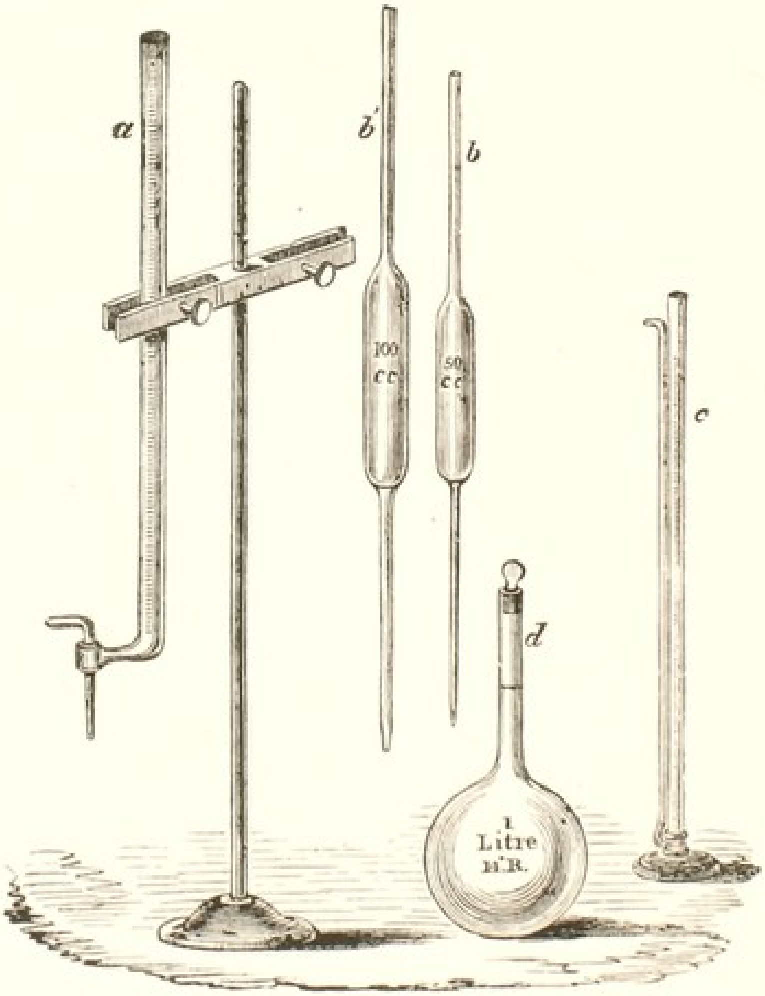


FIG. 61.—VARIOUS MEASURING APPARATUS.

548. Apparatus Employed for Measuring Purposes.—These include measuring flasks, burettes, and other appliances.

549. Burettes and Floats.—Figure 61, on page 490, is an illustration of various forms of measuring apparatus. The instrument marked *a* is termed a burette, and is used for the purpose of accurately measuring small quantities of liquid when delivered. There is at the bottom a glass stop-cock ; the tube is graduated throughout. The most useful size of burette is that holding 50 c.c. ; such an instrument is graduated in 500 divisions ; these are numbered at each c.c., from the top downwards. In using the burette it is first cleaned, and then rinsed with a little of the solution with which it is to be filled, then filled up almost to the top. When a long and narrow tube, such as a burette, contains a liquid, the top is not exactly level, but is always slightly curved, with, in the case of water and aqueous solutions, the concave surface upwards. It is customary, in comparing the height of a liquid with the graduation marks, to read from the bottom of this curve, or "meniscus," as it is termed. The next thing is to run the liquid out through the stop-cock until the zero mark is reached. Fix the burette upright in the burette stand, and place the eye level with the zero graduation, then turn the stop-cock carefully, and let the liquid run out until the bottom of the meniscus exactly coincides with the zero line. The burette is generally used for the purpose of running a liquid into a solution until some particular change takes place, then the height of the reagent in the burette is again read off, and the quantity that has been used determined. So when the change, whatever it may be, is complete, again bring the eye level with the bottom of the meniscus, and read off the graduation with which it coincides. Accurate reading of

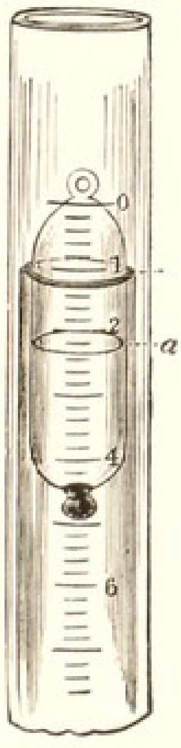


FIG. 62.—ERDMANN'S FLOAT.

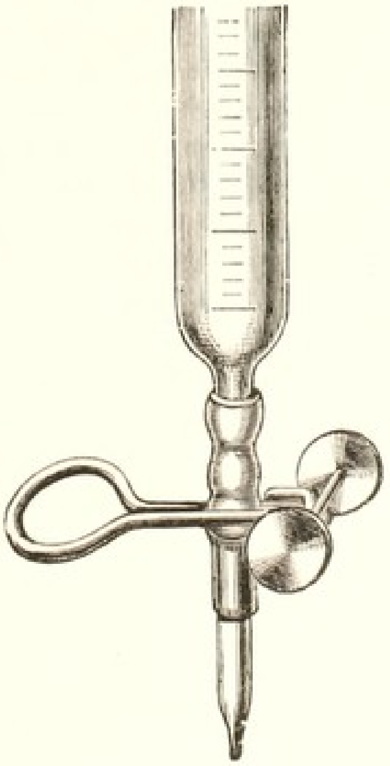


FIG. 63.—MOHR'S BURETTE, WITH SPRING CLIP.

the burette is much assisted by the use of "Erdmann's Float;" this little piece of apparatus, which is figured on page 491 (Fig. 62), consists of a piece of glass tubing of such a size as to be able to slide readily up and down within the burette. The tube is closed at both ends, so as to form an elongated glass bulb, which contains a small quantity of mercury. Around the float a single line, *a*, is marked with a diamond. When using the float it is dropped in the burette, and the line around it brought to agree with the zero mark at starting, and afterwards the height is read from the line on the float. A form of burette very convenient for general use is that known as Mohr's; it differs slightly in shape from that figured in the preceding illustration. Mohr's burette is made either with a glass stop-cock, or else with a glass jet fastened on with a piece of india-rubber tubing, as shown in Figure 63. A strong spring compresses the tubing, and so stops the burette. The flow of the liquid is regulated by means of pressing the two buttons, shown, between the finger and thumb. The figure shows only just the lower end of the burette. The glass stop-cocks of burettes and other instruments should always be slightly greased, so as to prevent their sticking. If a burette is likely to be put aside for some time, it is well to withdraw the stop-cock altogether, and put it away separately.

550. Pipettes.—Turning once more to Figure 61, there are two instruments marked *b, b;* these are pipettes, and are used for delivering a definite volume of any liquid; the capacity of the two figured is respectively 50 and 100 c.c. In the tube just above the bulb there is a mark (not shown in the figure), which indicates the point to which the pipette must be filled. When using the instrument, place the lower end in the liquid to be measured, and suck at the upper until the liquid rises above the graduation mark, then stop the upper end with the tongue; next quickly substitute the tip of the finger for the tongue, without allowing the liquid to run out. This requires some little practice, but repeated trials overcome any difficulty at first experienced. Next raise the finger *very slightly* until the liquid begins to run from the lower end; let it do so until the bottom of the meniscus coincides with the graduation mark, then hold the end of the pipette over the vessel into which the liquid is to be poured, take away the finger and let the tube drain. The pipette, if correctly graduated, will thus deliver the exact amount of liquid marked on it. The following are convenient sizes for pipettes: 2, 5, 10, 20, 25, 50, and 100 c.c. One 10 c.c. pipette will be required graduated throughout its whole length, somewhat like a burette; it is, in fact, used for very much the same purpose.

551. Measuring Flasks.—The only other piece of apparatus that need be explained at present is the graduated flask, *d*, Figure 61; this has also a mark round the neck showing the graduation line. The same remarks apply to its use as those already made in reference to the other pieces of measuring apparatus.

Other pieces of apparatus required, with the methods of using them, will be described as occasion for their employment arises.

CHAPTER XXI.

COMMERCIAL TESTING OF WHEATS AND FLOURS.

552. Importance of Commercial Testing.—Long experience at handling wheats and flours enables the practical miller or baker to judge from its appearance the quality of a sample of either wheat or flour with, as a rule, considerable accuracy. Still, it is well known that such judgments are at times altogether at fault, and that wheats, which are apparently similar to the eye, yield flours of very different values. In such a country as our own, where enormous quantities of wheat and flour are purchased from foreign countries, it is a matter of national importance that we get the fullest and best value for our money. Hence the author has deemed that the problem of devising a simple and trustworthy system of wheat and flour testing is one worthy of most serious attention. He ventures to hope that the methods suggested in the following pages are at least a step toward the realisation of such a system.

553. Wheat Testing.—The simplest and most direct tests that can be made on whole wheat are its weight per bushel, and weight of 100 grains of average size. The use of the former test is obvious; the latter gives data which at times is useful to put on record as to the average weight and size of the grains of the sample. Other tests can be made on the finely-powdered whole meal of the grain. Among these are the percentages, respectively, of moisture, and crude and "real or true" gluten as determined by analysis. A determination of cellulose would yield information as to the percentage of bran present, but unfortunately the analytic estimation is too tedious to be often used for that purpose.

The best mode of testing wheats is undoubtedly that of first reducing the same to flour, and then testing the flour. With this end in view, the larger mills are frequently fitted with small reduction plants by which an experimental quantity of wheat may be reduced to flour, and this tested before the *whole* of the wheat is ground. The plant for this purpose may be of various sizes, from a fairly complete small roller mill installation to a specially made machine for reducing purposes, the different separations being made by hand. On the flour thus obtained, determinations may be made of such kinds as are employed on flour obtained during the ordinary course of manufacture. It does not follow that the experimentally-made flour will be equal in every respect to that obtained in practice; but usually the results are comparative with each other sufficiently near to afford very valuable information. The practical miller will naturally make allowances for the milling peculiarities of the wheats he may be thus examining.

554. Weight per Bushel.—This operation is so familiar to all millers that an explanation of it is scarcely necessary. As is well known, there is a special piece of apparatus sold that is made for the purpose. A cheap and efficient substitute for this may easily be prepared and used where a student has such a balance as the coarser one previously described. Get a coppersmith to make a cylindrical measure about 3 inches in diameter and 3 inches deep. Procure from a dealer in chemical apparatus a counterpoise box; these are brass boxes with lids which screw on. Put the empty measure on the one side of the balance and the counterpoise on the other, fill with shot until it exactly balances the measure. Next fill the measure exactly full of distilled water, *level with the brim*, and again weigh, always placing the counterpoise on the weight pan. The weight in grams of the water held by the measure represents its capacity in c.c. Now the weight of a bushel of water (=80 lbs.), and that of the water contained in the little vessel, are always constant; and, as the weight of the water the vessel contains is to the weight of the wheat that is being tested, so is the weight in pounds of a bushel of water to that in pounds of a bushel of the wheat. Expressing this in the usual way we have—

As weight of water held by vessel : weight of wheat held :: 80 : lbs. per bushel;

$$\text{or, } \frac{80 \times \text{weight of wheat held}}{\text{weight of water held}} = \begin{array}{c}\text{weight of wheat in}\\ \text{pounds per bushel.}\end{array}$$

Now for any particular vessel the weight of water it holds is always constant, so that 80 in the upper line, and the weight of water in the lower, may be reduced to a single factor, and the weight in pounds per bushel at once determined by multiplying the weight of grain, held in the measure, by that factor. Suppose that the capacity of the vessel is 200 c.c., then $\frac{80}{200} = 0{\cdot}4$ is the factor, and the weight of wheat in grams held by the vessel would simply have to be multiplied by that figure. In taking weights per bushel the little measure should be carefully filled, and then struck level by means of a pencil or other round piece of wood.

555. Weight of 100 Grains.—For this estimation it is important that the grains selected shall represent the average sample: if they are simply picked up one by one out of a heap, the weight is almost certain to be in excess of the true average; for a person under these circumstances almost invariably unconsciously selects the largest grains. To obviate this, fold a strip of paper so as to form a V-shaped gutter; take a handful of the wheat and let it pour in a small stream along the length of this gutter. Then commence at the one end and count off the 100 grains, taking each as it comes. Weigh on the pan of the balance and enter the weight in the note-book.

556. Grinding of Samples.—The fine whole-meal for gluten and moisture determinations is best obtained by passing the wheat through a drug mill; that used by the author is a small drug mill, known as the "Enterprise" drug mill. It is of American manufacture, and is efficient and simple. An ordinary coffee mill might answer the purpose, but most likely would not cut up the bran sufficiently fine. The process adopted by the writer is as follows:—The mill is set as fine as it will run without clogging. (It need scarcely be mentioned that every part must first be thoroughly cleaned.) The wheat is then poured in the hopper and run through as rapidly as possible. The grist is next put into a fine sieve, about 20 or 24 meshes to the inch, and sifted. The bran is returned to the mill, and run through and again sifted; this operation is repeated on the coarser particles until the whole of the meal has been thus sifted. Care must again be taken at the end to clean every particle out of the mill and add it to the meal; this is essential, because the latter particles are more branny than the former. The meal is next stirred up thoroughly, and then stored in a tightly corked or stoppered bottle. The reduction of the bran is effected with comparative ease in the drug mill referred to, because its action is a cutting one. The simple crushing of such a mill as a coffee mill would most likely have but little action on the bran. In this way a whole-meal is obtained, which of necessity is an exact representative of the grain. It may be asked whether the wheat should be cleaned in any way previous to grinding for analysis. The answer to such a question is that this must depend on the purpose for which the analysis is required. An analysis made for the purpose of buying or selling by should be performed on a sample representing the bulk of the parcel of grain in question; it should therefore be in no way cleaned or washed. When a miller requires to know the analytic character of a variety of wheat in the cleaned state, the analysis would obviously be made on the sample after cleaning. Undoubtedly the safest plan is to analyse the sample exactly as collected, unless the analysis is made for some special purpose. If a clean wheat is analysed the weight of cleaned wheat obtained from a definite weight of the uncleaned wheat should first be ascertained.

The mode of performing gluten and moisture determinations is described in detail in the subsequent paragraphs on flour testing.

557. Flour Testing.—For commercial purposes an examination of flour should deal with the Strength, Yield, and Colour of the flour. Flavour, amenability to certain modes of working, and other special qualities, scarcely come within the province of commercial testing for general purposes. In determining the qualities mentioned, it is important that results be not merely comparative, but absolute—that is to say, they should not merely record the properties of one flour as against another, but should register in terms of some definite scale or measure the amount and character of each particular quality. Throughout the whole of the following scheme of testing this end has been borne in mind, and where the methods employed seemed cumbersome compared with others in more common use, it should be remembered that the aim has been to afford, and especially register, information that other tests do not give. It is, for example, comparatively easy to say which of two flours, judged side by side, is of the better colour, and also which of the two yields the stiffer dough; but it is more difficult to provide data by which the colour and dough stiffness of one flour here may be compared with another in America, or with another to be examined six or twelve months hence.

Commercial flour testing should have then as its object the determination of the

I. Strength or capacity for producing volume and boldness of loaf.
II. Bread yield of the flour.
III. Colour.

Considering these in the order given, we have first to deal with

558. Strength.—The strength of a flour largely depends on the quantity and character of the insoluble proteids contained in the flour. In a crude form these are obtained in the well-known washing process for gluten. One great objection to the gluten test is the difficulty of knowing precisely when the whole of the starch has been removed, and then stopping short of washing away any of the gluten itself. In many flours the gluten begins to disintegrate and wash away before the whole of the starch disappears. With some little experience the same worker can get concordant results, but this is not invariably the case with two workers testing against each other; one will then frequently throughout a whole series uniformly get higher results than the other. When in addition to this inherent difficulty there is that of one of the two workers being interested in making his results as low as possible, while the other wishes them to be high, the likelihood of discordant results is much increased. As, therefore, considerable differences may exist in the percentages of crude gluten obtained, both in the wet and dry state, it is recommended that in addition the "true gluten" or proteid matter be also determined by a direct nitrogen estimation. Even when there are marked discrepancies in the crude gluten as obtained by washing, the true gluten varies only within narrow limits.

With the view of determining strength, it is recommended that the following estimation be made:—Percentage of gluten wet and dry by the washing-out process, and of true gluten by nitrogen determination on the dry gluten; all of these to be calculated on the whole flour. Appearance and physical character of the gluten to be noted. Percentage of total proteids in the whole flour.

559. Gluten Extraction.—Thirty grams of the flour should be accurately weighed and transferred to one of Pfleiderer's small doughing machines (made especially for the purpose). To this should be added in the machine 15 cubic centimetres (=15 grams) of water from a graduated pipette. The whole should then be thoroughly kneaded, receiving 100 revolutions by the counter after the flour and water are first roughly mixed. (While the machine is exceedingly convenient, the dough may as an alternative be made by hand.) From the resultant dough one or two portions of exactly 15 grams each should be accurately weighed, and then transferred to a small glass containing sufficient cold water to keep them entirely submerged, in which they must be allowed to remain for exactly an hour. (The second piece is only to be weighed off in event of a duplicate being required.) The weighed portion of dough contains exactly 10 grams of flour, and should be washed in the following manner :—Prepare some water at a temperature between 70° and 80° F., and partially fill a clean bowl with same. Wash the lump of dough by kneading it gently between the fingers in the water, using no muslin or other enclosing substance. The starch is gradually washed away, and the remaining dough acquires the consistency and characteristic feel of gluten. Take care that no fragments are washed off the main lump ; and after the gluten is approximately freed from starch, place it aside on a clean surface of glass or porcelain : let the washing water settle, and decant it very carefully through a fine hair sieve. Should there be any fragments of gluten on the sieve, pick them up with the main piece and do the same with any remaining in the basin. Take some more of the tepid water and repeat the washing some little time longer ; change the water about two or three times, with the same precaution against loss as before. The last washing water should remain almost clean. The gluten may now be taken as pure, freed as far as possible from adherent moisture and weighed.

In the case of Hungarian and certain other flours of very high water-absorbing power, it is sometimes advisable to make a slacker dough for gluten extraction than that just described. For this purpose add 20 c.c. of water to the 30 grams of flour, and take 16·66 grams of the dough for each estimation. This weight contains, as before, exactly 10 grams of flour.

For the drying of the gluten pieces of paper should be prepared beforehand in the following manner :—Take a sheet of cartridge paper and cut it up into small pieces three inches square. Place these in the hot-water oven and dry at 212° F. for two days. Take them out and allow to cool in a desiccator, and weigh them off rapidly to within a decigram. Mark the weight in pencil on the top left-hand corner of the paper. Keep a store of these in a clean box.

Having weighed the gluten as above described, mould it between the fingers and notice its physical condition, whether tough and elastic, soft and flabby, or "short" and friable. Make a note of same. Mould it into a ball and place it on the centre of one of the weighed papers. On the one corner mark the date, and below, the name or number of the flour, with the weight of the wet gluten. Next place the gluten in the hot-water oven and dry at 212° F. for at least 36 hours, preferably two days ; then weigh to the decigram, subtract the weight of the paper, and express the result in percentages. The gluten adheres to the paper, and thus may be kept as a record of the flour.

To determine the true gluten, break up the crude dry gluten into coarse fragments, and estimate nitrogen by the Kjeldahl method, as described in Chapter XXIII. The percentage of true gluten should be returned on the whole flour, and should be at least 80 per cent. of the crude gluten.

By means of the same process (Kjeldahl) determine the total proteids in the flour.

560. Extraction of Gluten from Wheat-Meal.—The meal may be weighed and made into a dough precisely as with flour ; or, if wished, 10 grams only may be weighed off and transferred to a basin, and then mixed with sufficient water to make a somewhat slack dough. This is allowed to stand as before for one hour under water Instead of washing the dough direct in the bowl, it is preferable to first enclose it in a piece of either fine muslin or, preferably, millers' bolting silk. This must be held securely in order to prevent any loss of the dough, which must be held under water in the bowl, and kneaded between the fingers until a fresh lot of water is no longer caused to become milky by the escaping starch. On opening the silk, it will be found not only to contain the gluten, but also the bran of the wheat, and these have to be separated from each other. With the harder wheats this is done without much difficulty, but in the case of those that are softer it is sometimes almost impossible to recover the whole of the gluten. After having washed out the starch, squeeze the water from the silk, and then open it out on a piece of glass. There will usually be one fairly sized lump of gluten ; take this out and rinse it moderately free from bran in a basin of clean water, next squeeze it well together, then pick off any tolerably large pieces of gluten that remain on the silk, and add them to the main lump. After each addition again squeeze the piece together and rinse off any loose bran. The difficulty is now to gather together any particles remaining in the bran—these are often so small as to be scarcely visible. Take the mass of tolerably clean gluten and add to it a portion of the bran, roll them together with considerable force between the palms, and then wash off the bran. This process of rubbing together the main lump of gluten and the bran effects the removal of any little fragments of gluten by their sticking to the larger piece ; which, in virtue of its adhesive property, picks them out from the bran, just as a magnet picks out iron filings from among those of brass. Treat the whole of the bran remaining on the silk in this manner ; the result will be a lump of gluten still containing a little bran. With a hard wheat, however, the whole of the gluten will have been thus recovered ; with the softer ones it is sometimes advisable to drain the water off the bran and again rub it all up with the gluten. In every case inspect the bran most carefully before throwing it away ; the bran should also be rubbed between the fingers ; this will often detect fragments of gluten that escape the eye. Having got the whole of the gluten together, wash it time after time until free from bran. This is a tedious operation, but one that can be performed by vigorous and careful treatment. Pour every lot of water on to the muslin in order to see that no gluten is lost. The washing must be continued until the gluten yields no turbidity to clean water.

The subsequent processes are performed on the wheat gluten precisely as with that from flours.

561. Hot-Water Oven.—Directions having been given to dry the gluten in a hot-water oven, that piece of apparatus must now be described. These ovens are usually made of copper, and are of the appearance and shape shown in Figure 64.

The oven consists of an inner and outer casing, with a space between

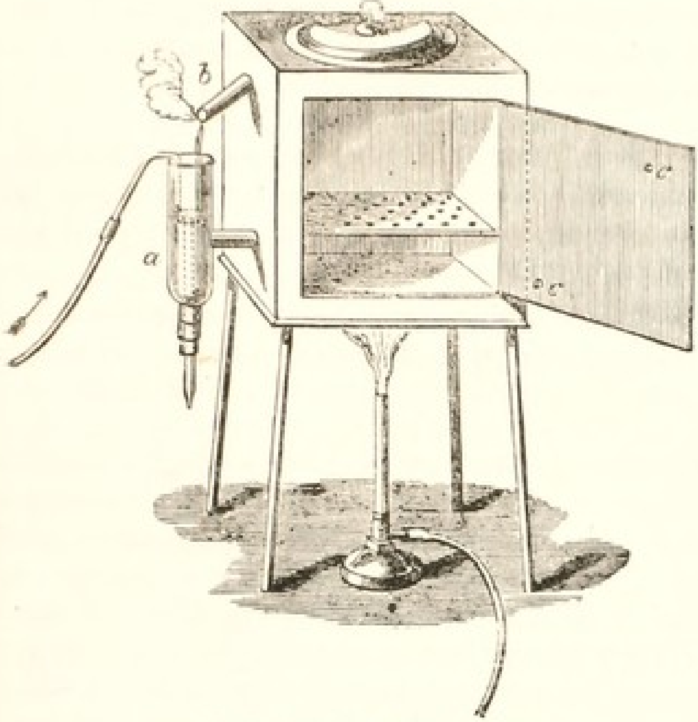


FIG. 64.—HOT-WATER OVEN.

them about an inch in thickness; the top, bottom, two sides, and back, are therefore double. This space for about half the height of the oven is, when in use, filled with water, which is kept boiling by the bunsen flame placed underneath. Anything placed in the oven is thus kept at a temperature of from 96—100° C., but, while there is any water within the casing, never above the latter temperature. In order to prevent the oven boiling dry, a little feed apparatus, *a*, is attached to the side; this, as shown, consists of a copper vessel open at the top, and communicating by means of a pipe with the water space of the oven. Through the bottom of *a* is passed a piece of glass tubing, the top of which reaches to the height at which it is desired that the water shall remain in the oven. This glass tubing is kept in its place by a piece of india-rubber tubing, which, while making a water-tight joint, allows the tube to be slidden up or down as wished. Through the pipe at the side, marked with an arrow, a small stream of water is led into *a*; this feeds the oven, and the overflow passes out through the glass tube, which should either stand over, or be led into, a drain. The pipe *b* is arranged so that any condensed steam may also drip into *a*.

Another very good plan is to have fitted to the top of the water oven an inverted Liebig's condenser, through the outer casing of which a stream of cold water is passed. The steam from the boiling water in the casing is then condensed by the condenser, and returned to the oven. The oven, having been once filled, will not need replenishing for a considerable time, as the loss of water is very little. The condenser should be made of brass or copper tubing; the inner tube about $\frac{5}{8}$ inch in diameter, and the outer $1\frac{1}{4}$ inch: the length should be from 24 to 30 inches. The cold water should enter the jacket at the bottom. When a condenser is used, the oven should also be fitted with a glass water guage, to show the height of the water. With this arrangement the oven may be filled with distilled water, and so loss of heat by the formation of crust be prevented.

Where time is an object, it is convenient to use an oil oven instead of one filled with hot water. The oven is similar in construction, but the jacket is filled with oil, and the temperature raised for wheat or flour drying to 105—110° C., being regulated by adjusting the burner, or by means of an automatic regulator.

562. Desiccator.—The desiccator is an instrument composed of a glass plate and bell jar, containing within it a small tray filled with concentrated sulphuric acid; this keeps the air within dry, and so preserves from damp anything placed inside to cool.

563. Bread Yield of the Flour.—This is governed partly by the degree of water present in the flour, and partly by the character and condition of its other constituents. It is recommended that the following determinations be made:

Moisture in the flour. Water absorbing power by direct measurement of the stiffness or viscosity of dough made from definite quantities of flour and water.

564. Moisture.—Of considerable importance in judging the value of a wheat or flour is the estimation of moisture. After a little practice with gluten tests, the moisture is a very convenient determination for the student next to make. The percentage of water or moisture is usually found by weighing out a definite quantity of the flour or meal in a small dish, and then drying in the water oven until it no longer loses weight. When a number of samples have to be assayed, some regular method of procedure is necessary. The following method may be adopted:—

Procure from the apparatus dealer one dozen selected glass dishes, $2\frac{1}{2}$ inches diameter. Mark these with the numbers I. to XII. on the sides with a writing diamond. Have a little box made in which to keep these dishes. The box should have a shelf, supported a little way from the bottom, containing a series of separate holes, one for each dish, so that they may be kept without danger of breakage. Clean and dry each dish, and then weigh it carefully; enter the weights in the notebook, and, previous to using each dish, test its weight. This may be done very quickly, as the weights are already approximately known. It will be found that, if used with care, the weight of the dishes will remain constant, within some four or five milligrams, for a considerable time. Time may be still further economised by having a series of counterpoises made for the set of dishes. These consist of little brass boxes in the shape of weights, the tops of which can be unscrewed. Brass counterpoises of this description can be readily obtained. Have engraved on the top of the counterpoises a series of numbers corresponding to those on the dishes; clean the counterpoises and dishes thoroughly, and balance the one against the other in the following manner:—Place No. 1 dish in the left hand balance pan, and the corresponding counterpoise in the other, together with its cover. Fill up the counterpoise with shot until it is as nearly as possible of the same weight as the dish, then add little shreds of tinfoil until the two exactly counterbalance each other; finally screw the lid and box part of the counterpoise together. Proceed in exactly the same way with all the dishes. In this case the shelf of the box for the dishes should also have little holes cut in it for the counterpoises, so that each may be kept immediately in front of its particular dish. Having a set of counterpoises, before using each dish test it on the balance against its counterpoise, and if necessary adjust the weight with the rider. As the dishes gradually become lighter through use, the rider will have to be placed on the left-hand or dish side of the balance. In case the balance is one which is only fitted with the rider arrangement on the right-hand side, the dish may, if wished, be placed on that side, and the weights on the left in weighing; this, however, is liable to lead to confusion and mistakes in reading the weights. As the dishes grow lighter, their weight against the counterpoise is really a minus quantity, and should be entered as such in the note-book. For a long time the difference between the two is inappreciable, but still, for the sake of accuracy, the test should always be made. When the dish and counterpoise differ more than ·005 gram, the latter should be re-adjusted. Having a number of determinations to make, weigh out exactly 10 grams of each flour in a dish, then place them in the hot-water oven and allow them to dry for 24 hours; at the end of that time the water will be expelled. Take out the dishes, allow them to cool in a desiccator, and weigh as quickly as possible. As the weight of each is approximately known, put the larger weights on the balance pan before taking the dish from the desiccator. After weighing, return the dishes to the oven for another hour, and again weigh; the two weighings should agree within a milligram. Dry flour is very hygroscopic; that is, it absorbs moisture with great rapidity. This is noticeable during weighing, for a sample will often gain while in the balance as much as five milligrams. The student will at first, for this reason, get his weights too high. The best plan is to put on the rider at a point judged to be too high, and then at each trial bring it to a lower number until it is found to be at one at which the dish is the heavier. Then take the lowest figure known to be above the weight of the dish, for if the rider now be moved upwards, the dish will often be found to gain in weight just as rapidly as the rider is moved upward. Before the dish is removed from the desiccator for the second weighing, put in the pan the lowest weights before found to be too heavy. After a time the student will find that he can get his two weighings to always practically agree; he may then, but not till then, dispense with the second weighing. It is evident that the flour after being deprived of its moisture will weigh less; the weight taken, therefore, less the weight of dried flour, equals the moisture; this, when 10 grams are employed, multiplied by 10 gives the percentage.

565. Effect of Humidity of Air on Moisture of Flour.—Flour is exceedingly hygroscopic and absorbs or loses moisture, according to whether the atmosphere is damp or dry, with great readiness. Richardson examined a series of flours immediately on coming from the mill, and again after being exposed to the atmosphere for a day, with the following results:—

	Original Moisture.	Gain or Loss.	Second Day.
No. 1.	9·48	+ 0·65	10·13
,, 2.	7·80	+ 2·15	9·95
,, 3.	7·85	+ 2·30	10·15
,, 4.	7·97	+ 2·15	10·12
,, 5.	13·69	– 3·28	10·41

It will be seen that, notwithstanding the wide differences in percentage of moisture on the first day, they had, at the end of the second, become practically equalised. Richardson next allowed these flours to remain exposed to the atmosphere for 16 days, making during that period 15 determinations of moisture. In one and the same flour during that time variations of nearly 5 per cent. were observed. In the following table the results are expressed in weight in lbs., which 100 lbs. of the original flour would have assumed under the conditions:—

No.	Original Weight.	Original Moisture.	Highest Weight during 16 Days.	Lowest Weight during 16 Days.	Amount of Variation.
1.	100 lbs.	9·48	102·88 lbs.	99·53 lbs.	3·35 lbs.
2.	100 ,,	7·80	104·87 ,,	100·00 ,,	4·87 ,,
3.	100 ,,	7·85	105·20 ,,	100·00 ,,	5·20 ,,
4.	100 ,,	7·97	105·95 ,,	100·00 ,,	5·95 ,,
5.	100 ,,	13·69	100·00 ,,	95·35 ,,	4·65 ,,

No. 1 of these flours was the well-known brand, Pillsbury's Best; it will be of interest to give the weight of this each time determined, and also the relative humidity of the air each day.

Date.	Weight of Flour.	Relative Humidity of Air	Date.	Weight of Flour.	Relative Humidity of Air.
March 7th.	100·00 lbs.		March 17th.	100·38 lbs.	42·2
,, 8th.	100·65 ,,	46·4	,, 18th.	101·88 ,,	59·5
,, 10th.	99·53 ,,	35·0	,, 19th.	102·03 ,,	60·1
,, 11th.	101·73 ,,	59·0	,, 20th.	102·48 ,,	55·6
,, 12th.	102·68 ,,	60·1	,, 21st.	101·43 ,,	51·8
,, 13th.	99·88 ,,	34·0	,, 22nd.	101·68 ,,	51·1
,, 14th.	101·08 ,,	...	,, 24th.	102·88 ,,	66·9
,, 15th.	101·53 ,,	48·2			

It will be observed that with an increased dampness of the air, the weight of the flour is also increased. Of course, in strictness, the weight of the flour is governed by the degree of humidity *prior* to the moisture determination, rather than that at the time the determination is actually made.

On exposing a sample of patent flour to an atmosphere kept absolutely saturated with water, it absorbed more than 26 per cent. of its original weight in sixty-four hours. The following table gives the weight at different intervals:—

Weight of flour taken	1·0000 grams.
,, after 35 minutes	1·0285 ,,
,, ,, 18 hours	1·0930 ,,
,, ,, 22 ,, ...	1·2005 ,,
,, ,, 42 ,, ...	1·2405 ,,
,, ,, 64 ,, ...	1·2670 ,,

These variations in weight of which flour is capable go far toward explaining discrepancies in water-absorbing power, and yield, of laboratory samples.

566. Water-Absorbing Capacity.—Undoubtedly one of the best methods of determining the water-absorbing capacity of a sample of flour is by doughing it, and then judging by the consistency of the dough. The dough may be tested in this manner shortly after being made up, and again after an interval of some hours. A more or less accurate judgment is thus formed of the water-absorbing power of the flour when first made into dough, and also its capacity for resistance to the changes which take place in the constituents of flour while standing for some time in a moist condition. The unfortunate point about such determinations is, that judging by the appearance and stiffness of a dough is exceedingly uncertain: one person's own judgment is not at all times alike, and the difficulty is multiplied infinitely when an attempt is made to compare that of several persons. Again, there is the fact that for all purposes of exactitude it is essential that some means shall exist for expressing results in actual figures.

Finding the problem in this state, the author devised and patented apparatus, which had as its object the determination of Water Absorptive Power, and giving a numerical expression of the result. The starting point was to decide on some mode of expressing Yield: the first idea was to make use of the number of quartern loaves of bread that could be produced from a sack of flour. But here the difficulty occurred that different bakers are in the habit of weighing their bread into the oven at different weights, to say nothing about the possibilities of different weights when the bread leaves the oven. Further, the use or non-use of "fruit" renders this method of considerable uncertainty. There is again the fact that some bakers work with slacker doughs than do others.

Thoms, of Alyth, has made some very important experiments on the strength of flour by the doughing test. He has adopted the method of taking 1¼ oz. of flour and measuring the water in drams: in a most valuable table published by him, he gives the results of such tests, in loaves per sack and barrel, with quantities of water, varying from 8 to 16 drams. The tabulated estimate of results per sack provides for loss in working, the actual figures given having been determined by the corresponding baking tests with 280 lbs. of flour.

After considering several possible modes of expression, the decision arrived at by the author was to give the quantity of water that a definite weight of the flour took, in order to produce a dough of definite and standard consistency. By almost universal consent the standard of weight of flour would, in this country, be the sack of 280 lbs., while water can be conveniently expressed in quarts. The quart being the quarter of a gallon, and the gallon weighing 10 lbs., render it easy to convert quarts into either gallons or lbs. It will be noticed that the adoption of this standard does not touch on the contested question of loss of water in the oven.

567. Water-Absorption Burette.—The operation of doughing resolves itself into taking any convenient quantity of flour, and adding sufficient water to it to make a dough of normal stiffness, and then calculating out the water employed into the proportion of quarts per sack. The simplest way of doing this is to fix on the quantity of flour, and then make a measuring instrument for the water ("burette" or "pipette"), which shall be graduated so that each division represents a quart of water per sack. Such a measuring instrument is the first part of the apparatus described; in using it, the flour is weighed out, and the quantity of water run in is at once read off, without any calculation whatever, as quarts per sack. The practical advantages of this method are evident, as from a small doughing test a baker can at once direct how much water is to be added per sack of any particular flour. The strength burette, together with the viscometer, is shown in Figure 66: at the top of the instrument is the zero mark, between which and "40" there are no graduations; the tube is then graduated in single quarts down to 80 at the lower end. At the bottom a glass jet is attached by means of a piece of india-rubber tubing; this is normally kept closed by the spring-clip shown, but may be opened at will by pressing the two buttons shown, one on either side. In use, the burette may be held in the hand, but is preferably fixed in a burette stand. It may be filled either by pouring in water at the top, or by opening the clip and sucking it up through the jet.

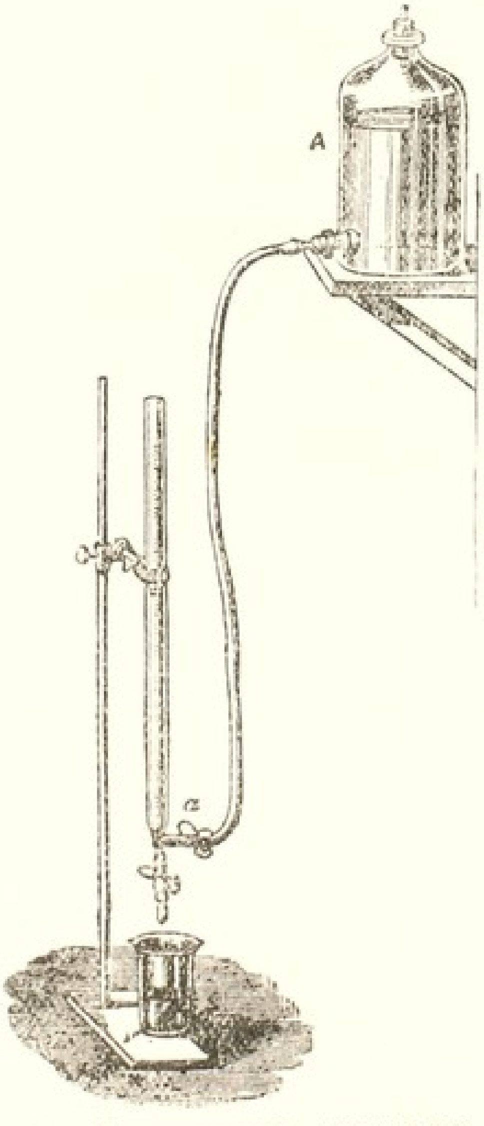


FIG. 65.—BURETTE, ARRANGED WITH RESERVOIR.

It is important to bear in mind that if great exactness is required in doughing tests, the dough, when made, should have a definite temperature. It is recommended that for this purpose that of 70° F. be adopted. If possible, a flour-testing laboratory should stand permanently at as nearly as possible that temperature. Before starting a series of tests, the water should be adjusted to 70° F.: and the flours, if cold, allowed to stand in a warm room sufficiently long to give the same temperature when tested by the thermometer.

Where a number of flours are being tested, it is an exceedingly convenient plan to have a water reservoir attached to the burette; the whole apparatus will then appear as shown in Figure 65.

In the lower part of the figure the burette is seen fixed in a stand. At *a* is a second tube opening into the burette above the clip: by means of india-rubber tubing, this second tube, *a*, is attached to a glass reservoir, A, which stands on a shelf above the level of the top of the burette. By means of a spring-clip at *a* the liquid in the reservoir is shut off from the burette. The burette being empty, open the clip *a*; the water flows from A upward into the burette; when the level coincides with the zero mark close this clip, and proceed to deliver the desired quantity of water by pressing the clip at the bottom of the burette. In this manner the instrument may be filled with great convenience and rapidity.

To test a flour, weigh out as exactly as possible one and a-half ounces of the sample, and transfer it to a small cup or basin. Next fill the burette with water until the level exactly stands at the top graduation mark. Then place the cup containing the flour under the burette, and press the clip, allowing the water to run out until down to as many quarts as it is thought likely the flour will require. Then, by means of the stirring rod, work the flour and water into a perfectly even dough ; try, by moulding it between the fingers, whether it is too stiff or too slack : if so, dough up a fresh sample, using either more or less water as the case may be. Having thus made a dough of a similar consistency to that usually employed, read off from the burette how much water has been used. The figures will express, without any further calculation whatever, how many quarts of water the flour will take to the sack. It is well before judging the stiffness of the dough to allow it to stand for some time. The author allows his doughs to remain an hour before testing them.

It is not safe to state from the doughing test alone how many loaves a certain flour is capable of yielding per sack, because different bakers, by working in different manners, do not get the same bread yield from one and the same flour. Each baker should therefore ascertain for himself by means of a baking test, working according to his own methods, how many loaves he obtains from a sack of any particular flour. He can then in the following manner arrange for himself a table showing the bread equivalent of the "quarts per sack" readings of the burette. To make this test, take a sack of flour and measure the quantity of water requisite to make a dough of the proper consistency. Then count the number of 2-lb. or 4-lb. loaves it yields on being baked. Suppose that the flour takes 70 quarts of water : then dough up a sample with the burette, using water to the 70 quart mark, and take dough of that stiffness as the standard. Any other flour of the same character which takes the same quantity of water to make a dough of similar consistency will turn out about the same yield of bread. Suppose another sample of flour takes 72 quarts of water, then it will make, neglecting the slight loss in working, 5 lbs. more dough (one quart of water weighs 2½ lbs.). Weighing the bread into the oven at 4 lb. 6 oz. per the 4-lb. loaf, every two quarts more water per sack means rather over another 4-lb. loaf produced. In exact figures the additional 5 lbs. of dough yield 4 lb. 9 oz. of baked bread, or practically 4½ lbs.

In this easy manner, by this instrument, a baker may determine for himself, without any but the simplest mental calculation, and working according to his own processes, how much bread a particular flour yields. It is advised that every baker should for himself construct a table of results, based on his own method of working. To do this, let him, as suggested, make a trial baking, and find out how many quarts of water a sack of any one flour takes, and how many loaves it produces. Enter those figures in the table, then for every two quarts more add on 4½ lbs. of bread or 1⅛ 4-lb. loaves : for every two quarts less subtract the same amount.

568. The Viscometer.—In order to carry the water absorption problem a step further, it is necessary, not only to have made the dough, but also to devise means for mechanically determining its consistency. This is the more difficult, as different kinds of flour produce doughs of different character. Thus, a spring American flour will yield a dough whose essential characteristic is rigidity; a Hungarian flour yields a soft dough, but one which, nevertheless, possesses most remarkable tenacity. Any instrument for measuring the consistency of dough must take into account these two somewhat opposite characters, giving each its proper value. The resistance of the dough to being squeezed, and its resistance to being pulled asunder, must both be taken into account. The second part of the flour-testing apparatus consists of an instrument for definitely measuring the viscosity of dough. This is effected by forcing a definite quantity of dough through a small aperture, and measuring the time taken in so doing, the force being constant. The machine for making this measurement is termed a "Viscometer," literally, a measurer of viscosity. It is so arranged that, in doing the work of forcing the dough through the aperture, both the stiffness and tenacity of the dough are called into play as resisting agents. The consequence is that a very soft and tenacious dough may prove its viscosity to be as great as that of a stiff dough with comparatively little tenacity. Undoubtedly this is in keeping with the observed facts of baking, for, as is often said, certain flours will bear being made much slacker than others; that is, their tenacity as dough more than makes up for their comparatively little stiffness or rigidity.

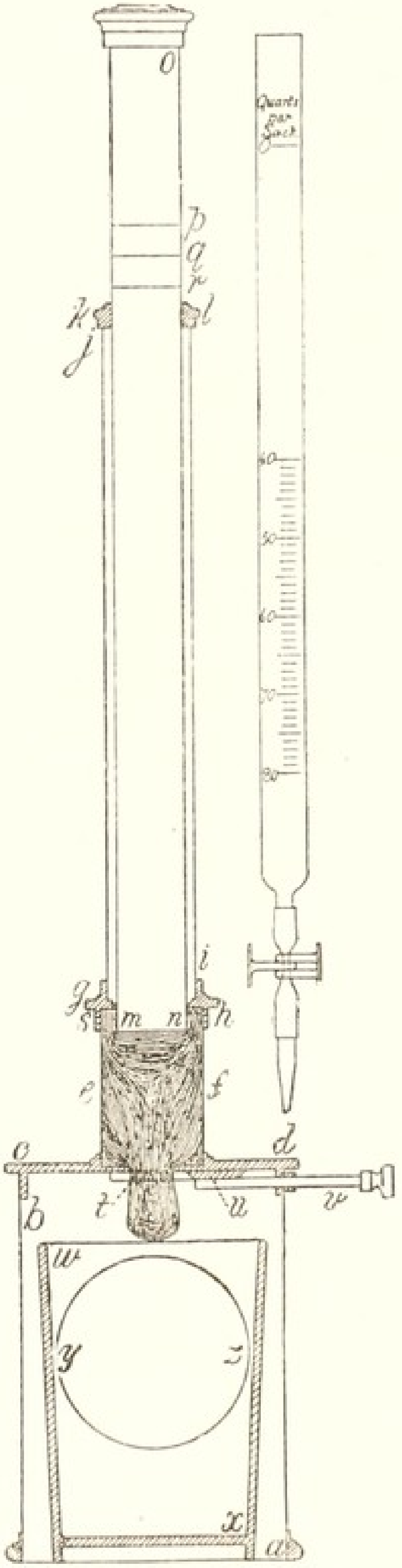


FIG. 66.—VISCOMETER AND STRENGTH BURETTE.

The viscometer consists essentially of a cylinder, having a weighted and graduated piston, and an aperture through the bottom for the exit of the dough; the stiffer the dough, the more slowly does the piston descend. Since the first instrument was made a number of alterations and refinements have been introduced with the object of diminishing certain causes of error which were revealed on experiment. In its present form the author is satisfied that the instrument is affected in its working by the condition of the dough, and that only; further, that it takes cognizance both of the tenacity and the rigidity of the dough. It is claimed for the viscometer that it affords a means of absolute measure of these two qualities of stiffness and tenacity. In certain cases where two doughs have been submitted to the judgment of bakers, and then tested by the viscometer, that judged the softer to the touch has been registered by the viscometer as the dough of greater consistency. The very simple explanation is that it is difficult to form an accurate judgment of tenacity by handling a small piece of dough. Flours which exhibit this particular combination of softness and tenacity are just those which bakers would say require to be worked slacker than others. Consequently, even in these instances, the viscometric measurement affords a valuable indication of the working water absorbing capacity of the flour. Millers and bakers who have seen the apparatus at work endorse this opinion. In using the instrument, the dough is first put into the viscometer, and the time which the piston takes to travel between two of its graduations is noticed.

Figure 66 is a sectional drawing of the viscometer, about one-third the actual size of the instrument. The lower part, marked *a b*, is a cylindrical base, through which are two lightening holes, marked *y z* The cylinder, *e f*, and flange, *c d*, are cast in one piece; *c d* has a collar turned down to fit inside *a b*, the edge of *c d* is milled. Through the bottom of the cylinder is a hole, marked *t*; the upper edge of this hole is rounded off, in order that no cutting edge shall be presented. This aperture may be opened or closed at will by the cover, *u*, which slides between a pair of guides, and may be drawn in or out by the rod and milled head, *v*. The piston, *m n*, consists of a thin disc of steel, the lower edge of which is rounded: this piston is attached to the bottom of a trunk, *m o*, the diameter of which is about one-sixteenth of an inch less than that of the piston. This piston trunk passes through the cylinder cover, *g h*; in the top of this cover is screwed a tube, *i j*, carrying at its upper end a collar, *k l*. Both this collar and the cylinder cover, *g h*, are bored to exactly fit the trunk of the piston. The cylinder cover tube, *i j*, and collar, *k l*, therefore together act as a guide for the piston, allowing it to slide steadily up and down with the minimum of friction. The bottom of the cylinder cover fits over the top of the cylinder, and is secured in its place by a pair of studs and bayonet catches, *s h*. On the upper part of the trunk are three lines, *p q r*, the distance between each pair being three-eighths of an inch. This trunk is loaded inside in order to give it the requisite weight. With the exception of the steel piston, *m n*, the instrument is throughout constructed of brass.

569. Method Employed in using the Viscometer.—It is first necessary to fix on a standard of stiffness for doughs: that adopted by the author is such as allows the piston of the viscometer to fall from mark *p* to mark *l* in sixty seconds. As such doughs are slacker than those employed for many purposes, a stiffer standard may, if wished, be selected; in such a case the readings may be taken, if desired, when the piston has made half its stroke, that is, has travelled from *r* to *q* instead of the whole distance, *r* to *p*. Each individual user of the instrument may thus determine on a standard for himself.

Whatever standard is selected, whether the sixty-seconds' standard employed by the author, or another, weigh out one and a-half ounces of flour, add water from the strength burette, and dough up the sample as before described, using a quantity of water, which, as well as can be judged, shall give a dough of standard consistency. The dough may be mixed by hand in a basin, but the author strongly recommends the use of one of Pfleiderer's small doughing machines made specially for testing purposes: these have the great advantage that they mix the dough thoroughly, and with absolute uniformity. The machine is made with water-tight bearings, and is fitted with a revolution indicator by which the number of turns given to the handle are registered. Place the flour and water direct in the machine, and turn the handle so that the upper edges of the blades approach each other. When the flour and water are roughly mixed, scrape down the sides of the machine by means of a small spatula: note the position of the revolution indicator, and give the dough fifty revolutions. When sufficiently mixed, take the dough from the machine and set it aside in a small glass tumbler, or other vessel, for one hour. Cover over with a glass plate in order to prevent evaporation. When examining a number of samples, dough them up one after the other for an hour, and then come back to the further testing of the first one, and take them in rotation.

Having thoroughly cleaned the cylinder and piston of the viscometer, fill the cylinder with the dough to be tested; to do this, slightly open the bottom aperture and push in the dough through the top, by means of a stout brass spatula. In this way fill the cylinder completely, taking care that there are no air spaces; shut the aperture, *t*, and then, holding the cylinder horizontally in the left hand, put on the cylinder cover, the piston being at the top of its stroke. Secure it by means of the bayonet catches, and stand the cylinder squarely on the base, *a b*. Arrange a vessel, *w x*, to receive the dough as forced through the instrument. Next, have ready a watch with seconds' hand (a chronograph is the most convenient thing, if one happens to be in possession of the worker); pull out the milled head, *v*, the piston begins to descend. As soon as the line *r* coincides with the top of *k l*, note the time, or start the chronograph: note again when the line *p* descends to *k l*, and observe how long the piston has taken to travel this distance. If exactly sixty seconds, or whatever other standard has been selected, the dough is of the standard consistency, and the quantity of water used is that required by the particular flour to make a dough of the standard stiffness. Feel the dough with the fingers and see, especially, whether it seems hard or soft. A soft dough, which nevertheless goes through the machine slowly, must possess great tenacity. Such flours have almost invariably high water-retaining power. The test having been made, turn back the bayonet catches, and withdraw the cylinder cover, piston, and guide from the cylinder. Remove the dough from the piston, and clean out the cylinder by means of a spatula. In handling the piston be careful not to hold it with the cover end uppermost, as the piston rod then slides backwards, and is stopped by the piston coming violently in contact with the cover. The piston being very thin is liable by rough usage in this way to be forced off the rod. When the instrument is done with, the cylinder should be kept soaking in water, so as to remove any traces of dough that might clog the valve at the bottom.

Having described the mode of using the instrument, its action on the dough may now be examined. In the first place, the lower edge of the piston and the upper one of the aperture through the cylinder bottoms are both rounded, therefore the dough is not subjected to any cutting action. In the next place, the piston during its descent meets with no resistance whatever except that due to the dough itself; as it passes *down* through the hole in the cylinder cover it is impossible for the dough to find its way *up* through that opening against the downward movement of the piston; consequently, there is no clogging whatever of the moving parts of the apparatus. The dough, in order to make its way out, has to alter its shape so as to pass through the small hole at the bottom, consequently its rigidity is here taken into account. At the end of the stroke, the piston is found to have pushed out a plug of dough from the centre of the cylinder, leaving a ring of dough standing round its outside. To force out this plug, the piston must have torn away these particles of dough from the annulus (ring) of dough left standing. Hence it is that this apparatus registers so thoroughly the tenacity of the dough as well as its rigidity. By shading the dough in the figure an attempt has been made to indicate the probable lines of movement of the dough as the piston passes downwards. An inspection of the drawing of the viscometer, and a study of its principles, show that it is the condition of the dough, and that only, which can possibly affect the speed at which the piston descends.

In practice it is well to have at least two tests made on the same flour with the viscometer. When the approximate water-absorbing power is known, these may well be taken at 2 quarts below and 2 quarts above this point respectively. Having obtained a pair of piston readings, one above and the other below the sixty seconds (or other predetermined) standard, the actual quantity of water corresponding to the standard may be calculated in the following manner :—For entering the tests it is recommended that a book be procured ruled both ways of the page : the water-absorption results should then be entered as shown in Figure 67, page 513. Supposing 70 quarts to have run through in 90 seconds, and 72 quarts in 50 seconds, then on drawing a line connecting these two points, the place where it crosses the horizontal line marked 60 in seconds, will give the water absorption in quarts. Thus referring to Flour No. 2, Figure 67, the 72 quart dough ran through in 86 seconds, and the 74 quart dough in 43 seconds : on these points being joined by a line, it cut the 60 seconds line at very nearly midway between the 72 and the 74 quart lines, therefore the water-absorbing capacity was taken as being 73 quarts. In this way, the absorptive power of various flours for intermediate points between two readings was arrived at. An inspection of Figure 67 shows that the upper portions of these lines, graphically representing absorbing capacity, are very nearly parallel to each other. The author finds if the first test made gives a viscometer reading between 45 and 90, that the water absorption may be deduced with sufficient correctness for most purposes in the following manner :—On a page, properly ruled both ways, set out two or three lines similar to those in Figure 67 representing the water-absorbing power of different flours. Then, supposing a flour under examination has run through the viscometer in 87 seconds, with 68 quarts of water, make a mark at that point, and draw from it a line across the 60 seconds line, and parallel to the lines of other flours previously set out. Reckon the water absorption from the point where it cuts the 60 seconds line. Such a flour would probably absorb about 69·5 quarts of water. Judging from a number of flours that have been tested in this manner, the single test gives results that very seldom are more than 0·5 quart off from those obtained by doughing the flour with two different quantities of water.

Examples of a few detailed viscometer tests are given in the following table. The heavier figures are the calculated quarts per sack for 60 seconds.

RESULTS OF VISCOMETER TESTS ON FLOURS.

No.	Names and Descriptions of Flours.
1.	Patent Flour, from American Hard Fyfe Wheat.
2.	Bakers' Flour, ,, ,, ,,
3.	Hungarian Flour, First Patent.
4.	English Wheat Flour.

TIME ALLOWED TO REMAIN IN DOUGH—ONE HOUR.

No.	Quarts per Sack.	Seconds.	No.	Quarts per Sack.	Seconds.
1	66	215	2	66	223
	68	193		68	200
	70	74		70	107
	71	**60**		72	86
	72	52		**73**	**60**
	74	44		74	43
	76	24		76	29
	78	10		78	16
	...	...		80	12
3	74	255	4	58	183
	76	170		60	120
	78	**60**		62	82
	80	38		**63**	**60**
	82	25		64	27
	84	18		66	19
	86	10		...	...

570. Stability Tests.—As the name implies, these are tests made in order to determine the rate at which a softening down of the flour occurs during the time it remains in the dough. An old-fashioned millers' method of testing flours consisted in doughing them, allowing them to stand for some twenty-four hours, and then examining the stiffness of the dough. Sound flours would stand fairly well, while those which were unsound yielded doughs which "ran to water." The stability tests, made by the author with the viscometer, were simply modifications of these. Samples of doughs were kept for different periods of time in tumblers with glass covers, which fitted air-tight in order to prevent evaporation; at the end of which time they were tested with the viscometer. The results of a number of such tests are given in the following table, and are also represented in Figure 67.

WATER-ABSORBING POWER OF FLOURS AFTER STANDING DIFFERENT LENGTHS OF TIME IN THE DOUGH.

No.	Names and Description of Flour.
5.	Straight Grade, from No. 2 Calcutta Wheat.
6.	” ” Saxonska Wheat.
7.	Town Households, No. 1.
8.	Town Households, No. 2.

No.	TIME ALLOWED TO REMAIN IN DOUGH.							
	IMMEDIATE.		HALF-HOUR.		THREE HOURS.		TWENTY-FOUR HOURS	
	Quarts per Sack.	Seconds.	Quarts per Sack.	Seconds.	Quarts per Sack.	Seconds.	Quarts per Sack.	Seconds.
5	70	114	70	93	68	92	62	77
	72	**60**	**71·5**	**60**	**70**	**60**	**64·5**	**60**
	72	53	72	50	70	56	66	49
	...	...	74	29	72	40	68	30
	...	...	...	...	74	24	72	16
	...	...	...	...	...	...	...	...
6	68	90	...	...	62	104	60	19
	70	66	...	...	**65·5**	**60**	62	11
	70·5	**60**	...	...	66	48	64	7
	72	45	...	...	68	33	66	5
	...	...	...	...	70	14	...	...
	...	...	...	...	...	...	...	...
7	68	116	...	...	64	120	56	125
	70	76	...	...	**66**	**60**	58	63
	72	63	...	...	66	53	**59**	**60**
	72	**60**	...	...	68	47	60	55
	74	38	...	...	...	...	62	40
	...	...	...	...	...	...	...	...
8	64	160	64	132	62	64	**55**	**60**
	66	76	**65·5**	**60**	**62**	**60**	56	35
	66·5	**60**	66	47	64	37	58	21
	...	...	68	25	66	30	60	18
	...	...	...	...	...	...	62	11
	...	...	...	...	...	...	64	8

The stiffness of dough is, as before remarked, affected to a very marked degree by its temperature, and this particularly applies to any tests allowed to stand for a length of time: it is well therefore in such tests to employ means of keeping the doughs at a uniform temperature during the whole time of standing.

Effect of Temperature.—In order to measure the effect of variations of temperature on water-absorbing power, the following tests were made:—Water was taken at 32°, 40°, &c., F., up to 110° F. In order to keep them at the desired temperature, the doughs were placed in small glasses covered with air-tight plates, and these immersed in a vessel containing water at the same temperature, in which they were kept for an hour. Three tests were made with each flour at each temperature, and from these the dough of the standard consistency was deduced in the manner previously described. The following are the results of the tests:—

WATER-ABSORBING POWER OF FLOURS AT DIFFERENT DOUGH TEMPERATURES.

No.	Names and Description of Flours.
1.	A High-Class Brand of Hungarian Patent Flour.
2.	A Patent Flour from Duluth Wheat.
3.	A High-Class Patent Flour from all English Wheat.

	Water absorbed to make dough of same consistency. Quarts per Sack.		
Temperature.	No. 1.	No. 2.	No. 3.
32° F.	84·5	72·0	64·0
40° ,,	81·5	72·5	64·0
50° ,,	77·5	70·0	61·0
60° ,,	76·5	69·0	60·5
70° ,,	70·5	66·0	55·0
80° ,,	69·0	62·5	54·0
90° ,,	67·0	61·0	52·0
100° ,,	66·5	58·5	47·5
110° ,,	61·0	56·5	44·5

From this table it will be seen that in every case there is a falling-off in water-absorbing power with the increase of temperature.

In the diagram, Figure 67, page 513, the results of the water-absorption tests on the table of flours, page 510, headed "Results of Viscometer Tests on Flours," have been drawn as a series of curves. On the horizontal lines (co-ordinates) are set off the number of seconds of time taken in each viscometer test, while the numbers representing the quarts of water taken are given on the vertical lines (abscissæ). The higher the water-absorptive capacity, the further to the right does the curve of the flour appear; and the more the rigidity of the dough is lessened by an equal increment of water, the more nearly vertical is the line of the curve. The results of tests on the loss of rigidity of dough of No. 8 flour, as a consequence of standing, are also given on in this figure. They are marked 8, *a*, *b*, *c*, *d*; 8 *a* being the "immediate" test, and 8 *d* that after twenty-four hours. The softening down, as the result of standing, is well illustrated in the diagram.

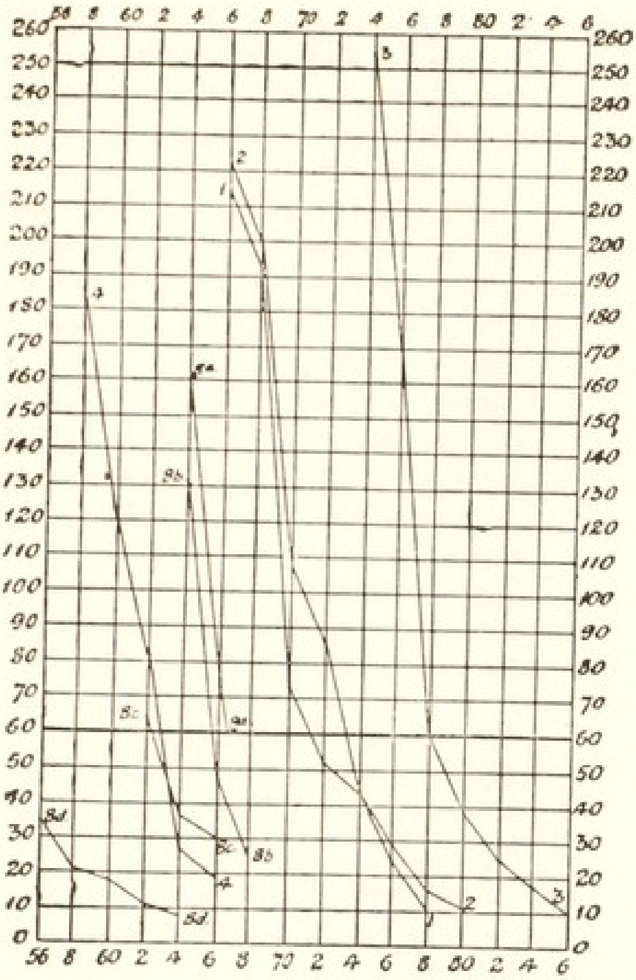


FIG. 67.—DIAGRAM OF WATER-ABSORPTION RESULTS.

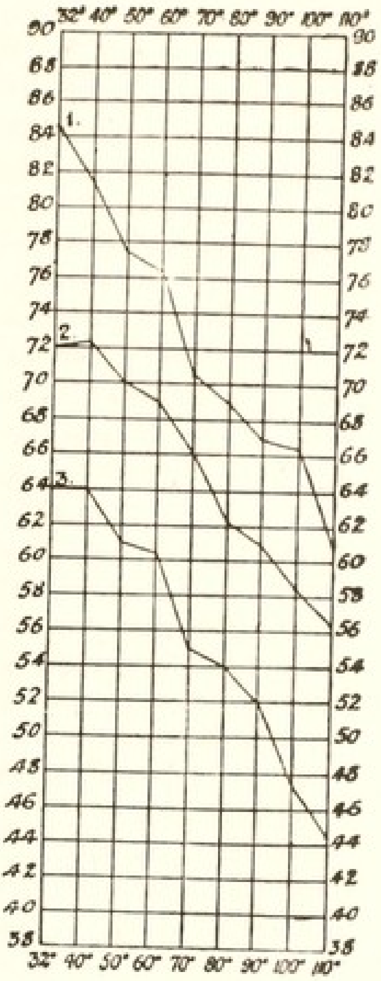


FIG. 68.—DIAGRAM OF VARIATIONS OF TEMPERATURE RESULTS.

Figure 68 above gives a graphic representation of the effect of variations in temperature, as expressed in the preceding table (page 512). The quarts per sack are given on the horizontal lines, and the various temperatures on the abscissæ. The greater the falling off in water-absorbing power with increase of temperature, or, in other words, the greater the softening of the dough, the more rapid is the descent of the curve.

571. Valuation of Gluten.—A number of attempts have been made to satisfactorily determine the quality of gluten, as considered apart from its actual percentage; it must be confessed, however, that the results obtained have been, from the standpoint of commercial testing, somewhat disappointing. As a result of experience in gluten testing, a judgment can be formed from the feel and appearance of the gluten when wet. Some glutens are soft and sticky, possessing at the same time but little or no toughness. Others, again, are highly elastic, and firm and springy to the touch; these latter are special qualities which render a flour of value for bread-making purposes.

The Aleurometer.—The instrument known as the aleurometer is the result of one attempt to measure these qualities of gluten. The principle is that of measuring the degree of expansion of the wet gluten on being maintained for some time at a temperature of 150° C. A small cylinder is provided, to which is attached by bayonet catches a bottom and top; through the latter of these passes a graduated piston rod, fixed in its turn to a piston sliding within the cylinder. A weighed quantity of gluten is placed in the cylinder, and the whole apparatus put in a hot oil or glycerin bath, maintained at 150° C. The gluten expands with the heat, and raises the piston, its maximum expansion being read on the piston rod. This instrument certainly divides the glutens of flour and wheat into strong and weak classes, but no very fine lines of distinction can with accuracy be drawn.

True Gluten.—The value of estimations of true gluten as a check on those of crude gluten has already been indicated; but they have also an additional importance. Suppose, for example, two flours each yield 35·0 per cent. of wet gluten. One is hard, elastic, and springy, while the other is soft and flabby, and causes the washing water to become "lathery." It will at once be said that the former is the higher quality gluten of the two, and quite correctly: but, further, the results would be entered that each yielded the same quantity of gluten. This latter deduction is not all the truth, for in the former case hardness of the gluten will have permitted most of the starch to be entirely eliminated with the least possible loss of real gluten constituents. In the second instance the gluten will have begun to wash away while yet there is a considerable quantity of starch remaining. Therefore the 35·0 per cent. in the first case will contain more real gluten and less foreign matter than in the second. The estimation of "true gluten" by a nitrogen determination will show that in No. 1 there is a higher percentage of actual gluten proteid matter than in No. 2, and that therefore the weaker character of the second flour is due not only to inferior quality of gluten, but also in part at least to a lower percentage of true gluten.

Gliadin Determinations.—It has already been shown that gluten consists of two proteid bodies known as gliadin and glutenin, and that the former of these, which is soluble in 80 per cent. alcohol, acts as the binding and toughening agent in gluten. In a following chapter an account is given of percentages of proteid in alcoholic extracts of flours; as the proteid thus extracted consists almost entirely of gliadin, some light is thrown on its effect on the particular character and quality of the flours discussed.

The Vesiculating Test.—R. C. Kedzie, in a recently published paper, describes a method he has employed for gluten or strength valuation of flours, depending on dissolving the proteids in a dilute solution of sodium carbonate, Na_2CO_3, and testing the resultant liquid. The test is founded on the fact that the insoluble gluten, by the action of the dilute sodium carbonate solution, is partly dissolved, and acquires a glairy consistency like the white of egg. On diluting this solution and setting free the carbon dioxide by tartaric acid, it forms a large mass of foam, because the sticky liquid retains the gas in the form of small bubbles. The volume of such foam affords a measure of the retentive power of the proteids present, and the persistence of such foam measures the strength of the proteids. If these are very strong, the bubbles will be fine, will not soon run together in large bubbles, and the foam will last many minutes before it breaks down into a ragged mass. One is thus able to see the vesiculating quality of the proteid bodies in a flour by the volume of foam, and to note their strength by observing its permanence. It is possible in this way to place a number of flours side by side for testing, and to compare them directly.

The test is conducted in the following manner :—An alkaline solution is prepared by taking 160 grams of sodium carbonate crystals (*not* bicarbonate), dissolving in water, and making the solution up to a litre. The acid solution is prepared by taking 31·468 grams of crystallised tartaric acid, dissolving in water, and making up to a litre. Three grams of the flour to be tested are weighed out into a small porcelain mortar: to this 20 c.c. of the alkaline solution are gradually added, the flour being rubbed up with it, until all is broken down into a uniform yellowish mass of the consistency of the white of egg. This is allowed to stand for an hour, and then poured into a tall cylindrical jar (test-mixer ungraduated), 12 inches high and 1¼ inches diameter, for which a good indiarubber cork should be provided. The mortar is thoroughly rinsed with 50 c.c of water, which is also added to the bottle, and thoroughly mixed by shaking. Next, 20 c.c. of the acid solution are to be poured out and rapidly introduced into the flour solution in the bottle. This is instantly corked and inverted, so as to mix the contents thoroughly; the bottle is then set upright, the cork removed, and the results watched. The height to which the foam rises is to be measured, the size of the bubbles is to be noticed, and the time in minutes noted before the vesiculation breaks down into a ragged mass. By skill in manipulating, five or six kinds of flour can be tested at one time, and the direct comparison is stated to be instructive.

The author at the time of writing has not had the opportunity of making any extended tests with this method. It seems doubtful, however, whether the characteristic differences one observes in the quality of various glutens can possibly be maintained in an actual proteid solution. Thus, there are many instances of flours which yield practically the same percentage of proteid matter and also of "true gluten," which nevertheless are decidedly different in character. The important point is whether these differences in character, which apparently depend largely on the physical condition in which the proteids exist in the flour, still continue after the whole of the proteids are reduced to a state of solution

Viscometric Gluten Valuations.—It being an accepted fact that the characteristic elasticity of wheaten flour is due to the quantity and quality of gluten, we are confronted with the following problem :—If a spring American flour be taken which yields 46·25 per cent. of wet gluten, and has a viscometer value of 67 quarts per sack, it may be compared with a winter American flour containing 27·93 per cent. of wet gluten, and having a viscometer value of 54·5 quarts per sack. Is the difference in absorptive power as registered by the viscometer due entirely to the different quantity of gluten present or partly to the quality of that gluten? As an attempt to solve this question, various flours were taken, and their gluten and viscometer readings determined.

The dry flours were then mixed with different quantities of pure wheat starch until they all yielded the same percentages of gluten; viscometric determinations were then made on these mixtures. The following table gives the results of such tests:—

VISCOMETER DETERMINATIONS ON MIXTURES OF FLOUR AND STARCH.

	I.—Spring American Patent.	II.—Winter American Patent.	III.—Second Class Winter American Bakers.	IV.—Hungarian Patent.	V.—English Wheat Patent.	VI.—British Milled First Patent.	VII.—British Milled Second Patent.
Original Percentage of Wet Gluten	39·2	28·2	32·0	35·0	27·75	31·9	38·4
Water-absorbing Power by Viscometer	68·6	54·8	69·0	76·0	61·0	60·5	64·0
Viscometer Readings, on Gluten being reduced by admixture of Starch to							
35 per cent.	65·0	...	...	...	...	...	...
30 ,, ...	62·7	...	...	71·3	...	60·0	63·0
25 ,, ...	62·0	55·5	66·0	70·7	59·5	...	...
20 ,, ...	61·4	55·4	62·0	66·0	57·5	57·5	58·5
Weight of Starch added to 100 parts of Flour to reduce Gluten to 20 per cent. ...	96·0	41·0	60·0	75·0	38·75	59·5	92·0

It will be seen that in the case of the flour with high water-absorbing capacity, they still retain that property on being diluted with starch to an uniform wet gluten-percentage level. Therefore, so far as wet gluten is concerned, it is evident that not merely quantity but also quality has a direct influence on the water-absorbing capacity of the flour. The calculation of how much starch has to be added is a very simple one, and is best illustrated by an actual example: thus, taking the first flour in the table, we find it yielded 39·2 per cent. of wet gluten. If 100 parts yield 39·2 per cent., how much starch must be added to reduce the percentage to 20 on the mixture?

$$\text{As } 20 : 39{\cdot}2 :: 100 =$$
$$1 : 39{\cdot}2 :: \quad 5 =$$
$$39{\cdot}2 \times 5 = 196{\cdot}0, \text{ weight of mixture.}$$
$$196 - 100 = 96, \text{ weight of starch to be added.}$$

This calculation resolves itself into the simple one:

$$(\text{Weight of wet gluten} \times 5) - 100 = \text{weight of starch to be added.}$$

In connection with the stronger flours, an interesting point is the bearing these experiments have on their capacity for mixing purposes. Such flours are largely employed in connection with weaker flours, which, while used for colour and flavour, are more allied to starch in strength properties. Evidence is here given of the comparative capacity these various flours have of bearing such admixture.

In view of the importance of true gluten estimations as a control on those of wet gluten, a series of determinations made on flours diluted with starch to an uniform true gluten basis would be of interest.

572. Colour.—This is probably at the same time one of the most difficult and most important tests to be made on flour. The great difficulty is that the colour of the flour itself is not necessarily a criterion of that of the bread produced. For example, some lower grade winter wheat flours look very white and even better coloured than harder spring wheat flours, whereas the bread made therefrom is exceedingly dark and ill-coloured. Further, the colour of the bread is dependent not only on that of the flour, but on the mode of working, and other factors which vary in themselves.

Unless tests are made for no other purpose than the comparison of flours placed side by side, it is absolutely necessary to have some means of measuring and registering colour. The most familiar, and on the whole the most successful, instrument for this purpose is that known as Lovibond's Tintometer or colour-measurer. As this appliance has been extensively employed in the following investigations, a description of it at this stage is necessary.

573. Lovibond's Tintometer. — The instrument itself is an optical device, Figure 69, by means of which a sample of flour, bread, or other body may be viewed side by side with a prepared surface of the purest white obtainable. With the instrument is furnished a set of transparent standard tinted glasses. These are numbered from ·01 upwards to 5·0, or higher if wished, so that any degree of depth of tint may be built up from these glasses, proceeding upwards by intervals of ·01 at a time. For flour-testing purposes three series of such tinted glasses are employed. One of these is a Yellow, the second a Red, and a third Blue.

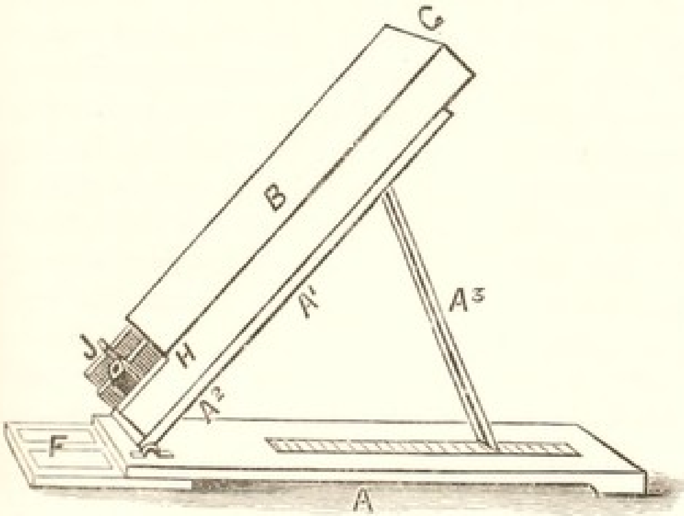


FIG. 69.—LOVIBOND'S TINTOMETER

The base, A, carries a stand, A^{1}, which is supported in an oblique position by the strut, A^{3}. On this stand is placed the optical instrument itself, B. This consists of a tube, blackened on the inside, and having apertures on the upper end, G, through which one looks in using the instrument. These openings are three in number, the outer ones being intended for use with both the eyes simultaneously, while that in the middle is for the purpose of one-eye examination. At the lower end of the tube, H, provision is made for the reception of two small cells, fitted with slits, into which the standard glasses, J, are to be inserted. At F, the coloured slabs under examination are placed for purposes of measurement.

The spongy texture of bread gives it a mottled appearance when viewed through this instrument, and so a special device is necessary by which the sponginess may be transformed into an even and uniform tint. This is shown in Figure 70, which is a plan of the tintometer arranged for this purpose. K M is a flat stand, on which the tintometer, B, is fixed. At L L, between the cells for standard glasses, and H, are placed two lenses such as those employed for spectacles. At W the standard white comparing surface is arranged, and the slice of bread under examination is fixed at Y. On looking through the eye-pieces at G, the lenses throw both the white surface, W, and the bread, Y, out of focus, so that they appear as even coloured, structureless surfaces.

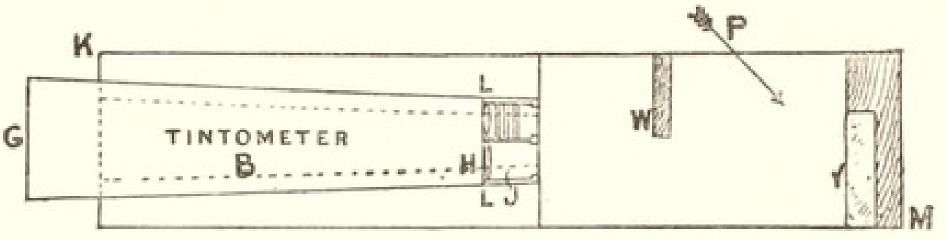


FIG. 70.—TINTOMETER FITTED FOR USE WITH BREAD.

To use the tintometer, the standard white comparing surface must first be prepared. Fill one of the little trays supplied with the instrument with some specially prepared plaster of Paris, also supplied: press down with a piece of clean glass until a smooth uniform surface is obtained: if for bread, fill the cavity in the stand at W in the same way.

When using the first arrangement of the instrument, stand it in a convenient position facing a window looking toward the north, and, if possible, so that the light is from a white, cloudy sky, rather than when the sky is perfectly blue. In this latter case it is well to place a piece of white paper or white opal glass between the light and the surfaces being examined. On the one side of the field, F, place the tray of white, and the flour on the other. On looking down through the tintometer the flour will look much the darker. In the cell over the white surface put in some of the standard colour glasses already referred to—say, for example, 1·0 Y. (yellow) and 0·50 R. (red). The white light from the prepared surface passes up to the eye through these, and gives that surface an apparent yellowish red tint. Note whether the tint as a whole is lighter or darker than the flour, also whether too red or too yellow. If too dark and too red, remove the red glass and substitute a lighter one, and again compare. If too light and too red, add a little more yellow, leaving the red undisturbed. Very quickly it is possible to get the tint matched approximately: it is in getting an exact match that the difficulty occurs. It is well to try one or two modifications of the standard glasses, and see which comes the nearest. If the eye is uncertain, it is often an assistance to place a dark glass, say 5·0 Y., in front of the eye-piece, and look through the middle aperture at both the flours; they appear much darker, but minute shades of colour are thus more readily distinguished.

Having got the tint which so closely as possible matches the flour, a register should be made of the numbers of the glasses composing it.

The bread form of the instrument should be arranged horizontally on a stand, so that it is at a comfortable height for the eyes of the observer when sitting, and so that the light comes from a window, over the shoulder, as shown by the arrow, P, Figure 70. (If necessary, the instrument may of course be arranged for the light to fall from the right instead of the left.) Care must be taken that neither the surface, W, nor that of the bread has the shadow cast on it of any part of the apparatus. The use of the standard glasses in measuring is the same as before.

It is scarcely necessary to say that colour judgments are difficult, and to point out that different persons' eyes appreciate colours differently. One difficulty with the tintometer is, the comparison is being made between an opaque coloured surface in the case of the flour, and a tint imparted to a beam of light in the case of the test-surface—there is a difference in quality which makes comparison difficult. A desideratum is some form of permanent, graduated, tinted surface which can be compared with the flour.

The great value of the tintometer is for from time to time permanently measuring and checking the colour of standard flour samples: this is well worth any trouble taken in so doing. The standards being thus kept verified, it will be sufficient for ordinary purposes to check and compare flours side by side with the standards.

As some help to the description of colour readings by the tintometer, the accompanying Plate, No. XIV., has been prepared. The various colours and tints have been matched as carefully as possible, and reproduced with as much accuracy as attainable by colour-printing processes. It is hoped that they will serve as a general guide to those not in possession of the instrument; but it must be understood that the colours are only given as approximate representations of the various tints, and not as absolute reproductions.

On the upper part of the plate is given, first, a series of examples of the Yellow scale from 0·5 to 2·5; that is, the rectangle of colour marked 2·5 would be approximately matched by the 2·5 glass in the tintometer. The same holds good with the other numbers of the series. There is next given a similar set of examples from the Red scale. As all flours are practically intermediate between these tints of Yellow and Red, and are matched by mixtures of various proportions of these, the third column consists of a mixture of Yellow and Red, the proportion being the same throughout the series of shades. The figures placed opposite give the tintometer readings of the actual coloured surfaces from which the original copy was prepared.

On the lower part of the plate is given, first, a representation of 2·5 Blue glass of the scale, and then as accurate reproductions as possible of some selected examples of flours, particulars of which follow:—

	Colour as read by Tintometer.
No. 1. Blue Glass	2·5
,, 2. Minneapolis Bakers' Flour	1·8 Y. + 1·4 R.
,, 3. Minneapolis Bakers' Flour, 2nd. sample	1·7 Y. + 1·6 R.

	Colour as read by Tintometer.
No. 4. Red Dog Flour, Spring Wheat	4·0 Y. + 4·3 R. + 1·2 B.
„ 5. Winter American Wheat Patent	0·45 Y. + 0·2 R.
„ 6. English Patent from Blended Wheats	0·7 Y. + 0·3 R.
„ 7. Hungarian Patent	1·05 Y. + 0·45 R.
„ 8. Spring American Wheat 40 per cent. Patent	0·90 Y. + 0·6 R.

To afford some guide to the strength and water-absorbing power of these flours, the gluten and viscometer absorption were also determined with the following results :—

No.	Gluten, per cent. Wet.	Dry.	Viscometer, Quarts per Sack.
2.	43·0	14·30	67·0
3.	36·8	12·20	67·5
5.	26·3	8·45	56·5
6.	33·0	11·00	59·5
7.	30·0	9·80	77·5
8.	35·5	11·83	65·0

574. Colour Investigations.—In obtaining the readings made in connexion with the following research, the judgment of four persons was, in many instances, utilised, while every reading was checked by at least two persons, and always, where the slightest doubt was felt, by three.

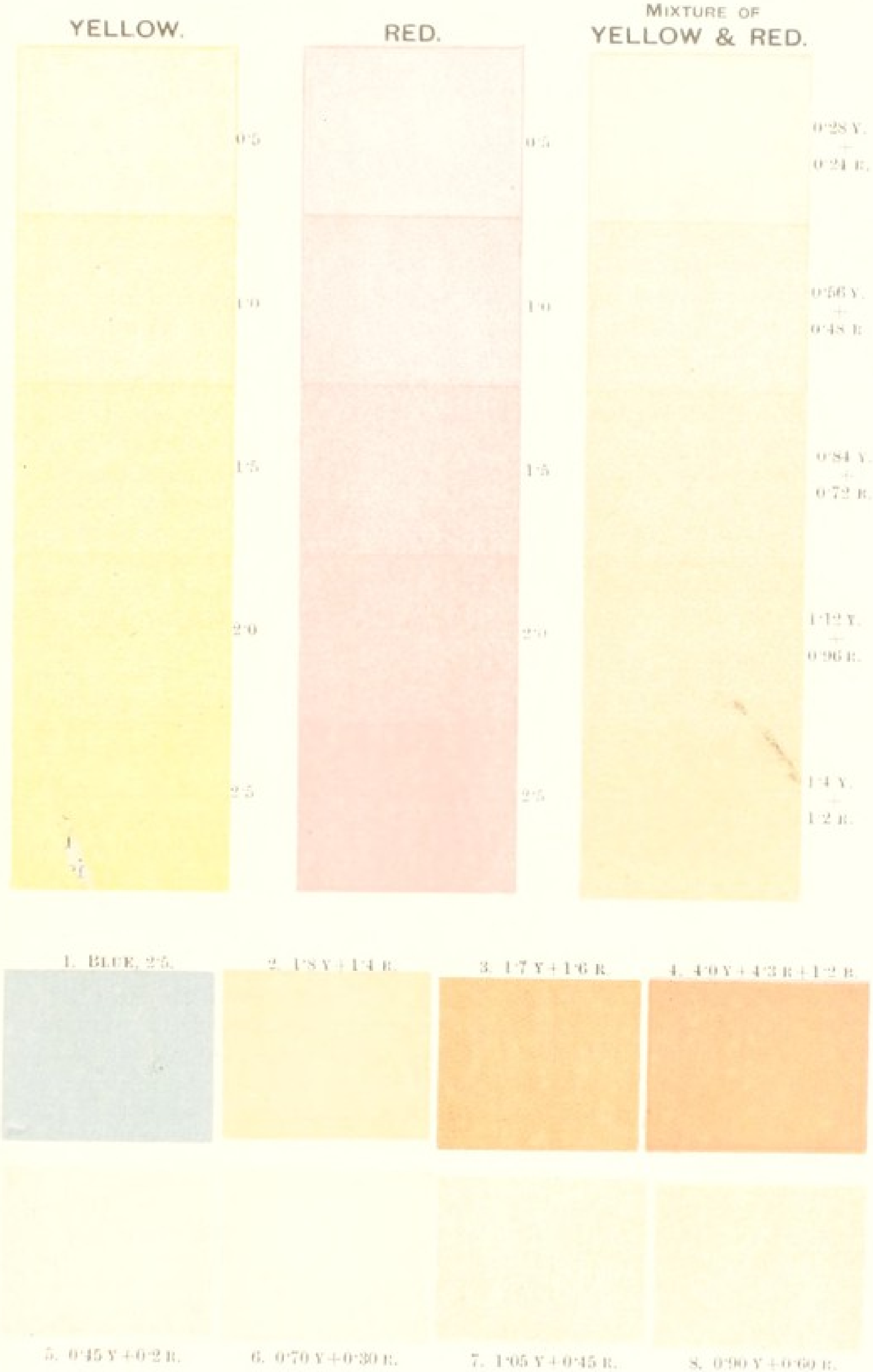
Among methods of judging the colour of flour the most obvious is that of testing the flour itself in the normal dry condition. To this there is the objection that the colour of dry flour depends not merely on the nature of the wheat and the flour constituents, but also on the comparative coarseness or fineness of the particles of the flour. Further, on exposure to air flour very quickly bleaches, although this of course does not affect the validity of a test made on a sample taken from bulk. The bleaching of flour is commonly ascribed to light, but this is not essential, for in the following experiment the samples were kept during the interval between readings in a dark cupboard. The following three dry samples gave tintometer readings as under, being simply pressed into smooth slabs and examined :—

	Immediate.		After standing one Day.	
	Yellow.	Red.	Yellow.	Red.
American Spring Bakers	0·27	0·06	0·25	0·04
Ditto, another sample	0·34	0·11	0·30	0·09
American Winter Bakers	0·20	0·02	0·11	0·02

A second and well-known method of testing colour is to dip the compressed slabs into water, so as to wet the surface, then allow the same to dry off, and read or compare the colours. The tint is in this instance darkened considerably by action of the air, coloured oxidative products being formed. In this case, again, the degree of granulation of the flour affects the depth of colour—a coarse flour absorbs more water, and becomes darker through taking longer to dry, while the surface has more or less "grain" as a result of roughness of the surface before wetting.

A third method consists of making the flour into dough, working it

PLATE XIV.



TINTOMETER REGISTRATION OF COLOUR OF FLOUR.

See Special Note to this Plate on pages 636–7.

until perfectly smooth, and then examining and comparing. One objection to this method is that the colour of the dough darkens rapidly on the outside, and hence, if an attempt be made to read off the colour, or even compare a series of three or more at a time, a new dough surface darkens visibly while the comparison is being made. To obviate this, the pellet of dough may be placed on a sheet of *colourless* glass, and the colour of the dough observed *through* the glass—in this way the colour of the dough proper is seen as distinct from that of the outer skin. It is no uncommon occurrence to take two flours from the same variety of wheat, the one very fine and the other granular, and compare them either dry or wetted in compressed slabs. The granular flour under both tests looks the darker, but on working them into dough, as just described, the coarser flour often produces the more "bloomy" dough; bakers will at once form their own judgment as to which of the two will under similar conditions make the best loaf. Also, of course, the outer skin of the same samples may be compared and read if necessary.

Investigation shows that the colour of dough is influenced by its degree of stiffness. Thus, a spring bakers' flour was made into dough with different quantities of water, and the following readings taken at the expiration of one hour. At the end of eighteen hours, in which the doughs were kept in a water-saturated atmosphere, the colour of the outer skins was also read :—

	Colour of Dough.			Colour of Skin.		
	Yellow.	Red.	Blue.	Yellow.	Red.	Blue.
1. Doughed with 50 per cent. of water	1·50	0·68	0·08	3·55	2·10	0·86
2. Doughed with 55 per cent. of water	1·42	0·63	...	3·75	2·10	0·56
3. Doughed with 60 per cent. of water	1·19	0·54	...	3·15	1·90	0·48

The colour both of dough and skin is darker in the tighter doughs; also this relation of colour holds good for some time, for at the end of eighteen hours the *order* of colour of the dough was the same as at the end of one hour.

In order to eliminate so far as possible the differences due to variations in tightness of doughs, the whole of the flours were in the subsequent tests treated with the quantity of water sufficient to make doughs of uniform stiffness. For this purpose each flour was tested by the viscometer in the manner previously described. The next step was to investigate the influence of the length of time the dough had stood on the depth of colour; this, be it remembered, always being read through colourless glass. The following results were obtained :—

Time.	Winter American Patent.		Winter American Bakers.		Spring American Patent.		Spring American Bakers.	
	Y.	R.	Y.	R.	Y.	R.	Y.	R.
1 hour after mixing	0·92	0·29	1·37	0·94	1·02	0·64	1·34	1·10
2 hours after mixing	1·02	0·36	1·49	0·97	1·09	0·64	1·49	1·00
3 hours after mixing	1·08	0·40	1·50	1·00	1·25	0·75	1·52	1·07
4 hours after mixing	1·10	0·43	1·51	1·00	1·20	0·65	1·47	0·97
22 hours after mixing	1·08	0·58	1·50	1·02	1·21	0·75	1·46	1·07

It may be well here to explain the precautions taken in order to get as exact readings as possible. First of all, every series of tests to be read were arranged in order of colour as apparent to the eye; then they were read in succession, commencing with the lightest. After matching No. 1, No. 2 was placed against its (No. 1's) standard tint glasses and seen to be darker, then measured. In all cases where there was any apparent discrepancy the reading received a checking by three persons. When making time measurements the following method was adopted :—First of all, at the expiration of the time, the colour glasses of the preceding reading were again placed in the instrument, thus taking, for example, the two hours' reading on the first flour just given, the one hour glasses, Y. 0·92 ; R, 0·29 were inserted, and the dough compared with them. It was thus definitely ascertained that a distinct darkening had occurred; its measurement then followed. Each reading was thus compared with that preceding throughout the whole series. It will be observed that a slight but steady darkening occurs throughout the whole series, the increasing red or foxy tint "saddening" the bloom of the yellow. Unless otherwise stated, future readings were made on doughs after standing one hour.

The author has recently adopted another method of preparing the flour for examination, which is really a modification of the Pékarised slab method. The testing Pfleiderer doughing machine is thoroughly cleaned by making a stiff dough in it, and thus removing anything that would injure the colour. A dough is made by taking 30 grams of flour and 15 grams of water, and then pinning it out into a thin sheet—say three-sixteenths of an inch thick—on a piece of glass. This is allowed to dry off in a dark place, and then read just like the Pékar slab. It has the advantage of giving a smooth surface with all errors due to the "grain" of the flour eliminated ; but has the disadvantage that the degree of darkening depends somewhat on thickness of the sheet.

The next and final test is that made by baking the loaf and then observing the colour of the bread. It is scarcely necessary to point out to bakers that colour is influenced by the kind of yeast used and mode of working ; but using the same yeast, it was thought well to register the effect produced by the mode of fermenting employed, and especially the time of fermentation. A spring American bakers' flour was first made into an off-hand dough in the following manner :—

10 lbs. flour,
5 lbs. water at 90° F.,
$1\frac{1}{2}$ oz. compressed yeast (Delft Pure), and
$1\frac{1}{4}$ oz. salt

were taken and made into dough at 5 P.M. The dough was then maintained at a temperature of 80—82° F. during the whole time of the experiment. At intervals a 2 lb. piece was taken, moulded, and baked. On the next morning the loaves were cut, the colour examined, and also the total acidity, reckoned as lactic acid, determined. On the second day also the colour was read, a freshly-cut surface being used for that purpose. The following table gives the results obtained. The first column gives the number of hours after setting the dough until the loaf was placed in the oven ; the first day's colour readings follow in the second column, the next day's in the third, and the acidities in the last :—

TESTS ON BAKERS' FLOUR—OFF-HAND DOUGH.

No.	Hours.	First Days's Colour. Y.	R	B.	Second Day's Colour. Y.	R.	B.	Acidity per cent.
1	4	2·11	1·41	0·30	1·85	1·25	0·16	0·57
2	6	1·75	1·25	0·18	1·91	1·10	0·26	0·63
3	8	1·75	1·00	0·10	1·85	1·10	0·26	0·66
4	10	1·75	1·20	0·10	1·75	1·30	0·26	0·69
5	12	1·70	1·15	0·05	1·66	1·20	0·24	0·73
6	13½	1·70	1·20	0·30	1·75	1·40	0·30	0·79

Fermentation had not proceeded sufficiently far to properly raise the first loaf, which was somewhat close and heavy, and also dark in colour; but it should be borne in mind its texture could scarcely be in fairness compared with that of the other numbers of the series. The last showed signs, but only slight, of darkening—due doubtless to the commencement of those changes which accompany sourness. The loaves Nos. 2 to 5 do not vary greatly in colour, but there is a slight diminution of the depth of tint. Taken as a whole, this series darkened before the second day.

In another series of tests two doughs were worked with a flour ferment. The one was from a spring American patent flour; the second from a bakers' grade from the same wheat. The following quantities were in each case employed:—

¾ lb. flour 3 oz. compressed yeast 5 lbs. (2 quarts) water at 102° F.	Ferment.
9¼ lbs. flour	Dough.

The ferment was allowed to work 45 minutes from the time of being set; then the dough was made, and one loaf immediately taken. This was allowed to prove, and at once baked. Loaves were taken at intervals as shown in the following table, in which is also given the colour and acidity both in the first and second day after baking. It should be added that the first loaf was baked at about 9.15 P.M.

TESTS ON BAKERS' FLOUR—FLOUR FERMENT AND DOUGH.

(Same sample as used in previous series.)

No.	Hours	First Day's Colour. Y.	R.	B.	Acidity per cent.	Second Day's Colour. Y.	R.	B.	Acidity per cent.
1	Immediate	1·80	1·15	0·50	0·65	1·40	0·96	0·06	0·59
2	2 hours	1·65	1·20	0·40	0·73	1·48	1·00	0·04	0·71
3	4 ,,	1·65	1·30	0·40	0·72	1·42	1·00	0·04	0·90
4	6 ,,	1·90	1·80	0·60	1·05	1·60	1·40	0·05	1·12
5	7½ ,,	2·20	2·08	0·75	1·17	1·60	1·45	0·08	1·27
6	9½ ,,	2·22	2·15	0·75	1·10	1·65	1·40	0·08	1·34

REMARKS.

No. 1. Very close and heavy.
No. 2. Sweet, good loaf.
No. 3. Colour slightly worse, odour faulty.
No. 4. Decidedly sour, rapid darkening in colour commenced.
No. 5. These changes intensified.
No. 6. These changes still more marked.

The colour here distinctly fell off, with increase of acidity, a distinct difference being observed even between Nos. 2 and 3. The off-hand doughs were, as a series, whiter than those prepared with a ferment, but this is probably due to the excessive fermentation in the latter series, which was intentionally pushed to an extreme. Taken as a whole these loaves were distinctly less coloured on the second day.

The following are the results of the corresponding series of tests on patent flour :—

TESTS ON PATENT FLOUR.

No.	Hours.	First Day's Colour.			Acidity per cent.	Second Day's Colour.			Acidity per cent.
		Y.	R.	B.		Y.	R.	B.	
1	Immediate	1·45	0·70	—	0·29	1·40	0·72	—	0·32
2	2 hours	1·40	0·62	—	0·35	1·60	0·73	0·05	0·37
3	4 ,,	1·30	0·60	—	0·50	1·32	0·65	0·06	0·52
4	6 ,,	1·75	0·98	—	0·63	1·60	1·01	—	0·68
5	7½ ,,	1·70	1·01	—	0·70	1·40	0·90	—	0·73
6	9½ ,,	1·70	1·02	—	0·75	1·48	0·93	—	0·82

REMARKS.

No.	First Day.	Second Day.
1.	Close and heavy—Sweet	Sweet.
2.	Bright and good bloom—Sweet	Sweet.
3.	Greyer, very little different—Sweet. Both 2 and 3 good volume	Incipient sourness.
4.	Smaller, darker, slightly sour	Sour.
5.	Smaller, darker, sourer	Sour.
6.	Very small, dark, very sour	Very sour.

Again, with an increase of acidity, there is also a darkening of colour ; and in the earlier numbers of the series also a darkening on the second day's reading as compared with the first. There is a property of bread colour to which attention has already been drawn by Abercromby, which property renders comparison difficult both to the eye and also the tintometer. That property is "a silky texture in the bread, which, by reflecting the light, gives an appearance of better colour." To this characteristic the author ventures to apply and appropriate the term "*sheen*." The difficulty is that a loaf looks more "*sheeny*" in one position than another ; not only may two observers, the one looking over the other's shoulder, get a different impression, but the sheen may be affected even by slightly turning or altering the position of the loaf. One reason why the patent flour breads suffer in colour on the second day is the loss of brilliance or sheen.

The table on page 525 gives the results of examining a number of flours for colour by the various methods described.

In every case the order of the substances as they appeared to sight is given, as well as the reading by the tintometer ; between these there are but few discrepancies, and these mostly occur in the case of bread, where the disturbing influence of irregular surface and scattered reflection of light acts most powerfully. But even in these the divergence is not great. The tintometer reading is probably the truer register of absolute colour, the disturbing effect of side reflections, &c., being practically entirely counteracted. But the public does not view bread through a tintometer as a preliminary to purchase, and hence a doubt

TESTS BY VARIOUS METHODS ON THE COLOUR OF FLOUR.

Bakers' Flours.	Colour of Dry Flour.			Colour of Wetted Flour			Colour of Dough.				Colour of skin of dough, order by sight at 3 hours.	Colour of same samples, one day later.		Colour of Bread.			Remarks.
	Order by sight.	Tintometer.		Order by sight.	Tintometer.		Order by sight.		Tintometer at 2¼ hours.			Dough, order by sight.	Skin, order by sight.	Order by sight.	Tintometer.		
		Y.	R.		Y.	R.	Imme-diate.	2¼ hours.	Y.	R.					Y.	R.	
W. *a.*	1	0·20	0·02	1	0·67	0·21	6	6	1·40	0·90	2			1	1·30	0·54	
W. *b.*	2	0·20	0·02	5	0·73	0·20	1	1	1·10	0·70	1			3	1·50	0·92	
W. *c.*	3	0·18	0·03	2	0·70	0·23	2	2	1·37	0·52	5			2	1·34	0·91	
W. *d.*	4	0·20	0·03	3	0·71	0·23	4	4	1·32	0·91	3			5	1·48	0·94	
W. *e.*	5	0·20	0·04	4	0·75	0·20	3	3	1·39	0·60	4			4	1·55	0·95	
W. *f.*	6	0·21	0·05	7	1·60	0·60	7	7	1·49	0·95	8			6	1·52	0·94	
S. *g.*	7	0·27	0·06	6	1·00	0·59	5	5	1·36	0·92	6			7	1·48	0·93	
S. *h.*	8	0·32	0·08	8	1·25	0·80	9	9	1·60	1·08	7			8	1·50	0·95	
S. *i.*	9	0·34	0·11	9	1·30	1·19	8	8	1·60	1·00	9			9	1·78	1·20	
Patent Flours.							Order by sight at 2 hours.				At 2 hours.						
W. *k.*	1	0·06	0·02	4	0·54	0·20	3		0·90	0·10	3	4	6	3	1·22	0·60	White, little yellow.
W. *l.*	2	0·06	0·02	3	0·48	0·12	2		0·92	0·10	2	3	3	1	1·25	0·59	Bloomy.
W. *m.*	3	0·09	0·02	6	0·55	0·20	6		0·96	0·10	6	6	5	9	1·31	0·57	Very yellow.
W. *n.*	4	0·07	0·02	2	0·42	0·06	4		0·90	0·11	4	2	2	7	1·30	0·64	White, less yellow than 6.
W. *o.*	5	0·07	0·02	1	0·40	0·05	1		0·92	0·10	1	1	1	5	1·20	0·64	White, less yellow than 4.
W. *p*,	6	0·07	0·02	5	0·50	0·20	5		0·92	0·10	5	5	4	8	1·29	0·64	White, little yellow.
W. *q.*	7	0·20	0·03	7	0·73	0·22	10		1·15	0·58	...	...	...	...	...	...	
S. *r.*	8	0·22	0·05	8	0·80	0·60	7		0·94	0·30	7	9	8	2	1·30	0·60	Bloomy, but slightly greyer than 1.
S. *s.*	9	0·22	0·06	9	0·84	0·58	8		0·96	0·30	9	7	9	4	1·39	0·62	Bloomy.
S. *t.*	10	0·30	0·08	10	0·85	0·60	9		0·96	0·40	8	8	7	6	1·36	0·65	Bloomy.

arises as to which is the most trustworthy baker's reading, that, or the general effect on the eye. A point of more importance is the relationship existing between the various modes of judging colour of flour, and the colour of the resulting bread. In the series of results just tabulated, the colour of the dry flour agrees most closely with that of the baked loaves; while, contrary to expectation, there is considerable discrepancy between the colour of the dough and that of the bread. It should be noted that if the flours (which were all American) be divided into the two classes of spring and winter, many of the differences disappear. Although a good many results are here accumulated, they do not afford sufficient data on which to generalise, but they *do* show the extent of agreement and disagreement between various methods of testing flour for colour in common employment.

575. Effect of Age on Flours.—The experiments set forth in the following table were made in order to determine the effect of age on American flours. All the tests were made at various times on 14-lb. samples, stocked meantime in close textured canvas bags. The first tests were made on the arrival of the flours in this country in October; the second series after the lapse of three months, in January; and the third after the expiration of another two months, in March. The colour on dry flour, wet gluten, and water absorption by viscometer were in each case determined:—

No. 1. Bakers' Flour from Duluth Wheat.
,, 2. Patent ,, ,,
,, 3. Bakers' ,, Manitoban Wheat.
,, 4. Patent ,, ,,
,, 5. Bakers' ,, Indiana Winter Wheat.
,, 6. Patent ,, ,, ,,
,, 7. Bakers' ,, Ohio Winter Wheat.
,, 8. Patent ,, ,, ,,

EFFECT OF AGE ON FLOURS.

		1	2	3	4	5	6	7	8
Colour.									
New	Y	0·30	0·21	0·27	0·22	0·20	0·07	0·18	0·06
	R	0·07	0·04	0·06	0·06	0·03	0·02	0·03	0·02
Three months old	Y	0·29	0·22	0·27	0·22	0·16	0·06	0·16	0·08
	R	0·07	0·02	0·06	0·04	0·03	0·02	0·02	0·01
Five months old	Y	0·28	0·21	0·26	0·22	0·16	0·06	0·14	0·06
	R	0·07	0·02	0·04	0·04	0·03	0·02	0·02	0·01
Wet Gluten.									
New		44·0	42·0	44·5	39·0	37·0	28·9	33·7	31·8
Three months old ...		43·7	41·7	37·4	36·2	30·6	29·1	33·3	30·2
Five months old ...		43·2	41·2	35·7	35·0	30·1	28·9	32·7	30·3
Water Absorption									
New		69·5	68·0	66·0	63·5	59·0	53·0	56·0	57·5
Three months old ...		68·5	67·0	67·5	66·0	60·0	55·0	56·0	55·5
Five months old ...		66·0	62·0	66·0	63·0	55·0	51·0	56·0	55·0

With increase of age a slight, but only a slight, amount of bleaching is observed. In connexion with this, it will be of interest to note the difference in colour between a sample of flour by which purchase was made on Mark Lane, and the colour of bulk when delivered some weeks later. The seller alleged that the difference in colour between bulk sample and selling sample was due to bleaching of the latter in the interval between date of purchase and arrival of the flour.

	Colour of Sample.	Bulk.
Dry Flour	0·10 Y. + 0·01 R.	0·32 Y. + 0·09 R.
Pékarised Flour ...	1·32 Y. + 0·50 R.	2·20 Y. + 0·90 R.
Dough, through glass ...	1·10 Y. + 0·60 R.	1·50 Y. + 0·90 R.

Comparing the above results with the amount of bleaching on authentic samples, comment is unnecessary.

The amount of gluten and also water-absorbing power by viscometer show generally signs of slight diminution.

576. Baking Tests.—It may seem at first sight strange, but for actual comparative tests it is a moot point whether the purely analytical methods do not give the most useful results for general purposes; they are obtained by processes in which all disturbing influences are so far as possible eliminated, whereas in baking tests the quality of the yeast, temperature of working, &c., are all disturbing elements. As seen by preceding results quoted, the colour and other characteristics of the bread are affected by differences in the mode of performing baking tests. In baking tests, again, the individuality of the baker must largely come into play, as he will naturally treat the flour in the manner most nearly comparable with his own general mode of working. As no two bakers work exactly alike, one set of results may not quite agree with those obtained by another baker working in a somewhat different manner, and with not altogether the same objects in view.

There follow a number of series of important baking and other tests made at different times, together with a description of the mode of working employed. They are useful, not merely for the data they afford, but also as illustrations of different experimental methods.

577. M'Dougall's Tests.—In Chapter XV., paragraph 402, an account of various milling tests by M'Dougall Brothers is given; the table on page 528 embodies the results of Baking Tests made by them on the flours obtained.

The quantities used were in each case 1 sack (280 lbs.) of flour; 30 lbs. of liquid potato ferment; 1 lb. distillers' yeast; and 3½ lbs. of salt. The colour, flavour, and texture, are expressed by a series of numbers, the highest quality being represented by the highest number. From these experiments, M'Dougall Brothers conclude that yield of bread does not mainly depend on the quantity of gluten contained by the flour, but principally on its degree of dryness.

A feature of these experiments, which has caused considerable controversy, is the very high position they give to Indian wheats, particularly as the Report was prepared at the request of the Secretary of State for India.

BAKING TESTS ON SINGLE WHEAT FLOURS—M'DOUGALL BROS.

WHEAT.	Water used.	Yield of Bread when cold.	Percentages.		Colour, Taste, and Texture.				
			Percentage of bread to flour.	Percentage of water to flour.	Colour, Exterior.	Colour, Interior.	Texture.	Flavour.	General Characteristics.
	Pounds	Pounds							
Indian (fine soft white) ...	141·4	364·0	130·0	50·5	10	11	8	7	11
Do. ...	149·6	367·5	131·2	53·4	13	13	9	9	12
Indian (superfine soft white)	141·6	372·0	133·0	50·6	8	10	9	7	10
Do.	148·0	362·0	129·3	52·3	12	13	10	9	11
Indian (average hard white)	141·0	370·5	132·4	50·8	6	7	10	7	7
Do.	149·6	365·0	130·3	53·4	10	9	10	9	9
Indian (average hard red)...	145·2	376·6	134·5	51·8	5	7	10	7	6
Do. ...	147·4	365·0	130·3	52·2	9	9	10	8	8
English	130·0	352·0	125·7	46·4	13	12	10	13	10
Australian	134·2	355·4	126·9	48·0	12	12	10	12	11
New Zealand	132·0	349·0	124·6	47·1	12	12	9	12	10
Californian	136·8	364·0	130·0	48·9	12	12	9	12	10
American (Winter) ...	130·0	346·0	123·5	46·4	13	12	10	12	11
American (Spring)... ...	130·0	354·0	126·4	46·4	8	10	12	10	9
Russian (Saxonska) ...	130·0	356·0	127·1	46·4	8	9	13	9	9
Russian (Taganrog) ...	145·4	354·5	126·6	51·9	10	11	12	9	9
Egyptian (Buhi)	136·8	362·5	129·3	48·9	7	6	7	6	5
Egyptian (Saida)	144·4	358·0	127·7	51·6	6	4	6	4	4

578. Clifford Richardson's Baking Tests.—In 1884 Clifford Richardson presented to the American Government a report of the results of baking tests made of American flours. The object of these tests was largely to investigate M'Dougall's results on flours from American wheats. Richardson prefaces his results by stating that "using flour under various conditions, it was found possible to vary the yield of bread per 100 lbs. of flour as much as 15 lbs. The conditions upon which this variation depends are largely physical, and include—

Percentage of water used in the dough,
Size of the loaves,
Temperature of the oven,
Time of Baking."

In further illustration of this point, Richardson gives a table (page 529), showing the extent to which the variation in yield is dependent on the percentage of water (other conditions remaining the same), the size of the loaves, difference of temperature, and on the time of baking.

Richardson further points out that "a dough made with any American flours, and as small a percentage of water as was used by the M'Dougalls, would be altogether too stiff for successful results." But here cognisance must be taken of the kind of bread made: in Richardson's experiments a slack tin or pan dough is throughout used, while the M'Dougalls baked their bread into crusty cottage loaves. The difference is largely due to difference in the character of the bread commonly made in America and England respectively. This point should always be borne in mind when comparing results obtained by observers in the two countries. A further important bearing it has is this—the flour, which will take a relatively high proportion of water for slack or tin dough, is not necessarily that which will also take a relatively high proportion when used for crusty cottage bread. Flours with soft, ductile glutens will often take a very large quantity of water, provided the dough is supported in a pan for baking, while they may in the stiffer dough be comparatively unable to stand without support, and so make a flat, runny loaf.

VARIATIONS IN BREAD YIELD—RICHARDSON.

Dependent on percentage of water used (other conditions being the same).		Dependent on size of loaves.		Dependent on difference of temperature.		Dependent on time of baking.	
Per cent. of water.	Yield of bread.	No. of loaves.	Yield of bread.	Temperature.	Yield of bread.	Time, Minutes.	Yield of bread.
54·5	134·5	1 loaf.	138·6	249°	136·9	50	134·6
58·4	136·9	10 rolls.	129·6	230°	140·8	30	140·2
62·1	144·9	...	...	...	...	...	...
62·1	145·5	...	...	...	...	...	...

In all American systems of flour-testing which have come under the author's personal notice, the baking tests are made on tinned bread. This, doubtless, gives the best results for the flour used in America. It is recommended, however, that American millers, who export to this country, should also have their flours tested by methods based on the production of crusty bread such as is most generally made in England.

Richardson made a dough with the whole of the water, allowed it to rise till the outer pellicle was just cracking, then re-kneaded it into loaves, which were put in tins or pans and then baked. The table on pages 530 and 531 gives the results of his experiments.

579. Flours collected in America.—In 1893 the author made an extended tour through the United States and Canada, collecting personally a number of the best known and highest quality flours, and subjecting them to commercial analysis and baking tests. The various analytic tests need no further explanation, but it may be mentioned that in the Baking Tests the method employed was the making of an off-hand dough of tightness sufficient for crusty cottage loaves. The quantities taken were one kilogram of water and sufficient flour to make a dough of requisite consistency. The water has been calculated to quarts per sack; other data are also given. Subjoined is a list of the flours, together with particulars of the mills, I.; variety of wheat, II.; varieties of flour and names of brands under which sold in the United Kingdom, III.; and character as claimed by

BAKING TESTS ON VARIOUS AMERICAN FLOURS.—CLIFFORD RICHARDSON.

In the following series of baking tests, in each experiment there were taken of water 650 grams, milk 500 grams, salt 25 grams, yeast 10 grams, with the weight of flour as under :—

Name of Flour.	Weight of Flour.	Relation of Water to Flour.	Raised.	Loss in Rising.	Raised in Pans.	Baked.	Temp. of Oven.	BREAD.				FLOUR.				
								Weight Hot.	% Hot.	Weight Cold.	% Cold.	% Moisture.	% Nitrogen.	% Proteids.	Gluten.	
															Wet.	Dry.
			h. m.		h. m.	m.	° C.									
Maryland Patent Flour	2,032	56·59	2 35	12	1 07	45	...	2,856	140·6	2,729	134·4	11·55	1·65	10·33	33·32	9·60
	2,049	56·12	3 00	30	1 00	45	228°	2,933	143·2	2,795	136·4	...	...	...	...	...
Maryland Straight -	2,014	57·09	2 56	28	1 06	45	...	2,937	145·8	2,754	136·7	11·08	1·75	10·94	32·49	10·28
	2,031	56·62	2 45	23	1 00	50	248°	2,866	141·1	2,746	135·2	...	...	...	...	...
Maryland Low Grade	2,024	56·82	2 35	18	0 55	45	243°	2,846	140·6	2,740	135·4	12·78	1·84	11·50	30·15	11·13
	2,024	56·82	2 45	32	1 00	55	243°	2,859	141·3	2,759	136·3	...	...	...	...	...
District of Columbia Patent - - -	2,073	55·48	2 30	59	1 00	45	236°	2,873	138·6	2,754	132·9	12·98	1·46	9·10	31·58	9·09
	2,056	59·93	3 00	36	1 00	45	230°	2,833	137·8	2,732	132·9	...	...	...	...	...
District of Columbia Straight - -	2,045	56·23	2 30	38	1 00	45	245°	2,867	140·2	2,757	134·8	12·38	1·53	9·56	33·40	9·76
	2,030	56·65	2 30	31	1 00	45	235°	2,830	139·4	2,730	134·5	...	...	...	...	...
Straight Virginia -	2,033	56·57	2 35	12	0 55	30	...	2,948	145·0	...	...	12·16	1·93	12·08	36·07	11·41
	2,044	56·26	2 41	19	1 02	45	...	2,886	141·2	2,792	136·6	...	...	...	...	...
	2,025	56·79	2 45	21	1 00	45	248°	2,931	144·7	2,808	138·7	...	...	...	...	...
Low Grade Virginia -	2,032	56·59	2 57	17	1 15	45	247°	2,89	142·6	2,785	137·1	11·77	2·02	12·60	36·81	11·60
	2,038	56·43	2 40	28	1 00	45	248°	2,870	140·8	2,738	134·3	...	...	...	..	...
Roller Patent Virginia	2,034	56·54	2 35	11	1 07	45	248°	2,838	139·5	2,733	134·4	12·10	1·73	10·81	37·89	11·08
	2,047	56·19	2 55	34	1 00	45	230°	2,914	142·4	2,781	135·9	...	...	...	...	...
Ohio Patent - -	2,149	53·51	3 16	32	1 15	48	...	2,986	138·8	...	...	12·85	1·70	10·62	29·63	10·47
	2,110	54·50	...	24	...	50	...	2,989	141·7	2,840	134·6	...	...	...	...	...

BAKING TESTS ON VARIOUS AMERICAN FLOURS.—CLIFFORD RICHARDSON—*continued.*

Name of Flour.	Weight of Flour.	Relation of Water to Flour.	Raised.	Loss in Rising.	Raised in Pans.	Baked.	Temp. of Oven.	BREAD.				FLOUR.				
								Weight Hot.	% Hot.	Weight Cold.	% Cold.	% Moisture.	% Nitrogen.	% Proteids.	Gluten.	
															Wet.	Dry.
			h. m.		h. m.	m.	° C.									
Indiana Patent - -	2,049	56·12	2 35	31	1 35	45	240°	2,908	141·4	2,780	135·7	12·33	1·59	9·94	33·60	10·03
	2,068	55·61	2 50	35	1 00	50	230°	2,898	140·1	2,772	134·0	...	...	...	...	...
Illinois Patent Flour -	2,041	56·35	2 35	4	0 55	45	...	2,914	142·8	2,791	136·8	12·00	1·93	12·08	37·36	11·56
	2,043	56·29	2 47	19	1 00	45	232°	2,862	140·1	2,754	134·8	...	...	...	...	...
Wisconsin Patent -	2,035	56·51	2 50	28	0 55	45	...	2,832	139·2	2,730	134·2	12·37	1·60	9·98	28·39	9·56
	2,031	56·62	2 30	29	1 00	45	245°	2,852	140·4	2,728	134·3	...	...	...	...	..
Roller Patent Wisconsin - - - -	2,034	56·54	2 52	13	1 00	45	249°	2,900	142·6	2,788	137·1	13·25	1·85	11·55	34·45	10·65
	2,040	56·37	2 30	33	1 00	45	234°	2,862	140·3	2,745	134·1	...	...	...	...	...
Best Minnesota Patent Process - - -	2,033	56·57	2 35	28	0 55	30	...	2,957	145·2	...	...	12·82	1·90	11·90	39·18	11·98
	2,028	56·71	2 43	18	0 57	45	...	2,825	139·3	2,747	135·5	...	...	...	...	...
	2,024	56·82	2 30	23	1 00	45	242°	2,802	138·4	2,784	137·6	...	...	...	...	...
Minnesota Low Grade	2,006	57·33	2 37	13	1 00	45	...	2,915	145·3	2,807	139·9	12·05	2·51	15·69	34·22	14·06
	2,029	56·68	3 05	26	1 00	45	234°	2,886	142·2	2,786	137·3	...	...	...	...	...
Minnesota Bakers' -	2,024	56·82	2 35	21	1 00	45	246°	2,885	142·5	2,742	135·5	11·77	1·95	12·19	36·71	11·71
	2,031	56·62	2 40	32	1 00	45	238°	2,928	144·2	2,803	138·0	...	...	...	...	...
Roller Patent Missouri	2,059	55·85	2 43	31	1 00	50	248°	2,846	138·2	2,738	133·0	12·04	1·67	10·44	32·24	9·23
	2,042	56·32	2 45	39	1 00	45	242°	2,859	140·1	2,746	134·5	...	...	...	...	...
New Process Oregon	2,085	55·16	2 40	41	1 00	45	240°	2,873	137·8	2,689	129·0	14·03	1·15	7·18	20·84	6·75
	2,087	55·10	2 30	24	1 05	45	240°	2,883	138·1	2,753	132·0	...	...	...	...	...

the millers, IV. The analytic and other results are tabulated on page 534. The various samples are arranged in alphabetical order:—

SPRING FLOURS.

Daisy Roller Mill Company.

I. Lake Superior Mills, Superior, Wisconsin. II. Selected grades of hard or Fife spring wheat grown on the lines of railroad leading north-west from Superior in North Dakota and Northern Minnesota. III. Patents and Bakers' Grades, milled especially for bakers' use, as distinct from flour for domestic use. Patent; "Wiskota" (copyright): Bakers; "The Leader," "Regal;" same grade. IV. Greatest possible strength obtainable in flour. Perfect granulation and freedom from impurities.

Duluth Imperial Mill Company.

I. Imperial Mills, Duluth, Head of Lake Superior, Minnesota. II. Selected hard wheats from Northern Minnesota. III. Patents and Bakers, sold respectively under the names of Patent; Imperial: Bakers; Zenith. IV. Strongest hard wheat flours, perfectly milled from pure wheats.

Freeman Milling Company.

I. Freeman Milling Company's Mill. West Superior, Wisconsin. II. Hard wheats exclusively, mostly bought direct in Northern Minnesota and North Dakota. III. Patents and Bakers sold under following brands:—Patents; "Superlative," "Superior," and "Best:" Bakers; "Whaleback" and "Extra." IV. The millers claim that their flour contains as high a percentage of gluten as any flour made, as they do not use any wheat except Northern Minnesota and North Dakota, which are naturally tributary to this market, and are admitted to contain more gluten than any other wheat. They aim in milling to get the highest percentage of gluten in the flour that it is possible to obtain.

Ogilvie Milling Company.

I. Mills in Winnipeg, Manitoba, and Royal Mills, Montreal, Canada. II. Hard Fife Wheat from the great wheat-growing provinces of Manitoba, &c., in north-west Canada. III. Patents and Bakers. Patent; Ogilvie's Hungarian Patent: Bakers; Ogilvie's Strong Bakers. IV. Exceedingly strong flours, giving long yield, also retaining water in an exceptionally high degree, and consequently producing moist bread.

WINTER FLOURS.

Blanton Milling Company.

I. Arcade Mills, located in Indianapolis, the heart of the winter wheat section of the United States. II. The wheat used is obtained in Central and Southern Indiana and Southern Illinois, and is principally Long Berry Red, and similar varieties. The Long Berry Red is, as is well known, the finest milling wheat raised in the winter wheat section. III. Flours manufactured for the United Kingdom are patent and choice extras. Brands are:—Patents; "Princess" and "Apollo." Choice Extras; "Queen Bess," "Crown Jewel," and "Diana." IV. Flour is manufactured from the best varieties of winter wheat, with the latest improved machinery, in the most approved methods. The millers claim for them uniformity, and the best qualities of winter wheat flours.

Blish Milling Company.

I. Seymour, Indiana. II. The varieties of wheat used are a blend of about 65 per cent. of the long-berried hard Red Mediterranean, and 35 per cent. of the small plump oval-berried Fultz, indigenous to the valleys of Southern Indiana and Illinois. III. "Marguerite," or "Copyright," is purely a Patent flour, being about one-third of the most perfect product of the grain. Their bakers' grade, Beauty, is a Clear, or the remainder of the flour product of the wheat, with an adequate amount of the so-called Red Dog low-grade withdrawn. Their straight grade, Success, is a blend of the two grades mentioned, or, as a matter of fact, a veritable Straight with low-grade withdrawn. IV. In addition to the above, the millers claim for their flours, not absolute uniformity, but as nearly that desirable end as can well be attained. Their output being limited as to quantity, as compared with the larger exporting mills, they are enabled to draw their wheat supplies from a comparatively small territory, where the grain is of like nature and grown and harvested under the same conditions. This insures wheat supplies of uniform character, and leaves only the mechanical operation to produce results at a variance with the standards, and this is not at all likely to occur with a fully and perfectly equipped modern mill, where the operatives are pecuniarily interested in its success.

H. C. Cole, Chester.

I. Cole's Mill, Chester, Illinois. II. Use none but best winter wheat grown in Southern Illinois, most of it within twenty-five miles of the mill; never have used any Kansas—hard or soft—nor spring wheats. III. Patent, branded H. C. Cole's Omega. Clear (straight), branded H. C. Cole's F. F. F. G. IV. The millers claim for their flours *absolute uniformity* of grade on each crop. Crops vary in quality, but as they are in one of the best winter wheat sections in America, and crop is never a total failure, the crop is very uniform one year with another. They use only winter wheat grown in their near neighbourhood, have large storage capacity—over 200,000 bushels—and carry large stock, which insures a thorough mixture and uniform quality.

J. C. Daniels & Co., Middletown, Indiana.

I. J. C. Daniels and Co., Middletown, Indiana. II. The wheat used is red winter wheat obtained from local markets of Indiana. III. Brands are "Fancy Patent" and "Gilt Edge." IV. A winter-wheat flour of uniform granulation, good colour and strength.

Geo. T. Evans, Indianapolis.

I. Hosier State Roller Mills, located in Indianapolis. II. Winter wheat exclusively used, obtained in Indiana and Eastern Illinois, or, say, within 100 miles of Indianapolis. III. Choice winter wheat flours are produced. Patents under brands of "Macbeth" and "Adonis." Extra Fancy under brands of "Aurora" and "Alexandra." IV. The miller claims for this flour that it is made from selected, well-cleaned, sound, winter wheat, carefully milled, and of uniform quality. Patent is of good colour and strength, making a uniformly white, well-flavoured bread. Extra Fancy, somewhat stronger, but not of as good colour, but making a good white, well-flavoured bread.

The Isaac Harter Milling Company.

I. The mill is located in Fostoria, Ohio, in the best wheat-producing section of the State of Ohio. II. The quality of wheat which is used is red, soft, milling wheat, Fultz and Mediterranean varieties. The millers have made it an established rule to grind nothing but the very best quality of wheat they are able to purchase, and are very particular on this point. III. They manufacture four grades of flour, viz.:—Patent, Straight, Clear, and Extra. When they make Straight flour they take out no Patent whatever, only Extra. Their principal brands are Harter's A No. 1, Imperial, Snowflake, Challenge, True Blue, Peerless, Fancy, and General Favourite. IV. The properties of their flour, as claimed by the millers, are strength and colour combined.

580. Jago and Briant's Report.—Mr. L. Briant, F.C.S., and the author, were in 1893 requested to report to the National Association of Master Bakers and Confectioners of the United Kingdom on the question of the grading of American flour. They prepared a Report which was presented to the Association in 1894, in which it was recommended that flour standards be formulated of which bakers might avail themselves in purchasing flour, and use them for comparing their bulk delivery with the quality of flour actually bought. This Report has been adopted by the Association, which has directed the author as its chemist to prepare such standards for the year 1894-95. The following are among its principal recommendations:—

Division into Classes.—For purposes of grading, it is advised that American flours be divided into the following three classes:—I. Spring wheat flours, milled from hard wheats grown principally in the Dakotas, Minnesota, and Manitoba, Canada. II. Winter wheat flours, milled from wheats of medium hardness, grown principally in Missouri, Illinois, Indiana, and Ohio. III. Kansas wheat flours, milled from hard winter wheats, grown principally in Kansas.

RESULTS OF ANALYTIC AND OTHER TESTS ON AMERICAN FLOUR SAMPLES.

Name of Flour.	Colour, Dry by Tintometer.		Gluten, per cent.		Moisture, per cent.	Viscometer Quarts, per sack.	BAKING TESTS.					Remarks on Doughs.
	Y.	R.	Wet.	Dry.			Calculated Water, per sack.	Fermented Dough, lbs. per sack.	Quartern Loaves weighed in at 4lb. 6oz.	Colour of Bread by Tintometer. Y.	R.	
Daisy, Bakers' -	0·34	0·10	46·25	15·00	13·00	67·0	56·8	418·5	95·6	1·78	1·20	Firm and elastic, dry and wiry.
,, Patent -	0·22	0·06	39·75	12·65	13·57	63·0	56·0	418·3	95·6	1·39	0·62	
Duluth, Bakers' -	0·30	0·07	44·00	15·30	12·84	69·5	56·0	420·7	96·1	2·02	1·12	
,, Patent -	0·21	0·04	42·00	13·40	12·39	68·0	56·0	411·6	94·0	1·31	0·58	
Freeman, Bakers'-	0·32	0·08	43·10	15·00	12·79	68·0	56·0	421·4	96·3	1·50	0·95	
,, Patent -	0·30	0·08	42·95	13·65	13·61	66·0	56·0	416·9	95·2	1·36	0·65	
Ogilvie, Bakers' -	0·27	0·06	44·50	14·65	13·34	66 0	56·0	420·0	96·0	1·48	0·93	
,, Patent -	0·22	0·06	39·00	12·50	13·75	63·5	56·0	419·7	95·9	1·30	0·60	
Blanton, Bakers' -	0·20	0·03	37·00	11·00	13·17	59·0	53·8	413·2	94·4	1·48	0·94	
,, Patent -	0 07	0·02	28·90	8·75	13·65	53·0	51·4	407·0	93·2	1·30	0·64	Fair stiffness.
Blish, Bakers' -	0·21	0·05	39·00	11·70	12·75	59·0	56·1	421·8	96·4	1·52	0·94	
,, 2nd Patent-	0·20	0·03	36·45	10·15	13·22	55·5	54·2	416·3	95·1	1·50	0·92	
,, 1st Patent -	0·07	0·02	27·93	8·43	13·30	54·5	50·4	403·4	92·2	1·20	0·64	Biscuit rather than bread flour.
Cole, Bakers -	0·20	0·02	36·70	10·90	12·72	56·0	55·4	418·6	95·6	1·50	0·92	A little tight, nice firm dough.
,, Patent -	0·06	0·02	29·75	8·95	13·61	53·0	52·6	412·5	94·2	1·25	0·59	Fair stiffness.
Daniels, Bakers' -	0·20	0·02	31·50	9·50	13·19	57·0	52·1	410·9	93·9	1·30	0·54	
,, Patent -	0·09	0·02	29·15	9·10	13·59	53·5	52·1	411·2	94·0	1·34	0·57	Fair stiffness.
Evans, Bakers' -	0·20	0·03	38·50	11·25	13·36	58·0	55·8	415·4	94·9	1·55	0·95	A little slack.
,, Patent -	0·07	0·02	30·95	9·20	13·78	53·0	51·9	410·8	93·9	1·29	0·64	Fairly strong and wiry.
Harter, Bakers' -	0·18	0·03	33·75	10·05	13·46	56·0	56·3	418·5	95·6	1·34	0·91	
,, Patent -	0·06	0·02	31·85	9·20	13·58	57·5	52·1	413·5	94·5	1·22	0·60	Nice firm dough.

Typical Grades or Standards.—In each class there should be three typical grades or standards :—*No. 1 Standard* should consist entirely of the best patent flour of the grain, and should not exceed in quantity more than about 40 per cent. of the entire flour product of the wheat. The dressing of this flour should, of course, be perfect. This standard should be reached by all "first patents." *No. 2 Standard* should be a veritable straight grade flour, containing the whole flour product of the wheat, except the Red Dog low grade, whose proper place is the offal department. These flours should be well dressed and free from specks. This standard should be at least reached by all so-called "second patents." *No. 3 Standard* should consist of the whole of the remaining flour, not Red Dog or offal, after the removal of the 40 per cent. of patent flour constituting the No. 1 Standard. These flours should be clear and well dressed. This standard should be reached by so-called "First bakers' grades."

Suggestions follow (in the Report) as to the obtaining of samples of flour from which to formulate standards, and also as to the methods of examination to be adopted : these agree very closely with those already described. Various flours were collected on the London market, and supplied to the authors of this report for examination. The following is a list of the flours, together with Mark Lane prices at time of collection :—

		Price.	
No.	Description.	s.	d.
1.	Minneapolis First Patent	24	0
2.	Minneapolis First Patent	24	0
3.	Duluth First Patent	24	0
4.	Kansas First Patent	21	0
5.	Minneapolis First Patent	24	0
6.	Minneapolis Second Patent	22	0
7.	Duluth Second Patent	21	6
8.	Minneapolis First Bakers	16	6
9.	Minneapolis First Bakers	16	6
10.	Duluth First Bakers	16	6
11.	Kansas First Bakers	17	0
12.	Minneapolis Low Grade	15	0

Nos. 1, 8, and 12—Nos. 2, 6, and 9—Nos. 3, 7, and 10—and Nos. 4 and 11—are in each case series from the same mill. The results of various tests are given on pages 536—8.

As an example of the formulation of standards from these flours, equal parts of Nos. 1, 2, and 5 were mixed and used as standard No. I., while equal parts of Nos. 8 and 9 were taken as No. III. standard. These give the following analytical results :—

		No. I. Standard.	No. III. Standard.
Wet gluten		40·8 per cent.	47·0 per cent.
Dry ,, ...		12·5 ,,	16·2 ,,
True ,, ...		10·96 ,,	12·88 ,,
Water absorption by viscometer		65·3 quarts.	65·5 quarts.
Colour, Pékarised	Yellow	1·05 ,,	1·75 ,,
	Red ...	0·76 ,,	1·44 ,,

With accurately adjusted standards it is possible to assign a value to an intermediate flour by calculations made on the results obtained by testing. Supposing the flour to be a pure spring wheat flour, its value would be ascertained by locating it in its proper intermediate position between the standards selected. As an example simply, the following calculation is given on the results of No. 6 flour : first, the

JAGO AND BRIANT'S REPORT ON FLOURS.

	Grade I.					Grade II.		Grade III.				Grade IV.
No. of Flour	1	2	3	4	5	6	7	8	9	10	11	12
Wet Gluten, per cent., 1 hour	41·5	40·5	40·5	45·0	40·5	42·0	45·2	43·5	50·5	47·5	52·0	10·0
Dry ,, ,, ,,	13·0	12·4	12·5	13·5	12·1	13·8	14·8	15·6	16·8	16·9	16·0	4·1
Ratio of Wet to Dry	3·2	3·2	3·2	3·3	3·3	3·0	3·0	2·8	3·0	2·8	3·2	2·4
True Gluten, per cent.	10·26	11·50	11·08	10.70	11·14	11·92	11·96	12·30	13·46	12·00	14·85	3·41
Duplicates of above (*a*).												
Wet Gluten, per cent., 1 hour	37·7	...	...	...	...	...	...	46·0	46·0	...	...	9·0
Dry ,, ,, ,,	12·5	...	...	...	...	...	...	16·0	15·3	...	...	3·2
Ratio of Wet to Dry	3·0	...	...	...	...	...	...	2·9	3·0	...	...	2·8
True Gluten, per cent.	10·37	...	...	...	...	...	...	12·90	13·10	...	...	1·78(*b*)
Wet Gluten, per cent., 3 hours	39·5	41·5	41·0	43·0	41·2	42·0	41·0	44·6	47·0	40·5	53·0	...
Dry ,, ,, ,,	12·8	13·4	12·2	12·0	12·5	13·8	13·4	15·6	15·8	14·1	16·3	...
Ratio of Wet to Dry	3·1	3·1	3·3	3·6	3·4	3·0	3·0	2·8	3·0	2·8	3·2	...
True Gluten, per cent.	10·26	11·43	10·88	11·27	11·00	11·41	11·54	12·50	13·42	11·50	15·1	...
Duplicates of above.												
Wet Gluten, per cent., 3 hours	39·2	41·5	...	...	...	42·2	...	50·2	48·0	...	...	...
Dry ,, ,, ,,	12·8	12·6	...	...	...	13·4	...	17·4	16·2	...	...	...
Ratio of Wet to Dry	3·0	3·2	...	...	...	3·1	...	2·8	2·9	...	...	...
True Gluten, per cent.	10·56	11·20	...	...	...	18·93	...	13·1	13·42	...	...	...
Total Proteids, per cent.	12·43	12·17	12·48	13·14	12·79	12·39	13·80	14·64	15·08	14·33	16·76	18·08
Soluble ,, ,,	2·72	1·76	1·96	2·12	2·41	2·05	1·66	1·87	1·98	1·62	1·76	3·80
Insoluble ,, ,,	9·71	10·41	10·52	11·02	10·38	10·34	12·14	12·77	13·10	12·71	15·00	14·28
Aqueous Soluble Extract, ½ hour	4·52	5·70	5·84	5·16	5·00	4·80	5·48	4·92	5·48	4·88	5·20	12·36
,, ,, 4 hours	6·99	5·70	7·51	6·22	6·73	5·70	6·48	5·9[illegible]	6·99	5·96	6·73	15·28
Mineral Matter, per cent.	0·400	0·400	0·475	0·360	0·480	0·520	0·525	0·675	0·750	0·720	0·840	2·470
Moisture, per cent.	13·48	12·47	12·31	12·45	12·91	13·02	12·58	12·85	12·75	12·73	12·25	12·56
Water Absorption by Viscometer, quarts per sack	63·5	66·0	66·0	68·5	66·5	67·0	67·0	65·0	66·0	68·0	68·5	64·0
Diastasic Value on Lintner's Scale	20°	20°	16·0°	12·5°	12·5°	23°	13°	20°	25°	20°	33°	45°

Colour Read on Flours when received.													
Compressed Dry Flour	Yellow	0·45	0·45	0·40	0·40	0·40	0·40	0·40	0·40	0·36	0·45	0·45	0·80
	Red	0·10	0·13	0·13	0·10	0·10	0·11	0·15	0·12	0·15	0·20	0·15	0·40
Order by Eye		3	2	...	1	1	...	...	...	...	4	...	...
Wetted and Dried, Pékarised	Yellow ...	1·00	1·05	1·25	1·20	1·10	1·00	1·20	1·50	2·0	1·30	2·00	6·0
	Red ...	0·70	0·70	0·95	0·85	0·90	0·85	1·00	1·33	1·55	1·30	1·53	5·5
	Blue ...	...	...	...	...	...	...	...	...	...	...	...	3·0
Order by Eye		2	1	...	3	1	...	...	...	...	4	...	...
Dough through Glass	Yellow	1·20	1·15	1·15	1·05	1·10	1·10	1·20	1·40	1·45	1·30	1·50	3·70
	Red	0·56	0·56	0·56	0·57	0·62	0·50	0·70	0·80	0·83	0·70	0·90	2·10
	Blue	...	...	...	...	...	...	...	...	...	...	...	0·70
Order by Eye		4	5	6	1	3	2	7	9	10	8	11	12
Crust of Dough	Yellow	1·20	1·40	1·75	1·10	1·61	1·20	1·71	1·71	1·70	1·71	3·00	6·00
	Red	0·73	0·82	1·05	0·65	0·90	0·80	1·16	1·20	1·30	1·20	2·20	5·00
	Blue	...	...	...	...	...	...	...	...	...	...	...	2·50
Order by Eye		2	4	6	1	5	3	7	9	10	8	11	2
Colour on Reading about Three Months after.													
Order by Eye—Dry Flour		1	3	7	4	2	5	8	9	6	10	11	12
Wetted and Dried, Pékarised	Yellow	0·90	0·95	1·05	1·05	1·05	1·05	1·05	1·50	1·50	1·40	1·90	5·5
	Red	0·55	0·50	0·72	0·67	0·63	0·82	0·82	1·33	1·30	1·20	1·40	5·5
	Blue	...	...	...	...	...	...	...	...	...	...	...	1·2
	"Bloom" (*c*)... ...	0·06	0·06	0·09	0·09	0·06	0·09	0·09	0·06	...	...	...	...
Order by Eye		1	2	5	4	3	6	7	8	9	10	11	12

(*a*) These glutens were extracted by a student comparatively inexperienced in gluten testing, and differ considerably in percentage from their duplicates when wet. The principal reason for their insertion is that they show that the "true gluten" (calculated from the percentage of nitrogen in the dry gluten) in the duplicates differs but slightly in percentage from that in the original series.

(*b*) The crude gluten extracted from this flour was obviously composed largely of cellulose; in appearance it was very fibrous, and undoubtedly contained a very low percentage of albuminous matter.

(*c*) These readings showed that the whole series of flours had bleached considerably during the three months they had been kept. On reading the colours by the tintometer it was noticed that, though the flour was matched accurately both in tint and depth of colour, still in some cases the flour was *brighter* than the matching colour. To register this, shades of neutral tint were interposed between the flour and the eye, and these were registered as "Bloom."

BAKING TESTS ON JAGO AND BRIANT FLOURS.

Flour No.	Water used.		Weight of Unfermented Dough.		Fermented Dough.			Bread.		Colour of Bread by Tintometer.	Order by eye of Bread (colour).	Order of Pile.	Remarks.
	Cubic Centimetres.	Quarts per sack.	Grams.	Lbs. per sack.	Grams.	Lbs. per sack.	Loaves per sack, calculated at 2lb. 6oz.	Grams.	Loaves per sack.	Y. R.			
1	317·5	63·5	893·5	446·7	860	430	98·3	767	96·0	1·20+0·74	3	3	All good volume loaves except No. 12, which was very small and close and very dark coloured. No. 5 had a slight excess of water.
2	330	66	906	453	877	438·5	100·2	773	96·6	1·50+1·10	4	5	
3	330	66	906	453	882	441	100·8	779	97·3	1·25+0·78	5	6	
4	342·5	68·5	918·5	459·2	895	447·5	102·3	782	97·7	1·20+0·70	2	1	
5	342·5	68·5	918·5	459·2	890	445	101·7	775	97·0	1·20+0·80	1	4	Nos. 4 and 5 were best as regards colour of crust, and No. 1 was next best.
6	335	67	911	455·5	902	451·5	103·0	791	98·8	1.21+0·72	10	11	
7	335	67	911	455·5	887	443·5	101·3	787	98·3	1·20+0·74	6	8	Nos. 4 and 11 gave very good results, being tough flours well suited for sponging.
8	330	66	906	453	877	438·5	100·2	773	96·6	1·50+1·10	6	2	
9	330	66	906	453	887	443·5	101·3	777	97·1	1·50+1·10	8	9	
10	340	68	916	458	897	448·5	102·5	785	98·1	1·50+1·00	9	7	
11	342·5	68·5	918·5	459·2	893	446·5	102·0	807	100·8	1·50+1·20	11	10	
12	320	64	896	448	869	434·5	99·3	783	97·8	Y. R. B. 3·00+2·30+1·0	12	12	

price of No. I. standard is 24s., and that of No. III. standard is 16s. 6d. Intermediate standards by calculation would have the following value :—

	S.	D.		S.	D.
No. 1	24	0	No. 2·2	19	6
,, 1·2 ...	23	3	,, 2·4	18	9
,, 1·4	22	6	,, 2·6	18	0
,, 1·6	21	9	,, 2·8	17	3
,, 1·8	21	0	,, 3·0	16	6
,, 2·0	20	3			

Let us first determine "Colour Price." An increase in red is far more detrimental to a flour than one in yellow. Probably red may be taken as three times as injurious as yellow: then we have on the standards the following as total colour :—

No. I.		No. III.	
Yellow	1·05	Yellow	1·75
Red, 0·76 × 3 = ...	2·28	Red, 1·44 × 3 = ...	4·32
Total colour ...	3·33	... ...	6·07

Difference = 6·07 − 3·33 = 2·74.

$$\frac{2\cdot74}{10}=0\cdot274\ \left\{\begin{array}{c}\text{increment of colour for each grade on above}\\ \text{price scale, or "colour unit."}\end{array}\right.$$

The colour of No. 6 flour is :—

$$\begin{array}{lllll}\text{Yellow,} & 1\cdot00 & & = & 1\cdot00\\ \text{Red,} & 0\cdot85 & \times\ 3 & = & 2\cdot55\\ \hline & & \text{Total colour} & \ldots\ \ldots & 3\cdot55\end{array}$$

Total colour, 3·55 − No. 1 colour, 3·33 = ·22 increment of colour. 0·22 is approximately colour unit (0·27), therefore the "colour value" of the flour is 1·2 standard = 23s. 3d. price.

Taking next the true gluten, and giving a value to it, that of No. 1 standard is 10·96, and of No. II. standard, 12·88 per cent. Making a similar calculation as with the colour, the amount of each gluten unit is 0·192, which corresponds to a difference in price of 9d.

In No. 6 flour the true gluten is 11·92.

$$11\cdot92-10\cdot96=0\cdot960,\ \text{excess of gluten.}$$

$$\frac{0\cdot96}{0\cdot192}=5\cdot0\ \text{units of excess of gluten.}$$

Therefore the gluten price of the flour is equal to No. 2·0 standard, or 20s. 3d.

Taking the mean of colour and gluten prices,

$$\left.\begin{array}{l}\text{Colour price, 23s. 3d.}\\ \text{Gluten ,, 20s. 3d.}\end{array}\right\}\text{21s. 9d. mean.}$$

The next consideration is the yield. This must be based on the greater or less quantity of bread yielded by the flour of a quality which is measured by the mean colour and gluten price. No. 6 flour absorbs by the viscometer 2 quarts = 5 pounds more water than the standards, and may approximately be estimated to yield 1 quartern (4 pounds) more bread, or about $\frac{1}{96}$ more than the normal : $\frac{1}{96}$ of 21s. 9d. is almost exactly 3d., and this, added to the mean colour and gluten price, makes 21s. 9d. + 3d. = 22s. as the standard price of the flour.

Inspection of this method will at once show that while it serves to indicate closely the value of a flour made from spring American wheat, yet it would not be trustworthy in the case of mixtures where weaker and whiter wheats were also employed. Everything else being equal, a higher percentage of true gluten should indicate an increased value, whereas we have given the increments of gluten a negative value, because they thereby show more clearly the position of the flour on the intermediate grade between the standards.

It will be necessary for a full scheme of valuation to give a positive value to true gluten ; but for such values to be accurately determined a much wider series of flours must be examined, embracing those of distinctively different characters, and including not only strong glutenous flours, but also weak starchy varieties distinguished for excellence in colour.

581. Foreign Flour-Testing Methods.—It is the practice of leading American millers to have baking tests made daily on their flours by professional specialists, who report not only on the flour of the particular mill, but also include the result of tests on other flours made the same day. Each individual mill knows the results of its own flours, but is not acquainted with the identity of any others of the series. Subjoined is a copy of the daily schedule of Mr. Charles Stoddard, of Duluth, U.S.A. The printed matter of the schedule is given in Roman characters, while the written data are quoted in script type. In the part of the table headed "General Comparative Baking Results," there were in this particular copy reports on seven mills' flours : only one, however, is here reproduced.

Very elaborate and complete arrangements are made for the testing and standardising of what is sold on the Paris market as "Twelve Marks Flour." For this purpose an association of millers selects eleven mills, each of which sends in a bag of flour with the object of preparing a standard. Another sample is selected from an outside mill, but this (No. 12) must at least equal the tenth in order of excellence of the eleven previously selected samples. These flours are then subjected to determinations of colour, gluten, moisture (and at times, mineral matter) ; also a baking test is made.

For the gluten determination 33·33 grams of flour are taken, mixed with 17 grams of water, and the dough washed under a stream of running water and over a sieve, by which all particles are caught. The resultant gluten is hand-dried as thoroughly as possible, and then weighed ; the result multiplied by 3 gives the percentage.

Moisture is determined by drying 5 grams of the flour in an oil-oven, heated to 105—110° C. until it ceases to lose weight. The first weighing is made after about two and a half hours, and two other weighings at intervals of a quarter of an hour. When desired, mineral matter is determined by incineration at a low red heat in a muffle furnace.

COPY OF CHARLES STODDARD'S

Flour Inspection and Daily Baking Report.

DULUTH, *July 26th, 1894.*

FLOUR MADE BY—*DAISY MILL (SUPERIOR).*

When Made—*July 25th, 1894*	PATENT.	BAKERS.
Grade		
Remarks on Dough	*White and elastic.*	*Light and elastic.*
No. Ounces of Flour	*16*	*8*
,, ,, Water	$8\frac{12}{16}$	$4\frac{7}{16}$
,, Grains of Yeast		
,, ,, Salt		
,, ,, Sugar		
,, ,, Lard		
Temp. Water for making Sponge		
,, Sponge Box		
Time for Sponge to rise	*2 hrs. 40 min.*	*2 hrs. 45 min.*
,, Kneading	*15* ,,	*10* ,,
,, First Rising of Dough	*1* ,, *30* ,,	*1* ,, *15* ,,
,, Second Rising	*1* ,, *50* ,,	*1* ,, *50* ,,
,, Third Rising in Oven	*As*	*usual.*
Temp. Oven when put in	,,	,,
,, ,, ,, finished	,,	,,
Time of Baking	,,	,,
Remarks on Loaf—*Fully up to the highest Standards—1st Patent, 1st Bakers.*		

GENERAL REMARKS.

CHAS. STODDARD, Inspector.

GENERAL COMPARATIVE BAKING RESULTS.

MILL NAME.	Extra Water	PATENTS.			BAKERS.		
		Colour.	Measurement.	Weight.	Colour.	Meas.	Weight.
DAISY.	$\frac{12}{16}$	*1*	*29·50 × 22*	*22·25*	*1*	*20·75*	*10·75*

REMARKS.

Explanation of Reports.—Colour-patents range in colour, Maximum 1, Medium 1.5, Minimum 2. If more than two below Head of the Lakes standard 1st patent.

Straights compared with Patents range in Maximum 2·5, Minimum 3·5. If more than 3·5 below Head of the Lakes standard straights.

Bakers' loaves compared with each other: Best 1st Bakers' range from 1 to 3 (best rarely mark 3, usually 1), Medium Bakers' range from 2 to 4 (best of which rarely mark 4).

Best 2nd Bakers' range from 5 to 6, Medium to poor 7 to 8.

Measurement indicates elasticity or rising power, showing whether the sample is in proper baking condition, or has the right combination of properties (starch and gluten) in itself to produce a good sized loaf. Measurements of Patents and Straights are made over and around top and bottom, lengthwise and sidewise. Bakers loaves over top and bottom. Minimum sized patent and Straight loaves "up to standard" (made of 14 oz. flour), 27 inches. Bakers (made of 8 oz. flour), 20 inches.

For the baking tests a plant of 32 small kneading machines, with all troughs, proving baskets, and other appliances required is provided. All these are marked with the same number. In making each test 2250 grams of flour and 1500 grams of water are taken. These are mixed with leaven (for which yeast may be substituted), salt, and allowed to stand for about six hours. Each dough is then placed in the kneading machine, worked for about twenty minutes, and then allowed to rise, moulded, and allowed to prove in flannel lined baskets. When ready, all are baked at the same time in a large bakers' oven.

From the various tests a standard is formulated, and month by month an announcement is made that "Twelve Marks Flour" for the time being shall contain a minimum of so much gluten and no more than a given percentage of moisture. Further, in colour and character of loaf the flour shall be equal to the standard. When a miller wishes to offer flour as equal to standard, it is subjected to inspection, samples are drawn, tested, and if satisfactory, the flour is sealed by the Association as "Twelve Marks Flour."

582. Baking Tests, Method adopted by Author.—The quantity of flour taken for a baking test may vary according to the custom and requirements in any particular district. Usually, however, it is desirable to keep the quantity as low as practicable, so that a test may be made on a small sample: at the same time the loaf should be of a fair size, so as to compare as well as possible with the bread made for commercial purposes. The author has recently adopted the following quantities, which he finds to answer well for general purposes.

Quantities—Flour, ... 560 grams = 19·71 oz.
Water as per Viscometric Absorption.
Salt, ... 6 grams.
Compressed Yeast, 10 grams.

The metric system of weights is adopted because of its greater simplicity and the readiness with which exact weights can be determined. The quantity, 560 grams, is 2 grams for every lb. of flour in the sack, so that one half the weight of any constituent or product is without any further calculations the weight in lbs. that would be obtained proportionately by treatment of the sack of flour.

The resultant loaf of bread usually weighs from 1½ lb. to 1¾ lbs., and although less than the weight of a 2-lb. loaf, is yet sufficiently near to enable a comparison to be instituted.

Bearing in mind that the author's tests are generally made with the view of affording data of service to bakers in all parts of the United Kingdom, where the proportions of water used vary very considerably, he, for general tests, has adopted the plan of making where possible three separate bakings on each flour, distinguished respectively as *a*, *b*, *c*. For *b* the quantity of water as per viscometer test is employed. It will be remembered that that instrument gives results in quarts per sack; and as a quart weighs 2½ lbs., the number of quarts × 5 gives the weight in grams or volume in cubic centimetres of water that must be taken to the 560 grams of flour. For *a*, 20 grams (equivalent to 4 quarts) less water is taken than in *b*: while in *c*, 20 grams more water is added than used in *b*. The three tests, therefore, represent quantities of water with differences of a gallon to the sack between each, and cover all variations in quantities for ordinary bread-making.

Mode of Fermentation.—First weigh out the flour, and put it in a pan of sufficient size (for which purpose an ordinary white-pudding basin, 8 or 9 inches internal diameter, answers well). Next take the temperature of the flour, and if anything below 70° F., carefully warm it until that temperature is reached. A most convenient method in the testing laboratory of doing this is to stand the basin containing the flour in hot water, and stir the flour continually with a spatula until sufficiently warm. A "ferment" is next made with the whole of the water to be used. This water may be either measured or weighed; if the former course be adopted, the measures should be specially graduated to deliver grams of water at 100° F. It has been found convenient to have the ferment, when set, at 90° F.; the initial temperature of the water should be so adjusted by experiment as to give this temperature at the finish; usually about 10° is lost in this operation, and therefore the water may be taken at 100° F. Make a hole in the middle of the flour (bay), and having the water in a measure, break down the previously weighed yeast into the water, and pour the whole into the bay. Work carefully a little of the flour into the liquor, so as to form a ferment of the consistency of a thin batter: this ferment, as above stated, should have a temperature of 90° F. For the fermentation there should, when practicable, be provided a proving cupboard, so arranged as to just take, on a series of shelves, a number of these basins, all of which must be labelled and marked. By some convenient means the temperature of this cupboard should be maintained at about 85° F.; this may be done either by the injection of a jet of steam, or the well-known plan of a small atmospheric burner at the bottom of the cupboard, with a vessel of water over it. The temperature of this cupboard should be under control, and must be kept uniformly at the desired degree.

Cover the basin containing the ferment with a light linen cloth, and place it in the proving cupboard for one hour; at the end of that time the ferment will be "ready," and should have nicely dropped. Add the finely-powdered salt, and stir in the flour and salt into the ferment with a bone spatula. Knead thoroughly either by hand, or preferably in one of Werner and Pfleiderer's small doughing machines, taking care that no loss occurs during the operation, and that the dough is made perfectly smooth. Return to the proving cupboard, and after one hour well "knock down" the dough: place again in the cupboard for half an hour, and then weigh the dough accurately. The bread may be baked in a tin, or for most purposes, preferably, as a cottage loaf. Mould, and allow to stand for a few minutes if necessary. Moulding should, if possible, be done without dusting flour; when any is used, a quantity should be weighed, and that remaining after the moulding of each loaf again weighed, and note made of the quantity used. This should not exceed 2 grams per loaf. Bake in an oven, the temperature and behaviour of which is known, and, if possible, together with loaves of a familiar flour, so as to be able to judge the comparative tendency of the flour to take the fire. When baked, allow the bread to stand twelve hours—say over night—and then weigh. Notice whether the bread happens to be burned at the bottom, and if so make a note, as the weight will thereby be affected.

Note the character of the loaf, compared with a standard or known sample; whether of good volume, bold and well shaped, twisted or flat; also the colour of the outer crust, and also in the partings between the top and bottom of the cottage.

If wished, the volume of the loaf may be determined by means of a cylindrical measure sufficiently large to hold it completely. The loaf is placed in this, and rape seed or other small seed added to fill the measure, the upper surface of which is then "struck." The quantity of seed used is then measured, preferably in a vessel graduated in cubic centimeters; and also the quantity of seed similarly required to fill the measure without the loaf. The difference gives the volume of the loaf.

Compare the appearance of the three loaves side by side, and decide which represents the bread from the best size or stiffness of dough. Note also whether there is a great difference between each, as some flours stand an excess of water over the normal far better than others.

Next cut the loaf in the direction of greatest outline, and observe the colour, texture, pile, and sheen of crumb; also moistness, odour and flavour of crumb. (It should be borne in mind that the flavour of a small baking test is not an absolute criterion of that of bread regularly made in full-sized batches.) The colour may be measured and registered when thought desirable by means of the tintometer, modified by the addition of de-focussing lenses.

If it is desired to keep a permanent record of its size, the cut loaf may be placed on a sheet of paper, and marked round with a pencil. This may be done on a leaf of a note book, and the other data placed on the opposite page. (See Figure 72.)

The following are given as an example of how baking tests may be entered in the note-book, together with deductions made therefrom:—

Description of Flour—High-Class English Patent.

Water absorption by Viscometer—60 quarts per sack.

	a.	*b.*	*c.*
Flour in grams	560	560	560
Water ,,	280	300	320
Yeast ,,	10	10	10
Salt ,,	6	6	6
Unfermented Dough in grams	856	876	896
,, ,, lbs. per sack	428	438	448
Fermented Dough in grams	827	850	860
,, ,, lbs. per sack	413·5	425	430
Fermented Dough calculated into loaves of 4 lb. 6 oz. per sack	94·5	97·1	98·3
Weight of Bread, 12 hours old, in grams	707	737	760
Weight of Bread, 12 hours old, in lbs. per sack	353·5	368·5	380
Loaves of 4 lbs. each per sack	88·4	92·1	95·0
Colour by Tintometer—Yellow	1·35	1·35	1·35
,, ,, —Red	0·70	0·75	0·75

In the above results the mode of determining lbs. per sack is self-evident: quantities in grams are simply divided by 2. Calculated loaves per sack from dough are obtained from lbs. per sack by reducing to ounces and dividing by 70 (ounces = 4 lbs. 6 oz.). The readiest way of performing this calculation is to multiply weight in grams by 8 and divide by 70, thus:

$$\frac{827 \times 8}{70} = 94{\cdot}5 \text{ loaves per sack.}$$

The results obtained as yield in bread by calculating at 4 lb. 6 oz. on the dough are more trustworthy than those by direct weighing of the bread itself, as single sample loaves will vary more in weight from the normal than does a full batch calculated on the weight of dough.

Results are returned by the author on a printed schedule, of which a copy is appended, page 546, on which are entered the results of examination of an American patent flour.

With the adoption of flour standards, the printed schedule will take the form given on page 547. No analytic results are quoted in this copy of the schedule; but simply as an illustration of the method of entering results, the *valuation* of an imaginary sample of flour is inserted.

583. Special Apparatus for Baking Tests.—When baking tests are being conducted on a large scale, certain special appliances enable results to be obtained not only with greater speed, but with more exactitude.

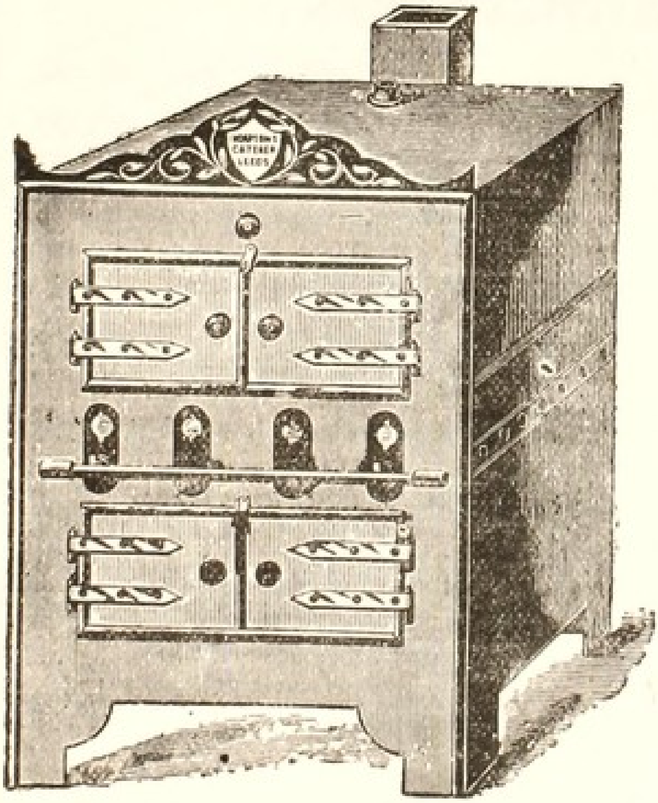


FIG. 71.—CATERER GAS OVEN FOR LABORATORY USE.

For water measuring purposes it is very convenient to employ a large burette and reservoir similar in character to that figured No. 65 for making viscometric determinations. The burette should have a capacity of 400 c.c., and should be provided with a large way tap. The reservoir should be open at the top, but provided with a cover: a number of tests having to be made, sufficient water should be in one operation adjusted to the right temperature, and used for the whole series that are started off together.

Where it is possible to bake sample loaves with a batch of ordinary bread, that forms one of the best modes of procedure. For laboratory work, however, a special oven is usually necessary. For this purpose the author has for some time used, and with very satisfactory

RESULT OF
ANALYTIC & BAKING TESTS ON SAMPLE OF FLOUR.

Received from

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....

....

By

WILLIAM JAGO, F.C.S., F.I.C.

(Chemist to the National Association of Master Bakers and Confectioners, &c.),

CORNWALL HOUSE, 35, QUEEN VICTORIA ST.,
LONDON, E.C.; and
32, CLARENDON VILLAS, BRIGHTON, ENG.,

.... *189*

DESCRIPTION.—*American Patent Flour.*

ANALYTIC RESULT:—

Wet Gluten, per cent., *43·0*. True Gluten, per cent., *10·70*.

Water Absorbing Power, by Viscometer, Quarts per Sack, *67*.

Colour, by Lovibond's Tintometer on Pékarised Flour, *0·98 Y. + 0·72 R.*

BAKING TESTS, QUANTITIES TAKEN:—

	a.	b.	c.
*Flour in Grams	560	560	560
Water ,, ...	*315*	*335*	*355*
,, in Quarts per Sack	(*63*)	(*67*)	(*71*)
Yeast in Grams	10	10	10
Salt ,, ...	6	6	6
Unfermented Dough in Grams	*891*	*911*	*931*
,, ,, lbs. per Sack ...	*445·5*	*455·5*	*465·5*
Fermented Dough in Grams	*863*	*881*	*910*
,, ,, lbs. per Sack	*431·5*	*440·5*	*455*
Fermented Dough calculated into loaves of 4 lb. 6 oz. per Sack, 12 hrs. old	*98·5*	*100·6*	*104*
Weight of Bread in Grams	*766*	*780*	*788*
Bread, calculated into loaves per Sack ...	*95·75*	*97·5*	*98·5*

REMARKS:—

Dough—*Worked well, quick sponging or tough doughing flour, "a" sample best consistency.*

Baked Loaf—*Good volume.*

Crumb—*Good colour, pile fair.*

Flavour—*Good.*

(Signed) *WILLIAM JAGO.*

* NOTE.—Weight in grams may be converted into lbs. per Sack by dividing by 2.

Outlines of Sections through centres of Loaves are traced on the back of this Form.

RESULT OF
ANALYTIC & BAKING TESTS ON SAMPLE OF FLOUR,
Compared with Bakers' National Association Standards.

Received from

....

....

....

By

WILLIAM JAGO, F.C.S., F.I.C.

(Chemist to the National Association of Master Bakers and Confectioners, &c.),

CORNWALL HOUSE, 35, QUEEN VICTORIA ST.,
LONDON, E.C ; and
32, CLARENDON VILLAS, BRIGHTON, ENG.,

....*189*

DESCRIPTION.—*First Patent, Spring American Flour.*

ANALYTIC RESULTS :–	SAMPLE.	STANDARD.
Wet Gluten, per cent	....	....
True Gluten, per cent	....	....
Water Absorbing Power, by Viscometer, Quarts per Sack	....	....
*Colour, compared with Standard	....	....

BAKING TEST–QUANTITIES TAKEN :–

	a.	b.	c.	
Flour in Grams	560	560	560	560
Water ,, ...	....	....	....	....
,, in Quarts per Sack	(........)	(........)	(........)	....
Yeast in Grams	10	10	10	10
Salt ,, ...	6	6	6	6
Unfermented Dough in Grams	....	....	....	....
,, ,, lbs. per Sack	....	....	....	....
Fermented Dough in Grams	....	....	....	....
,, ,, lbs. per Sack	....	....	....	....
Fermented Dough, calculated into loaves of 4 lb. 6 oz. per Sack, 12 hours old	....	....	....	....
Weight of Bread in Grams...	....	....	....	....
Bread, calculated in loaves per Sack	....	....	....	....
*Bread, Colour compared with Standard ...	....	....	....	....

The present price of No. *I.* Standard being *20s.* per sack, the above flour compares as follows :—

†Approximate Bread Yield and Volume of Loaf, value	*20s. 3d.*
*Approximate Colour, value	*19s. 0d.*
Aggregate value (20s. + 3d. – 1s.), checked by baking test	*19s. 3d.*

REMARKS.—*The flour is somewhat lower in colour than No. I. Standard, but this is partly compensated by higher yield, giving an approximate Standard value of 1·3.*

* The colour of each standard is taken as being that represented by its number ; thus, No. I. Standard has a colour of 1·0, and No. II. of 2·0. Intermediate colours are determined by dividing the difference in the pair of Standards into 10 parts ; thus, when the colour of a flour is given as 1·2, it means the colour is as nearly as possible matched by a mixture of 2 parts of No. II. Standard with 8 parts of No. I., while a colour of 1·9 would represent 9 parts of No. II. Standard mixed with 1 part of No. I. The difference in price between Nos. I. and II. is also divided into 10 equal parts, and in fixing approximate colour value 1 such part is deducted from the price of No. I. Standard for each 0·1 of lower colour.

† Bread yield value is based on water absorbing power, together with necessary strength to maintain boldness of volume.

Approximate or mean value is governed by both the above, but is further checked by a judgment based on the general character of the flour as revealed by Baking Tests.

(Signed) *WILLIAM JAGO.*

NOTE.—Weight in grams may be converted into lbs. per Sack by dividing by 2.

Outlines of Sections through centres of Loaves are traced on the back of this Form.

results, one of Thompson's "Caterer" gas ovens, made and sold by Musgrave Bros., of Leeds. The oven is fitted with a tiled sole, and a baking chamber entirely shut off from the gas flame and products of combustion. As shown in the front, immediately underneath the oven doors, four lines of gas burners enter beneath the sole; from this hot air chamber a series of iron pipes convey the heat up around the sides to the crown of the oven: the whole of the oven is lined on the outside with slagwood, reducing the escape of gas to a minimum. Each line of burners can be regulated separately; those in the middle give an increased bottom heat, while those on the outside raise the heat of the crown. For baking tests it is well to line the sides and back of the oven with tiles to act as upsets, as the bread is better baked with top and bottom heat only. The oven bakes very evenly, is very steam-tight, and clean and inexpensive to use: in fact, is well adapted all round for this purpose.

It has already been mentioned that a proving cupboard should be provided for these samples during fermentation. Not only should this be carefully regulated as to temperature, but it is also well to provide means for keeping its atmosphere saturated with moisture, so as to prevent as far as possible evaporation from the fermenting samples. In the following tests fermentation was conducted in a dry prover, and undoubtedly certain irregularities are caused by unequal evaporation during fermentation. Such a cupboard should be fairly airtight, and either steam admitted at the bottom or generated by means of a vessel of water fixed over a small burner.

584. Special Series of Baking Tests.—At the time when this new work was projected, an appeal was made to the leading mills of Great Britain and other countries for samples of representative flours for purposes of analysis and baking tests for this book.

The following is a list arranged in alphabetical order of the firms who have responded, together with particulars of their flours and properties as claimed by the millers:—

BRITISH FLOURS.

Messrs. Barlow & Sons, Bilston Flour Mill, Wolverhampton.

1. **"Unicorn" Flour.**—High-class confectioners' flour, suitable also for Vienna bread and rolls, possessing brilliant colour and great strength.
2. **"XX" Flour.**—High-class flour, with fine bloom, above average strength, suitable for sponging or making best quality loaf by itself; suitable also as a milder confectioners' flour.
3. **"Blue Tie" Flour.**—Sound flour, rather over average strength, having flavour combined with fair colour.

Messrs. Cadge & Colman, Steam Flour Mills, Peterborough.

4. **"XXX" Flour.**—Patent flour, characterised by high colour and flavour, suitable for high-class bread and pastry. Prepared largely from English wheats, but with admixture of good foreign.
5. **"Superfine" Flour.**—Coloury and flavoury straight grade flour, wheat mixture as before.
6. **"White's" Flour.**—Bakers' flour, possessing good colour and flavour.

Messrs. J. & J. Colman, Carrow Works, Norwich.

7. **"Extra" Flour.**—Patent flour, suitable for pastry and high-class bread, manufactured from English, Indian, and high-class American wheats.

8. **"Household" Flour.**—Strong bakers' grade, fine flavour, wheat mixture as per "Extra."

9. **"Special" Flour**—Adapted for scaling and housekeepers' purposes. Prepared from nearly all English wheat, with a small percentage of Indian.

Messrs. Thomas Lewis & Co., City Steam Mills, Bangor.

10. **"Snowdon Flake" Flour.**—High-class patent flour.

11. **"XX" Patent.**—Second patent flour, sold at 3s. per sack less than Snowdon Flake.

12. **"Yellow Tape" Flour.**—High-class bakers' flour, sold at 2s. per sack less than XX Patent.

Messrs. Priday, Metford, & Co., City Flour Mills, Gloucester.

13. **"Extras" Flour.**—Fine strong flour having plenty of colour, suitable for high-class bread and pastry.

14. **"Leather Tie" Flour.**—Prepared specially for confectioners' purposes.

15. **"Plain Tie" Flour.**—A good sound strong flour for ordinary baking purposes, giving a high yield of bread.

Messrs. J. Reynolds & Co., Albert Flour Mills, Gloucester.

16. **"New Process" Flour.**—Strong bread or sponging flour of best quality; made from selected American and Russian wheats.

17. **"Extras" Flour**—Mild bread or best confectionery flour of fine quality; made from a blend of American, Plate, Russian, and English wheats.

18. **"Leather Tie" Flour.**—Mild bread flour for good quality bread, wheats as per preceding flours.

Messrs. W. H. & J. Rogers, Ashley Mills, Bedford.

19. **"Patent" Flour.**—Good pastry and fancy bread flour of good colour and rich flavour; made from mixture of good quality foreign and English wheats.

20. **"Extra Fine" Flour.**—Very strong and good coloured, straight run of flour for bread-making.

21. **"Super's" Flour.**—Good coloured and sweet flavoured doughing flour for medium quality bread, specially suited for mixing purposes by those bakers who use a fair proportion of stronger flour in sponges. At the same time this flour has a fair average strength of its own.

Messrs. S. M. Soundy & Son, Abbey Mills, Reading.

22. **"Three Stars" Flour**—Strong sponging flour for first-class bread.

23. **"Yellow Tie" Flour.**—Special colour and flavour for bread or pastry.

24. **"Blue Tie" Flour.**—Doughing flour for high-class bread.

25. **"White Tie" Flour.**—A household bread flour.

The whole of these contain a proportion of primest Berkshire wheats for purposes of flavour.

Messrs. John Ure & Son, Regent Mills, Glasgow.

26. **"Regent" Flour.**—Strong sponging flour of good colour, made from No. 1 Northern Duluth Wheat.

27. **"Minnesota Straight" Flour**—Strong sponging flour for medium quality bread, made from Hard Duluth Wheat.

28. **"Golden Crown" Flour.**—Very fine doughing flour for high quality bread, made from No. 2 Red Winter American wheat.

Vale of Evesham Flour Mills Co., Ltd., Evesham.

29. **"White Lily" Flour.**—High-class flour, possessing sufficient strength to admit of its being used alone for fine white bread, where colour and flavour are first essentials: where greater strength is required can be blended with spring American patents. Made from one-third fine white Vale of Evesham wheats, one-third fine red do., one-ninth finest spring American, one-ninth finest Russian, one-ninth No. 1 Plates.

30. "Snowdrift" Flour.—Makes a white, bloomy, good baking loaf, with flavour as a special characteristic: well adapted for toning down hard home and foreign milled flours. Made from half English local wheats, and half a mixture of sound Russian, spring and winter American, and Plate wheats.

31. "Decorticated Wheat Meal."—A special meal made from the very finest wheats obtainable, the mixture including native strong red wheats, blended with sufficient finest Russian and No. 1 Hard Spring American to give requisite strength. The wheat is cleaned and scoured in order to remove first skin, ground on millstones, and dressed from *coarse* particles of bran.

Messrs. William Vernon & Sons, The Atlantic, Brunswick Street, Liverpool.

32. "Millenium" Flour.—A coloury flour with excellent bloom and flavoury: suitable for the highest quality bread; made from 2 parts River Plate, 2 Walla Walla, 1 Australian, and 1 hard Manitoba wheats.

FOREIGN.

Blish Milling Co., Seymour, Indiana, U.S.A. Represented by Messrs. Mowat Bros., 54, West Howard Street, Glasgow.

33. "Copyright" Flour.—Characterised by fine colour and sweetness, much used for doughing the highest class bread. Also, beautiful biscuit flour.

34. "Success" Flour.—Characterised by strength and colour, used for doughing fine bread. Suitable for scaling and home baking.

35. "Beauty" Flour.—Strong and fair colour, specially adapted for making a good white common loaf of great bulk, nearly as strong as some of the best Minnesota brands, and has great sweetness.

Lake of the Woods Milling Co., Montreal, Canada, represented by the Canadian Produce and Consignment Co., 18, St. Swithin's Lane, London, E.C.

36. "Hungarian" Patent Flour.—A patent flour from the finest No. 1 Manitoba Hard Wheats.

37. "Second Patent" Flour.—A lower grade patent flour from the same wheat.

Glasgow Agents, Messrs. Bruce & Wilson; Bristol Agents, Messrs. Morgan, Taylor & Co.

The Washburn Crosby Co., Merchant Millers, Minneapolis, Minn., U.S.A.

38. First Patent Flour.—Highest class flour from Hard Minnesota Wheats.

39. Second Patent Flour.—From same wheats.

40. "Bakers'" Flour.—From same wheats.

The millers claim that all these rank at the very top of similar grades for strength, uniformity, and clearness.

The results of the various analytic and baking tests are set out in the following tables (pages 552–7). In Figure 72 are given the sectional outlines of a few loaves selected from this series and drawn to a reduced scale (compare page 544). The sections marked *a* contain least water, *b* another 4 quarts, and *c* 8 quarts more than *a*.

The following are particulars of each loaf:—

		Water taken for *b* Test. Quarts per Sack.
No. 1.	Strong British Milled Patent Flour ...	60
,, 2.	Minnesota Straight	70
,, 3.	Spring American Second Patent	63·5
,, 4.	Number 2 Winter Wheat Patent	56·5
,, 5.	British Milled Household Bread Flour ...	58·0
,, 6.	Straight-Run British Bread-Making Flour ...	60·0
,, 7.	British Milled Bakers' Grade Flour ...	62·0
,, 8.	English Wheat Flour	56·0

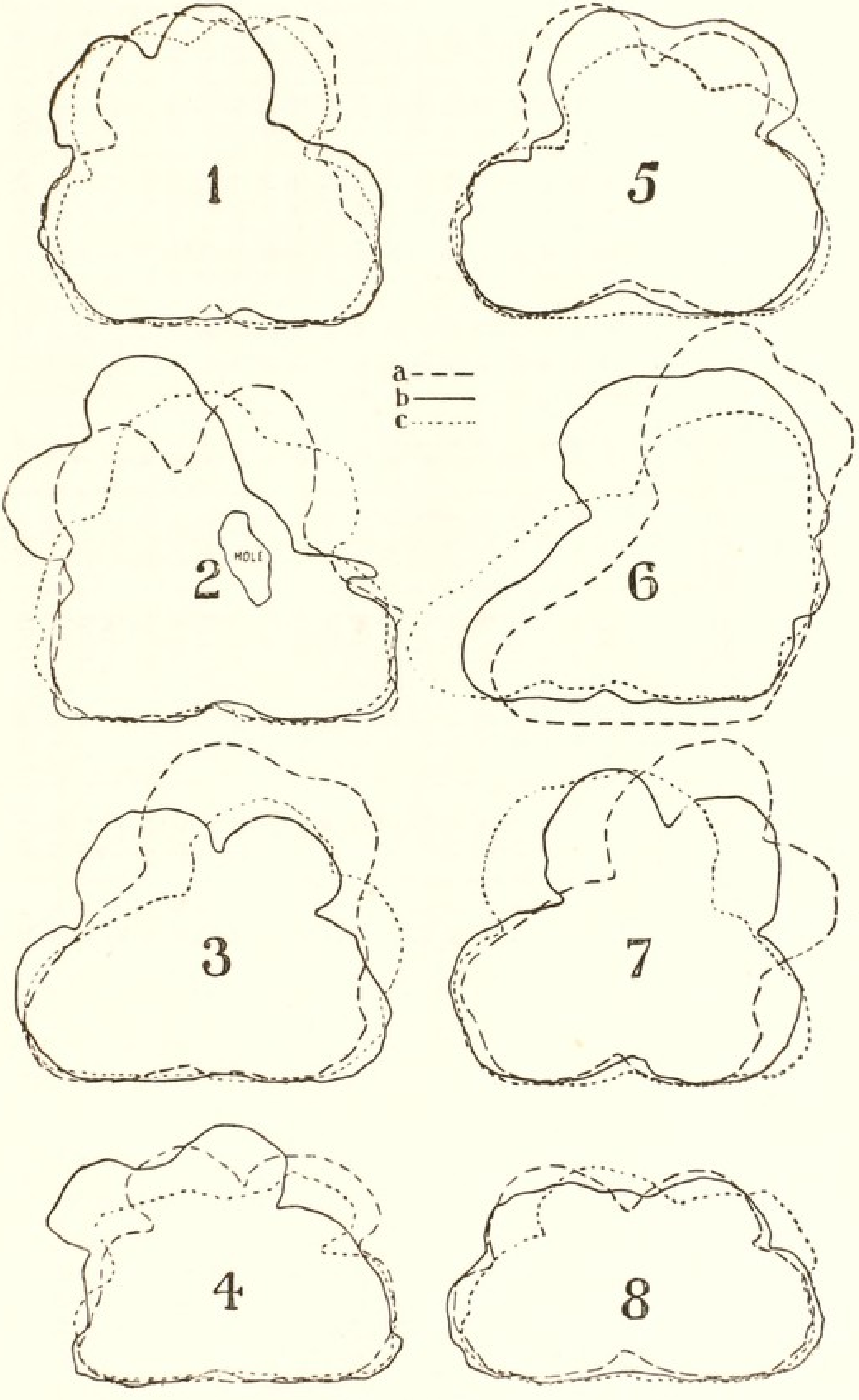

FIG. 72.—SECTIONAL OUTLINES THROUGH VARIOUS LOAVES.

ANALYTICAL AND PHYSICAL TESTS ON SPECIAL FLOURS.

No.	Name of Flour.	Gluten, per cent.			Total Proteids.	Moisture, per cent.	Water absorption by Viscometer.		Colour by Tintometer.	
		Wet.	Dry.	True.			Quarts per sack.	Lbs. per 100 lbs.	Pékarised Flour.	Doughed Flour.
	British Flours.								Y. R.	Y. R.
1	"Unicorn"	38·2	13·5	10·54	11·73	13·22	65	58·04	0·95 + 0·50	1·90 + 1·00
2	"XX"	38·0	12·6	9·78	11·20	12·75	62	55·36	1·00 + 0·60	2·00 + 1·10
3	"Blue Tie"	40·5	13·5	10·10	11·29	13·17	62	55·36	1·00 + 0·70	2·25 + 1·40
4	"XXX"	41·4	11·3	8·93	10·23	13·91	53	47·33	0·65 + 0·40	1·60 + 0·90
5	"Superfine"	41·5	12·4	9·32	10·58	13·77	53	47·33	0·90 + 0·65	1·55 + 1·05
6	"Whites"	41·4	12·5	9·53	11·38	13·84	53	47·33	0·80 + 0·50	1·50 + 1·01
7	"Extra"	34·0	10·69	8·30	9·26	13·58	57	50·80	0·73 + 0·50	1·80 + 0·90
8	"Household"	38·9	12·6	8·75	10·45	14·08	60	53·58	0·78 + 0·50	1·90 + 1·10
9	"Special"	32·7	9·98	8·50	10·05	14·63	56	50·00	0·75 + 0·50	1·90 + 1·10
10	"Snowdon Flake"	31·9	10·0	8·54	9·61	11·89	66	58·94	0·70 + 0·40	1·50 + 0·85
11	"XX Patent"	33·4	10·5	8·84	9·61	11·65	66	58·94	0·90 + 0·52	1·55 + 1·00
12	"Yellow Tape"	32·5	10·3	8·74	9·88	11·60	64	57·15	0·80 + 0·50	1·50 + 0·85
13	"Extras"	36·3	10·6	8·99	11.25	10·90	60	53·58	0·70 + 0·35	1·45 + 0·80
14	"Leather Tie"	38·5	12·6	10·97	12·18	10·51	62	55·36	0·70 + 0·35	1·50 + 0·80
15	"Plain Tie"	46·9	15·6	12·45	12·76	10·62	65	58·04	0·90 + 0·60	1·55 + 0·95
16	"New Process"	37·5	12·3	10·82	11·96	12·57	61	54·47	0·70 + 0·50	1·80 + 1·10
17	"Extras"	38·0	11·2	9·98	10·98	12·17	59	52·68	0·70 + 0·35	1·40 + 0·80
18	"Leather Tie"	37·5	12·1	10·28	10·98	12·25	57·5	51·34	0·70 + 0·35	1·40 + 0·85
19	"Patents"	36·0	11·6	8·94	10·24	14·55	59	52·68	0·85 + 0·50	1·80 + 0·90
20	"Extra Fine"	41·0	13·47	9·39	11·16	14·07	60	53·58	0·95 + 0·70	2·20 + 1·30

ANALYTICAL AND PHYSICAL TESTS ON SPECIAL FLOURS—*continued.*

No	Name of Flour.	Gluten, per cent.			Total Proteids.	Moisture, per cent.	Water absorption by Viscometer.		Colour by Tintometer.	
		Wet.	Dry.	True.			Quarts per sack.	Lbs. per 100 lbs.	Pékarized Flour.	Doughed Flour.
	British Flours.								Y. R.	Y. R.
21	"Supers"	36·5	12·4	8·34	10·94	14·23	60	53·58	0·80 + 0·60	2·20 + 1·40
22	"Three Stars"	40·4	12·1	10·28	11·38	12·84	60	53·58	0·80 + 0·45	1·45 + 0·80
23	"Yellow Tie"	35·0	10·0	8·60	10·05	13·18	57	50·80	0·65 + 0·40	1·45 + 0·90
24	"Blue Tie"	40·7	12·8	10·25	11·38	13·52	58	51·79	0·70 + 0·50	1·60 + 1·05
25	"White Tie"	43·7	14·7	11·57	12·80	12·60	61	54·47	0·95 + 0·85	1·95 + 1·25
26	"Regent"	44·0	14·7	11·50	12·27	13·54	67	59·83	1·00 + 0·80	1·55 + 1·00
27	"Minnesota Straight"	45·0	16·56	12·83	14·44	13·01	70	62·51	1·30 + 1·15	2·15 + 1·25
28	"Golden Crown"	36·7	11·72	8·64	9·48	13·04	56·5	50·45	0·70 + 0·50	1·50 + 0·90
29	"White Lily"	37·8	12·5	9·08	10·76	14·41	57	50·80	0·80 + 0·50	2·00 + 1·10
30	"Snowdrift"	39·0	12·4	7·98	10·89	14·61	56	50·00	0·72 + 0·50	2·00 + 1·10
31	"Decorticated Wheat Meal"	36·2	13·0	9·31	13·20	14·14	68·5	61·17	....	....
32	"Millenium"	34·0	10·1	9·17	12·49	13·22	57	50·80	0·60 + 0·30	1·50 + 0·70
	Foreign Flours.									
33	"Copyright"	30·0	9·5	7·17	8·46	12·08	55	49·11	0·40 + 0·30	1·30 + 0·75
34	"Success"	34·7	11·0	8·39	10·54	12·36	60	53·58	0·70 + 0·50	1·50 + 0·93
35	"Beauty"	41·0	12·4	9·58	11·07	12·01	63	56·62	0·85 + 0·80	1·60 + 1·12
36	"'Hungarian' Patent"	43·0	14·57	10·70	11·29	12·56	67	59·83	0·90 + 0·72	1·50 + 1·00
37	"Second Patent"	51·8	17·4	11·78	13·86	12·27	68	60·72	0·80 + 0·75	1·85 + 1·25
38	"First Patent"	40·5	14·6	12·16	13·25	12·34	61·5	54·92	0·70 + 0·50	1·55 + 0·85
39	"Second Patent"	45·0	16·5	13·35	13·86	11·98	63·5	56·70	0·90 + 0·70	1·95 + 1·30
40	"Bakers'"	51·7	18·7	13·86	16·43	12·12	64	57·15	1·30 + 1·30	2·55 + 1·60

BAKING TESTS ON SPECIAL FLOURS.

No. of Flour.		Water used.		Weight of Unfermented Dough.		Fermented Dough.			Bread.		Colour of Bread by Tintometer.	Remarks on Bread.
		Cubic Centimetres.	Quarts per Sack.	Grams.	Lbs. per Sack.	Grams.	Lbs. per Sack.	Loaves per Sack, calcd. at 4 lb. 6 oz	Grams.	Loaves per Sack.	Yellow. Red.	
1	*a*	305	61	881	440·5	851	425·5	97·2	748	93·5	1·21 + 0·61	Shape and general appearance good, volume good, texture fine, pile of *c*, best, bloom and colour good.
	b	325	65	901	450·5	866	433	99·0	759	95	1·20 + 0·60	
	c	345	69	921	460·5	887	443·5	101 3	791	99	1·23 + 0·60	
2	*a*	290	58	866	433	852	426	97·3	741	92·6	1·35 + 0·60	Good bloom, especially on crust, good colour; *b*, best viscosity.
	b	310	62	886	443	868	434	99 2	755	94·3	1·35 + 0·60	
	c	330	66	906	453	888	442·5	101·1	774	97	1·38 + 0·60	
3	*a*	290	58	866	433	835	417·5	95·4	731	91	1·10 + 0·80	Medium volume, moderate texture, colour fair; *c*, best pile.
	b	310	62	886	443	853	426·5	97·5	741	93·3	1·13 + 0·80	
	c	330	66	906	453	875	437·5	100	762	95·2	1·13 + 0·80	
4	*a*	245	49	821	410·5	800	400	91·4	706	88·2	1·30 + 0·80	Colour fair, volume small, viscosity apparently between *b* and *c*. Doughing flour of excellent flavour for high-class bread.
	b	265	53	841	420·5	820	410	93·7	719	90	1·30 + 0·80	
	c	285	57	861	430·5	840	420	96	750	93·7	1·30 + 0·80	
5	*a*	245	49	821	410·5	807	403·5	92·2	721	90·1	1·20 + 0·65	Colour good, volume small, pile and texture close, essentially doughing flour, good flavour.
	b	265	53	841	420·5	830	415	95	741	92·6	1·20 + 0·65	
	c	285	57	861	430·5	849	424·5	97	758	94·7	1·20 + 0·65	
6	*a*	245	49	821	410·5	796	398	90·9	694	87·0	1·30 + 0·70	Colour average, small volume, evidently doughing flour.
	b	265	53	841	420·5	820	410	93·7	721	90·0	1·30 + 0·80	
	c	285	57	861	430·5	832	416	95·0	735	92·0	1·30 + 0·80	
7	*a*	265	53	841	420·5	825	412·5	94·3	717	89·6	1·34 + 0·72	Good bloom and colour, small volume, doughing flour for high-class bread, flavour good.
	b	285	57	861	430·5	844	422	96·4	742	92·7	1·34 + 0·70	
	c	305	61	881	440·5	864	432	98·7	758	94·7	1·34 + 0·65	
8	*a*	280	56	856	428	839	419·5	95·9	738	92·2	1·30 + 0·75	Small volume, good colour, tendency to redness in crust.
	b	300	60	876	438	858	428	98·0	745	93·1	1·30 + 0·70	
	c	320	64	896	448	874	437	99·9	786	94·5	1·34 + 0·75	
9	*a*	260	52	836	418	822	411	94	714	89·2	1·40 + 0·83	Colour fair, slightly grey in crust, small volume, scaling flour.
	b	280	56	856	428	836	418	95·5	727	91·0	1·32 + 0·80	
	c	300	60	876	438	848	424	97	749	93·6	1·55 + 0·93	
10	*a*	310	62	886	443	860	430	98·3	751	94	1·30 + 0·70	Pile fair, colour good; *b*, good shape; *c*, very flat, yield good.
	b	330	66	906	453	870	435	99·4	764	95·5	1·30 + 0·70	
	c	350	70	926	463	896	448	102·4	789	98·6	1·30 + 0·70	

BAKING TESTS ON SPECIAL FLOURS—*continued.*

No. of Flour.		Water used.		Weight of Unfermented Dough.		Fermented Dough.			Bread.		Colour of Bread by Tintometer.	Remarks on Bread.
		Cubic Centimetres.	Quarts per Sack.	Grams.	Lbs. per Sack.	Grams.	Lbs. per Sack.	Loaves per Sack, calcd. at 4 lb. 6 oz.	Grams.	Loaves per Sack.	Yellow. Red.	
11	*a*	310	62	886	443	879	439·5	100·4	773	96·6	1·20 + 0·75	Good volume, bloom and colour; *c*, showing excess of water.
	b	330	66	906	453	890	445	101·7	789	98·6	1·25 + 0·80	
	c	350	70	926	463	900	450	103	810	101·2	1·25 + 0·80	
12	*a*	300	60	876	438	856	428	97·8	758	94·7	1·20 + 0·75	Good shapely loaves, medium volume; *a*, best of series, good colour.
	b	320	64	896	448	875	437·5	100	773	96·6	1·20 + 0·75	
	c	340	68	916	458	890	445	101·7	785	98·1	1·20 + 0·75	
13	*a*	280	56	856	428	837	418·5	95·6	738	92·2	1·20 + 0·60	Good bloom; good volume, colour and flavour; *c*, best loaf of series, yield good.
	b	300	60	876	438	852	426	97·3	747	93·3	1·20 + 0·60	
	c	320	64	896	448	868	434	99·2	770	96·2	1·20 + 0·60	
14	*a*	290	58	866	433	850	425	97·1	751	93·8	1·20 + 0·65	Good pile, volume, colour, and bloom; *c*, best loaf of series.
	b	310	62	886	443	862	431	98·5	771	96·3	1·15 + 0·70	
	c	330	66	906	453	883	441·5	100·9	788	98·5	1·15 + 0·65	
15	*a*	305	61	881	440·5	853	426·5	97·5	758	94·7	1·30 + 0·80	Very good volume, colour medium for grade of flour; *c* best loaf, but somewhat burnt at bottom, occasioning loss in weight, yield very high.
	b	325	65	901	450·5	872	436	99·6	774	96·7	1·30 + 0·80	
	c	345	69	921	460·5	892	446	101·9	779	97·3	1·30 + 0·80	
16	*a*	285	57	861	430·5	838	419	95·7	735	91·8	1·30 + 0·60	Sponging flour, good pile and volume, colour very good, yield good.
	b	305	61	881	440·5	857	428·5	97·9	755	94·3	1·30 + 0·60	
	c	325	65	901	450·5	877	438·5	100·2	776	97·0	1·30 + 0·60	
17	*a*	275	55	851	425·5	833	416·5	95·2	742	92·7	1·10 + 0·55	Shapely loaves, good colour and pile, dough flour, volume good, flavour good.
	b	295	59	871	435·5	850	425	97·1	755	94·3	1·10 + 0·55	
	c	315	63	891	445·5	866	433	98·9	760	95·0	1·11 + 0·55	
18	*a*	267·5	53·5	843·5	421·7	822	411	93·9	730	91·2	1·00 + 0·70	*a*, Best viscosity, colour fair, pile good in *a*; volume fair, flavoury doughing flour.
	b	287·5	57·5	863·5	431·7	843	421·5	96·3	754	94·2	1·10 + 0·70	
	c	307·5	61·5	883·5	441·7	858	429	98·0	760	95·0	1·10 + 0·80	
19	*a*	275	55	851	425·5	830	415	94·8	724	90·5	1·10 + 0·53	Colour good, bloom fair, volume good, doughing flour for best breads.
	b	295	59	871	435·5	848	424	96·9	747	93·6	1·12 + 0·54	
	c	315	63	891	445·5	865	432·5	99·0	763	95·3	1·12 + 0·54	
20	*a*	280	56	856	428	831	415·5	94·9	703	87·8	1·10 + 0·52	Slightly burnt at bottom, colour good, good bloom, volume good.
	b	300	60	876	438	850	425	97·1	732	91·5	1·10 + 0·53	
	c	320	64	896	448	868	434	99·2	755	94·3	1·10 + 0·53	

BAKING TESTS ON SPECIAL FLOURS—*continued*.

No. of Flour.		Water used.		Weight of Unfermented Dough.		Fermented Dough.			Bread.		Colour of Bread by Tintometer.	Remarks on Bread.
		Cubic Centimetres.	Quarts per Sack.	Grams.	Lbs. per Sack.	Grams.	Lbs. per Sack.	Loaves per Sack, calcd. at 4 lb. 6 oz.	Grams.	Loaves per Sack.	Yellow. Red.	
21	*a*	280	56	856	428	838	419	95·7	720	90·0	1·03 + 0·56	Slightly burnt at bottom, colour fair, volume good.
	b	300	60	876	438	850	425	97·1	731	91·3	1·03 + 0·56	
	c	320	64	896	448	872	436	99·6	756	94·5	1·03 + 0·56	
22	*a*	280	56	856	428	827	413·5	94·5	707	88·3	1·35 + 0·70	Good volume and colour; *c*, flat. Essentially a sponging flour, but of good flavour.
	b	300	60	876	438	850	425	97·1	737	92·1	1·35 + 0·70	
	c	320	64	896	448	860	430	98·2	760	95·0	1·35 + 0·70	
23	*a*	265	53	841	420·5	810	405	92·5	722	90·2	1·20 + 0·70	Good volume and colour, high-class doughing flour, and also suitable for pastry.
	b	285	57	861	430·5	832	416	95·0	732	91·5	1·20 + 0·70	
	c	305	61	881	440·5	852	426	97·3	760	95·0	1·20 + 0·70	
24	*a*	285	57	861	430·5	835	417·5	95·4	718	89·7	1·50 + 0·90	Good volume, fair colour, flavoury doughing flour; rather lower grade than No. 23.
	b	305	61	881	440·5	850	425	97·1	730	91·2	1·50 + 0·80	
	c	325	65	901	450·5	872	436	99·6	755	94·3	1·50 + 0·90	
25	*a*	270	54	846	423	821	410·5	93·8	711	88·8	1·30 + 0·75	Colour moderate, volume medium, pile fair; *b*, best loaf. Good doughing flour for household bread.
	b	290	58	866	433	844	422	95·6	718	89·7	1·40 + 0·85	
	c	310	62	886	443	861	430·5	98·6	746	93·2	1·30 + 0·75	
26	*a*	315	63	891	445·5	856	428	97·8	746	93·2	1·00 + 0·65	Large well-formed loaves, carrying moisture well, good colour and pile, moist, good volume. Especially shows good characteristics of Short-run Patent.
	b	335	67	911	455·5	874	437	100·0	758	95·5	1·00 + 0·65	
	c	355	71	931	465·5	882	441	100·8	768	96	1·10 + 0·75	
27	*a*	330	66	906	453	877	438·5	100·2	752	94	1·30 + 0·95	Good well-formed loaves, carrying moisture well, fair colour, rather burnt at bottom, very strong sponging flour.
	b	350	70	926	463	882	441	100·8	755	94·4	1·20 + 0·94	
	c	370	74	946	473	900	450	103	759	95	1·20 + 0·94	
28	*a*	262·5	52·5	838·5	419·2	810	405	92·5	730	91·2	1·00 + 0·80	Small and close, somewhat flat, typical doughing flour, fair flavour and good colour.
	b	282·5	56·5	858·5	429·2	834	417	95·3	739	92·4	1·00 + 0·72	
	c	302·5	60·5	878·5	439	846	423	96·7	742	92·7	1·00 + 0·72	
29	*a*	265	53	841	420·5	851	425·5	97·2	748	93·5	1·10 + 0·70	Small volume, good colour, excellent flavour, texture and pile moderate; *c*, best loaf, slightly burnt at bottom, good bloom. Doughing flour for use with stronger sponging flours.
	b	285	57	861	430·5	866	433	98·9	759	94·7	1·10 + 0·70	
	c	305	61	881	440·5	887	443·5	101·3	771	96·3	1·10 + 0·72	
30	*a*	260	52	836	418	816	408	93·2	712	89·0	1·30 + 0·77	Colour good, bloom good, size moderate, somewhat same character as No. 29, flavour special characteristic.
	b	280	56	856	428	832	416	95·0	734	91·7	1·25 + 0·77	
	c	300	60	876	438	855	427·5	97·7	754	94·2	1·25 + 0·77	

BAKING TESTS ON SPECIAL FLOURS—*continued.*

No. of Flour.		Water used.		Weight of Unfermented Dough.		Fermented Dough.			Bread.		Colour of Bread by Tintometer.	Remarks on Bread.
		Cubic Centimetres.	Quarts per Sack.	Grams.	Lbs. per Sack.	Grams.	Lbs. per Sack.	Loaves per Sack, calcd. at 4 lb. 6 oz.	Grams.	Loaves per Sack.	Yellow. Red.	
31	*a*	345	69	921	460·5	905	452·5	103·4	800	100·0	......	*c*, Best viscosity, moist loaves, very good flavour, carrying the excess of moisture well, hence high yield.
	b	365	73	941	470·5	927	463·5	105·9	812	101·5	......	
	c	385	77	961	480·5	942	471	107·6	830	103·7	......	
32	*a*	265	53	841	420·5	820	410	93·7	728	91·0	1·20 + 0·50	Small loaves, very good colour and pile, good bloom, very flavoury, evidently high-class doughing flour for use with stronger sponging flours.
	b	285	57	861	430·5	837	418·5	95·6	741	93·8	1·20 + 0·50	
	c	305	61	881	440·5	857	428·5	97·9	761	95·1	1·20 + 0·50	
FOREIGN FLOURS.												
33	*a*	255	51	831	415·5	807	403·5	92·2	719	89·9	1·20 + 0·70	Volume small, colour very good, flavour good, typical winter wheat flour, confectionery and biscuit flour, and doughing flour for use with high proportion of strong flours.
	b	275	55	851	425·5	830	415	94·8	746	93·2	1·20 + 0·70	
	c	295	59	871	435·5	853	426·5	97·5	760	95·0	1·20 + 0·70	
34	*a*	280	56	856	428	835	417·5	95·4	752	94·0	1·30 + 0·80	Volume small, colour good, confectionery or doughing flour, for use with proportion of strong flours.
	b	300	60	876	438	852	426	97·3	759	95·0	1·30 + 0·80	
	c	320	64	896	448	874	437	100	778	97·2	1·30 + 0·80	
35	*a*	297·5	59·5	872·5	436·2	846	423	98·1	756	94·5	1·30 + 1·00	Small volume, colour good, confectionery or doughing flour.
	b	317·5	63·5	892·5	446·2	866	433	99·0	765	95·6	1·30 + 1·00	
	c	337·5	67·5	912·5	456·2	884	442	101·0	788	98·5	1·30 + 1·00	
36	*a*	315	63	891	445·5	863	431·5	98·5	766	95·7	1·20 + 0·70	Good volume and colour, pile good, yield high, loaf moist and good flavour.
	b	335	67	911	455·5	881	440·5	100·5	780	97·5	1·20 + 0·70	
	c	355	71	931	465·5	910	455	104	788	98·5	1·20 + 0·70	
37	*a*	320	64	896	448	875	437·5	100	777	97·1	1·29 + 0·80	Volume very good, yield high, flavour good, pile fair, bottom crust of *c* burnt.
	b	340	68	916	458	887	443·5	101·4	788	98·5	1·32 + 0·83	
	c	360	72	936	468	897	448·5	102·5	795	99·3	1·30 + 0·81	
38	*a*	287·5	57·5	863·5	431·7	846	423	95·2	758	94·7	1·20 + 0·70	Volume good, pile and colour very good, thoroughly representative of highest class Minnesota flour, strong sponging flour.
	b	307·5	61·5	883·5	441·7	858	429	98	752	94	1·20 + 0·70	
	c	327·5	65·5	903·5	461·7	876	438	100·1	775	97	1·20 + 0·70	
39	*a*	297·5	59·5	873·5	436·7	837	418·5	95·6	738	92·2	1·30 + 0·75	Good pile, volume and colour, strong sponging flour for high-class bread.
	b	317·5	63·5	893·5	446·7	863	431·5	98·6	760	95·0	1·30 + 0·75	
	c	337·5	67·5	913·5	456·7	883	441·5	100·9	778	97·2	1·30 + 0·75	
40	*a*	300	60	876	438	846	423	96·7	742	93	1·60 + 1·00	A baker's flour of good volume, pile and colour moderate, yield good, strong sponging flour for household bread ; *a*, burnt at bottom.
	b	320	64	896	448	855	427·5	97·7	738	92·2	1·60 + 1·00	
	c	340	68	916	458	876	438	100·1	742	93	1·60 + 1·00	

NOTE.—The remarks placed against the flours in the above tables are based on opinions formed as to their merits compared with those generally possessed by flours of the class to which they respectively belong.

585. Alternative Scheme for Baking Tests.—For the convenience of those who prefer to work entirely with English weights the following directions for making a baking test are given: the quantity used, 3 lbs., produces from 4 lbs. to 4½ lbs. of bread. This may be baked either in tin or cottage loaves.

First determine the water-absorbing capacity of the flour, either with burette alone, or in conjunction with the viscometer. Make a dough either of full viscometric strength, or as much tighter as may be necessary to suit the requirements of the district. This can readily be done by deciding once for all on a constant deduction from the water-absorbing capacity according to the sixty-seconds' standard.

With 7 lbs. of flour, each ounce of water used is equivalent to one quart per sack. For tests on 3 lbs. of flour the water in ounces, equivalent to quarts per sack, is obtained by multiplying by $\frac{3}{7}$; thus 50 quarts per sack equal 21·4 ounces per 3 lbs. of flour. The following table gives the proportionate quantity of water for 3 lbs of flour, from 50 to 81 quarts per sack:—

50 quarts =	21·4 ounces.	66 quarts =	28·3 ounces.
51 ,,	21·8 ,,	67 ,,	28·7 ,,
52 ,,	22·3 ,,	68 ,,	29·1 ,,
53 ,,	22·7 ,,	69 ,,	29·6 ,,
54 ,,	23·1 ,,	70 ,,	30·0 ,,
55 ,,	23·5 ,,	71 ,,	30·4 ,,
56 ,,	24·0 ,,	72 ,,	30·8 ,,
57 ,,	24·4 ,,	73 ,,	31·3 ,,
58 ,,	24·8 ,,	74 ,,	31·7 ,,
59 ,,	25·3 ,,	75 ,,	32·1 ,,
60 ,,	25·7 ,,	76 ,,	32·6 ,,
61 ,,	26·1 ,,	77 ,,	33·0 ,,
62 ,,	26·6 ,,	78 ,,	33·4 ,,
63 ,,	27·0 ,,	79 ,,	33·8 ,,
64 ,,	27·4 ,,	80 ,,	34·3 ,,
65 ,,	27·8 ,,	81 ,,	34·7 ,,

Quantities.—Flour 3 lbs., water as per table, from strength, salt ½ oz., yeast ¾ oz. Weigh all ingredients as accurately as possible.

First, weigh out the flour, and put it in a pan of sufficient size; take out about an ounce of the flour and put it aside in a small cup. Counterpoise a jug on the balance, and weigh out the requisite quantity of water, warmed to a temperature of about 85° F. Weigh the salt and rub it with the hands into the flour; add the weighed yeast to the water and mix it thoroughly, taking care to break down any lumps with the fingers. Make a hole in the middle of the flour, and pour in the yeast and water; stir it sufficiently to work enough of the flour into the water to form a thin sponge: cover this over by drawing up a little of the flour from the sides. Let this stand for an hour in a warm place, covered over with flannel. Then knead the whole into a dough. Clean all fragments of dough from the hands, and rinse them in a little of the reserved flour; let the rinsings go into the dough. Let the dough ferment for from 3 to 4 hours. In the meantime, grease and weigh a

4-lb baking tin. Dust a perfectly clean kneading-board with a little of the reserved flour, and turn out the dough from the basin, cleaning it as thoroughly as possible with the fingers. Mould the dough into a loaf, using up in so doing the remainder of the reserved flour. Transfer the loaf to the tin, taking care that as little as possible is lost. Notice to what extent the dough has become slacker during fermentation, also whether elastic or possessing very little tenacity. Let the dough prove in the tin for about an hour, then weigh. Next bake for an hour, or an hour and ten minutes, according to the heat of the oven. Remove the loaf from the tin and allow it to cool; in an hour weigh the loaf. Note the colour of the crust, odour of the bread when warm, &c. Next, with a sharp knife, cut the loaf across its highest part; note the colour, texture, flavour, and degree of moisture of the interior. Keep for a day or two and repeat these observations.

If it is desired to keep a permanent record of the test, a good plan is to place the cut loaf on a sheet of paper, and mark its size round with a pencil. A large-sized exercise book, without lines, answers this purpose very well. The other data may be so arranged as to come inside the outline of the loaf.

Another convenient method of making a baking test is by taking a definite quantity of water, and adding flour to the same until a dough of the right consistency is obtained. The dough is then weighed: the weight of water, yeast, and salt used always being a constant, that of the flour is simply obtained by difference from the weight of the dough. A table is easily calculated giving equivalent yields per sack from weight of dough in each case.

General Interpretation of Results.—This it is hoped has been rendered sufficiently clear by the explanatory remarks on the different constituents and properties of flour, by which the description of each is accompanied. It must be remembered that baking tests on small quantities of flour are only to be viewed as comparative; because, as in all operations conducted on a commercial scale, the results obtained in practice fall below those yielded by direct tests on small amounts of material. Consequently, it must not be assumed, because 7 lbs. of flour yield a certain weight of bread when baked with every precaution taken against loss, that the sack of 280 lbs. will yield 40 times that weight of bread. Still it is well, from time to time, to gauge the theoretical yield by a small test, as information is thus obtained as to how closely the practical and theoretical yields agree with each other. By keeping a closer watch on this point, many bakers could lessen considerably various sources of loss which now occur, and are almost unnoticed. In case it is wished to make the baking test a means of estimating how much the actual working yield of flours is, a careful comparison must first be made between the results obtained by a small baking test, and one on a sack of the same flour. Divide the yield of bread from the sack by that from the quantity used for small test: then the quotient may be used as a multiplier in order to convert the small test yield into working yield per sack. Thus, suppose that this quotient is, in the case of a 7 lb. test, 39: then whatever weight of bread is yielded by a 7 lb. baking test, that quantity multiplied by 39 gives the approximate yield per sack. But the figures thus obtained must not be relied on too absolutely, as disturbing elements occur when working on the large scale which are avoided when making experimental tests. It is on the whole safer to view experimental tests as affording information on the comparative merits of flours, rather than as an indication of absolute yield by the flours when baked in large quantities.

CHAPTER XXII.

DETERMINATION OF MINERAL AND FATTY MATTERS IN WHEATS AND FLOURS.

586. Determination of Ash.—To determine ash, weigh a platinum crucible or small dish, and then add five grams of the flour or meal; place the dish on a pipeclay triangle resting on the ring of a retort or tripod stand, and burn the flour by gently heating with the bunsen. The volatile matter burns off readily, and leaves behind a cake of ash mixed with carbon; the heat must be continued until the carbon has disappeared, leaving only the ash, which must be white, or of a greyish tint. The heat must not be raised too high; the burning off of the carbon may be facilitated by occasionally stirring it with a fine platinum wire. Take care that when this is done none of the ash is lost by being removed with the wire. When the burning is complete allow the dish to cool in the desiccator, and weigh.

The normal percentage of ash in flour is about 0·7. The higher grades of roller-made flour contain very low percentages of ash.

587. Determination of Phosphoric Acid, P_2O_5, and Potash, K_2O, in Ash.—When it is desired to estimate both these constituents, take 50 grams of flour, and heat in a platinum dish until the whole of the volatile matter, and most of the carbon, is burned off, then moisten with concentrated hydrochloric acid without removal from the dish. Evaporate to complete dryness, first over the water-bath and then by gentle ignition with the bunsen. This operation renders the silica present insoluble; add warm dilute nitric acid to the ash, and filter from silica and any unburnt carbon: wash the filtrate with the warm acid. The solution thus obtained contains the phosphoric acid, together with the iron, lime, and other bases. This solution must now be made up to a definite volume in a measuring flask, say 250 c.c.; 100 c.c. may then be taken for the phosphoric acid estimation, and a similar quantity for the determination of potassium.

588. Phosphoric Acid Estimation.—For the purposes of this estimation two special reagents are required, known respectively as "Molybdic solution" and "Magnesia mixture."

589. Molybdic Solution.—Dissolve 150 grams of ammonium molybdate, Am_2MoO_4, in a litre of water. Make up a litre of nitric acid of about 1·20 specific gravity; this may be obtained sufficiently near by taking 500 c.c. of commercially pure acid of 1·4 sp. gr., and adding thereto an equal quantity of water. Pour the molybdate solution into the nitric acid (the mixture must not be reversed). The solution thus obtained must be kept in the dark.

590. Magnesia Mixture.—Dissolve 110 grams of magnesium chloride, $MgCl_2$, and 140 grams of ammonium chloride, AmCl, in

1300 c.c. of water; dilute this mixture down to two litres with the strongest liquid ammonia.

591. Mode of Analysis.—By means of a pipette draw off 100 c.c. of the solution of ash (made up as before directed), and pour it into an evaporating basin. Concentrate by evaporation over a water-bath until the volume is reduced to about 30—40 c.c., transfer to a beaker, carefully rinsing the basin with distilled water in small quantity. Add to the solution thus obtained about 100 c.c. of molybdic solution, and allow the mixture to stand for at least three hours at a temperature of about 50° C. The top of the hot-water oven is a very good place on which to put the beakers during this time; the solution may, if it happens to be convenient, be allowed to stand a longer time—all night, for instance—without injury. A bright yellow precipitate forms, which contains all the phosphoric acid, together with molybdic acid; but as the composition of the precipitate is not constant, it cannot be weighed for the purpose of determining phosphoric acid. The bases remain in the filtrate. Bring the precipitate on to a small filter, and there wash with a solution of ammonium nitrate until the washings no longer redden litmus paper. Test the first portion of the filtrate by adding a drop of sodium phosphate solution to a very small quantity, and warm gently—a yellow precipitate shows that the molybdate has been added in excess. Should there be no precipitate, some more molybdic solution must be added to the main portion of the solution, which must then be allowed to stand as before in a warm place. Next dissolve the precipitate in the least possible quantity of warm ammonia solution (one part strong ammonia to three parts of water). This operation is best performed by pouring the warm ammonia on to the filter. When this has passed through, if any more of the precipitate remain on the filter, return the filtrate to the filter, and repeat this operation until the whole of the precipitate is dissolved. While pouring the filtrate back on the filter, place another beaker in order to catch any drops of the filtrate. Wash out one of the beakers, and also the filter, with the warm ammonia solution. This solution contains the phosphoric acid as ammonium phosphate; to it add about 10 c.c. of magnesia mixture, and one-third of the total volume of strong ammonia, set aside in the cold for three hours, or a longer time if wished. Test a small portion of the filtrate for excess of magnesia mixture by adding a drop of sodium phosphate solution; in the event of there being no precipitate formed, some more magnesia mixture must be added to the solution in order to completely precipitate the phosphoric acid. Filter and wash the precipitate with dilute ammonia, dry, and then ignite in a weighed platinum crucible, and weigh. Before ignition separate the precipitate as thoroughly as possible from the paper; burn the latter separately, and let the ash drop into the cover of the crucible. The precipitate, after ignition, consists of magnesium pyrophosphate, $Mg_2P_2O_7$. The magnesia mixture precipitates ammonium magnesium phosphate, thus:—

$$\underset{\substack{\text{Ammonium}\\\text{phosphate.}}}{Am_3PO_4} + \underset{\substack{\text{Magnesium}\\\text{chloride.}}}{MgCl_2} = \underset{\substack{\text{Magnesium}\\\text{ammonium}\\\text{phosphate.}}}{MgAmPO_4} + \underset{\substack{\text{Ammonium}\\\text{chloride.}}}{2AmCl.}$$

On ignition the precipitate is decomposed, undergoing the following change:—

$$\underset{\substack{\text{Magnesium}\\\text{ammonium}\\\text{phosphate.}}}{2MgAmPO_4} = \underset{\substack{\text{Magnesium}\\\text{pyrophosphate.}}}{Mg_2P_2O_7} + \underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Water.}}{H_2O.}$$

The reason for completely detaching the precipitate from the filter paper is that the carbon of the paper reduces the phosphate to phosphide, thus lessening its weight.

Magnesium pyrophosphate, $Mg_2P_2O_7$, contains anhydrous phosphoric acid, P_2O_5, combined with two molecules of magnesia, MgO. The molecular weight of the salt, compared with that of the acid, is

$$\begin{array}{ccccccccccccc} Mg_2 & & P_2 & & O_7 & & & \qquad & P_2 & & O_5 & & \\ 48 & + & 62 & + & 112 & = & 222. & \qquad & 62 & + & 80 & = & 142. \end{array}$$

As 222 by weight of the pyrophosphate contain 142 by weight of phosphoric acid, the weight of the precipitate, whatever it may be, must be multiplied by $\frac{142}{222} = 0{\cdot}64$; this gives the phosphoric acid in the quantity taken, and when that quantity has been two-fifths the total solution from 50 grams, the result, on being multiplied by 5, gives the percentage of phosphoric acid.

592. Washing and Ignition of Precipitates.—In all quantitative estimations it must be remembered that none of the substance being worked on must be lost; therefore when transferring a solution or precipitate from one vessel to another, rinse out all remaining traces of the body. Thus, with the yellow precipitate produced by the molybdate, first carefully pour the supernatant solution down a glass rod, as shown in Figure 73, without disturbing the precipitate Then fill the beaker with the washing solution and commence filtering. In order to remove the precipitate from the beaker, a small brush made of a quill is very useful. Cut the stem of a quill across near the bottom of the feather end, so as to leave the fibres of the feather projecting beyond the stump. Next cut off all the feather except about an inch at the bottom; then with one cut of a sharp scissors or knife cut the remaining feather part to a width of about a quarter inch. In this way a little brush is made, which readily finds its way round the edge of the bottom of the beaker. For washing purposes the chemist uses a "wash-bottle," as shown in Figure 74.

FIG. 73.—PRECIPITATE WASHING.

To make a wash-bottle, fit a good cork (india-rubber is preferable) to a 20 or 24-ounce flask. Bore through it two holes, through which pass pieces of glass tubing bent, as shown in the figure; the ends of these tubes must be rounded off; to the left-hand one is attached, by means of india-rubber tubing, a fine glass jet. The length of the tubes must be so arranged that the direction of this jet can be controlled by the forefinger of the hand holding the wash-bottle. To obtain a large stream of water, pour it from the shorter tube; on blowing through the shorter tube a fine stream of water is projected from the jet on the end of the other tube.

FIG. 74.—WASH-BOTTLE.

The precipitate is usually dried by placing it together with the funnel in the oven. The operation of transferring the precipitate from the paper to the crucible requires great care. First thoroughly clean, and ignite the crucible and cover; allow them to cool in the desiccator, and weigh. **Crucible and cover must always be weighed together.** While the crucible is cooling get ready a sheet of glazed paper; this should be black for light-coloured precipitates, and yellow for any black precipitates. Trim this paper with either a sharp pair of scissors or knife, so as to produce clean cut edges. Also have in readiness a piece of platinum wire about a foot in length. Clean the bench and spread out the sheet of paper, place on it the crucible and cover. Take the filter paper out of the funnel, fold it together at the top, and *very gently* rub the sides together so as to detach the precipitate. Hold the paper all this while over the glazed sheet; next open the filter and pour its loose contents into the crucible. Having cleaned the paper as thoroughly as possible, fold it into a strip about three-quarters of an inch wide; then roll it up into a coil, and wind the platinum wire tightly round it. Hold the bunsen burner at an angle of 45 degrees over the crucible cover, and burn the paper to an ash in it: the paper will readily leave the wire when burned.

In order to ignite crucibles, they are suspended in what are called "pipeclay" triangles; these consist of pieces of common clay pipe, threaded on iron wire, the ends of which are twisted together. A *clean* pipeclay triangle is placed on the ring of the retort stand, and then the crucible placed on it: the crucible is first gently heated by the bunsen, and then more strongly by the foot blowpipe. After ignition the crucible is allowed to cool in the desiccator, and then weighed. The weight of the precipitate is obtained by deducting from the gross weight that of the crucible and the filter ash.

593. Weight of Filter Ash.—This determination is usually one of the first made by the chemical student. The best filters hitherto have been those of Swedish make, but now certain German houses supply filters almost if not quite as good. The most convenient sizes for quantitative work are 2¾, 3½, and 4½ inches diameter. Several packets should be ordered at a time, and it should be stipulated that they shall be from the same parcel of paper. To determine the weight of the ash, take twenty filters, fold and burn them one or two at a time, allowing the ash to drop in a weighed crucible; ignite until a perfectly white ash remains, and again weigh. One-twentieth of the weight is taken as that of the ash of a single filter. Provided the various sized filters are of the same paper, the ash of one size may be calculated from that of another. The areas of circles are as the squares of their diameters, cousequently the ash of a four-inch paper would weigh four times as much as that of a two-inch paper; other diameters could be calculated in the same manner. The weight of ash of filter papers of the better quality is now usually declared on the package.

594. Potash Estimation.—To a second portion of 100 c.c. of the solution already prepared, add ammonia and *pure* ammonium oxalate in slight excess; filter off the precipitated iron and lime compounds. Evaporate the filtrate to dryness, and ignite gently in order to expel ammonium salts. Dissolve the residue in a small quantity of hot water, filter if necessary, add hydrochloric acid in slight excess, and evaporate to dryness. Dissolve the residue in a very small quantity of water, add some platinum chloride solution and a drop of hydrochloric acid, and evaporate to a sirupy consistency. If the solution lose its orange tint during evaporation, more of the platinum chloride solution must be added. Treat the moist residue with strong alcohol, of a strength of at least 80 per cent, filter off the precipitate on a small counterpoised or weighed filter; wash with alcohol until the washings are colourless. Dry at 100° C. and weigh. The precipitate consists of K_2PtCl_6: 487·7 parts by weight of this body are equivalent to 94 parts of K_2O (potassium oxide).

595. Counterpoised and Weighed Filters.—When working on precipitates that are decomposed by a red heat, it becomes necessary to adopt some method other than ignition in a crucible before weighing. It is usual under these circumstances to either weigh or counterpoise the filter beforehand. If the filter is to be weighed, prepare first of all a test-tube shaped stoppered weighing bottle (these can be procured of the apparatus dealer). Dry this in the hot-water oven, cool and weigh. Fold the filter, insert it in the bottle, and dry in the hot-water oven until the weight is constant. The best plan is to set the filter drying over night; the bottle must, of course, be open while in the oven; in the morning stopper it, allow it to cool in the desiccator and weigh. Return to the oven for an hour, and then again weigh; the two weights should agree within a milligram; if not, the drying must be continued until they do. The washed filter and precipitate must first be dried in the oven in the ordinary manner, then transferred to the weighing bottle, and treated exactly as was the original filter. The weight of filter and precipitate, less that of the filter, gives the weight of precipitate. Where the greatest possible accuracy is required this method is to be preferred.

But when speed is an object, a counterpoised filter may be used. Take two Swedish filters, and trim one of the pair until they exactly counterpoise each other when tested on the analytic balance. In this case they are simply to be weighed direct on the pans. Place the one of the papers, folded but unopened, on one side of the funnel, and then put in the other, opened in the usual way. Filter and wash, then dry both filters, and when weighing, again use the empty paper as a counterpoise, placing it on the weight side of the balance. In this method of working, the assumption is that the two papers being of the same weight to start with, and taken from the same lot of filters, will contain the same weight of moisture. Further, that as they are subjected to the same treatment, they will also counterpoise each other at the final weighing. The use of counterpoised filters effects a great saving of time, and yields results of sufficient accuracy for most technical purposes.

596. Determination of Fat.—The fat of meal and flour is estimated by treatment with either ether or rectified light petroleum spirit. Either of these reagents, especially if warm, dissolves fat with readiness, while none of the other constituents of wheat are soluble in these compounds. In order to effect the estimation, a weighed quantity of the sample is first dried in the hot-water oven, and then treated with repeated quantities of ether or petroleum spirit until a small quantity of the reagent leaves no greasy stain on being evaporated on a piece of white filter paper. If ether be used, that known as "methylated" may be employed. Rectified light petroleum spirit, distilling entirely below 80° C., and leaving no weighable residue, can be purchased from dealers in chemicals for analysis. Both ether and petroleum spirit are extremely volatile and inflammable; both give off at ordinary temperatures an inflammable and explosive vapour. The greatest care must therefore be observed in working with these substances.

597. Soxhlett's Extraction Apparatus.—As ether and petroleum spirit are so volatile and inflammable, special forms of fat extraction apparatus have been devised for this estimation. Their object is to keep the liquids out of contact with the air of the room, and also to make a small quantity of the reagent suffice by repeatedly doing duty. Among the most effective of these apparatus is that devised by Soxhlett, and illustrated in Figure 75, in which the complete apparatus is shown in section.

Directions will first be given for the fitting up of the apparatus, and then its use and the principles involved therein will be described. The apparatus proper, known familiarly as a "Soxhlett," is that portion *a c*; this is to be procured from the apparatus dealer. Fit the lower end by means of a well-fitting cork into a good Bohemian flask, *n*, preferably one with a rounded bottom, and about four or six ounces capacity. To the top of the Soxhlett, *a*, fit another cork, and through it bore a hole for the tube of a Liebig's condenser, *j k*. The body of this condenser should be from 18 inches to 2 feet in length; the inner tube must have an internal diameter of half an inch, and must not be constricted at the end—these directions are of considerable importance. Fit a cork and bent leading tube to *k*. Fit up a four ounce flask, *m*, with a cork through which passes a leading tube and two-bulbed thistle funnel, *l*. Pour sufficient mercury in this funnel to just fill the space between the two bulbs. Instead of this flask and funnel, *m l*, a small U-tube, about $\frac{3}{8}$ inch diameter, and with limbs 5 inches long, may be employed. By means of a piece of glass tubing bent to shape, this U-tube may be corked direct to the top of the condenser, *k*, and then sufficient mercury added to just cover the bend. The whole apparatus is then self-contained, which is a decided advantage. With a condenser of ample length this mercury arrangement may be entirely dispensed with, and the top of the condenser tube simply covered with a test-tube or small beaker. A small water bath, *o*, is also required.

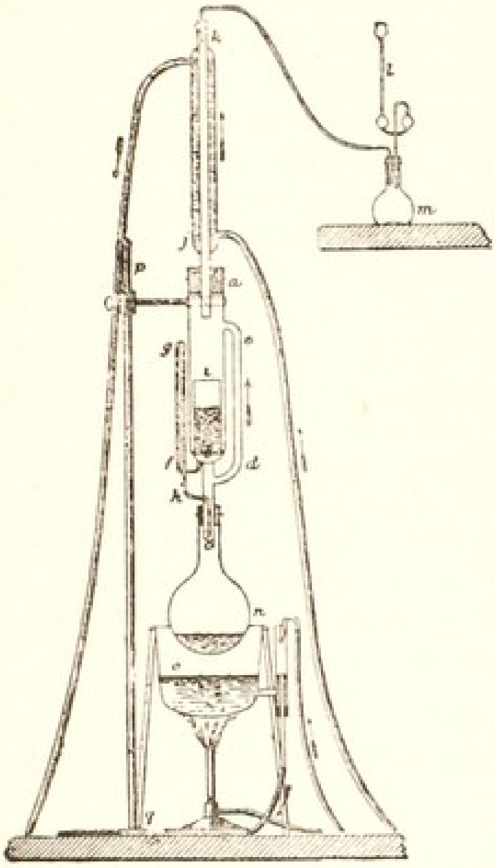

FIG. 75.—SOXHLETT'S EXTRACTION APPARATUS.

Dry 10 or 20 grams of the meal or flour for one or two hours in the hot-water oven, taking as much as can conveniently be placed in the apparatus. Take a square piece of Swedish filter paper, big enough to fold up into a little cylindrical case, *i b*. Fold this so that no liquid can escape through the case except through the pores of the paper, even when full. This specially folded filter is easily prepared by taking the end of a ruler, or other flat-ended cylinder, placing the end in the middle of the paper, then doubling it across the diagonals, and folding the corners round the ruler. Transfer the meal to the filter, and drop this into the Soxhlett.

For flours, instead of this folded filter, it is convenient to use a small glass percolator: this is easily made by taking a piece of glass tubing of such a size as to drop easily into the Soxhlett, and cutting it to about the same length as the case, *i b*. A piece of filter paper is then tied securely to the lower end. Ether percolates through flours with extreme slowness; and consequently, when a paper case is used, much of the ether simply finds its way through the sides of the case, without penetrating the interior of the mass of flour. Attach the Soxhlett to the flask, *n*, and place it on the bath. Next see that all lights are extinguished within 10 or 12 feet of the apparatus. Bring the ether or petroleum spirit from an outer store-room, and pour it in the Soxhlett through a funnel until the level of the liquid rises to *g*; it will then syphon over into the flask, *n*. Next pour in about an ounce more of the liquid, and at once, before doing anything else, carry the ether or spirit back to the store-room. Next attach the condenser, *j k*, and push in the corks as tightly as possible. Support the apparatus by means of a retort stand, *p q r*, and ring. If using the flask, *m*, place it on a shelf conveniently near, and connect the leading tube at *k* to that of the flask by means of a piece of india-rubber tubing. Connect the lower end of the condenser to a water tap by means of india-rubber tubing, and arrange another piece to the upper end to take the waste water to the drain. Bring a water supply to the bath, and also fix an india-rubber tube leading to the drain. Arrange a bunsen underneath the bath. Before going further, once more examine each cork and joint, to see that all are airtight. Turn on a stream of water through the condenser. Next light the bunsen, and keep it going with a gentle flame. The ether will soon boil; when it does so, arrange the flame so as to keep it boiling steadily, but not too violently. The ether vapour ascends through *d e*, and drives the air before it up through the condenser, and out of the flask, *m*, through the mercury in the funnel, *l*. As soon as the ether vapour reaches the condenser, it is condensed, and runs back in a small stream, dropping into the filter, *i b*. The complete condensation is furthered by the use of the mercury funnel, which offers a slight resistance, and thus prevents the escape of ether while still allowing a passage for air. As the condensed ether drops, the body of the Soxhlett fills up to the level of *g*; the ether then returns to the flask by means of the syphon, *f g h*. It carries back with it the fat it has dissolved out of the meal; as the ether continues boiling in *n*, pure ether is continuously distilled over, the fat remaining in the flask. By this treatment one quantity of ether can be made to act on the same meal an indefinite number of times. If all the joints are in good condition, no odour of ether will be observed during the whole of the time the apparatus is in work. The apparatus may be allowed to remain in action for an hour or more. Turn out the bunsen underneath the bath, and also all other lights in the vicinity. Take the apparatus to pieces, cork up the lower flask; test a drop of the ether remaining in the Soxhlett, in order to see if it contains any fat, by allowing it to fall on a piece of white filter paper, when it should produce no stain.

The ether solution requires next to be evaporated to dryness and the fat weighed.

598. Treatment of Ethereal Solution.—Having obtained an ethereal or petroleum spirit solution, containing all the fat in the sample being analysed, filter if not perfectly clear. It will be next necessary to drive off the solvent, and thus procure the fat in a suitable state for weighing. Take, for the purpose of evaporation, one of the counterpoised glass dishes, and tare it in the balance, making a note of its weight against the counterpoise. It must here again be mentioned that ether vapour is not only inflammable, but also highly explosive when mixed with air. In default of special apparatus for the purpose, heat the water-bath to boiling, and then take it into a room in which there are no lights. Partly fill the dish with the ether solution, place it in the bath, and allow it to evaporate spontaneously, refill from time to time from the flask, and finally rinse the flask with a little pure ether, pouring the rinsings into the dish. If necessary, heat some more water and replace that in the bath as it becomes cool. When most of the solvent, whether ether or petroleum spirit, has been thus driven off, place the dish in the oven, heat for two or three hours, and then weigh until constant. Well ventilate the room before any lights are brought in. By this method the whole of the ether used is lost; but by the use of the following device, a considerable quantity may be saved:—Take a piece of glass quill tubing, about four or five feet long; arrange this, by means of india-rubber corks, through another piece of glass tubing about three feet in length and an inch diameter, so as to serve as a jacket. Bend the two ends of the inner tube downwards, so that the one may be attached by a cork to the ether flask, and the other lead into a receiver. Fill the jacket with cold water and cork up. Attach the flask, *n*, containing the ethereal solution to this condenser, and distil off the ether by placing the flask on the hot-water bath, holding it all the time; in two or three minutes the ether will have boiled off, and may be collected in the receiver. For these small quantities of ether the jacket will contain sufficient water to effect the condensation. The concentrated fatty solution may next be poured from the flask into the dish, and then the flask rinsed out with successive very small quantities of ether.

CHAPTER XXIII.

SOLUBLE EXTRACT, ACIDITY, AND PROTEIDS.

599. Soluble Extract.—The proportion of a meal or flour soluble in cold water is of importance in judging of the character of a sample. This soluble portion is termed the "soluble extract," or "cold aqueous extract," and consists of the soluble proteids, sugars (maltose and sucrose), gum (dextrin), soluble starch, and soluble inorganic constituents of the grain, principally potassium phosphate. The solution made for the purpose of this estimation is also available for the determination of the acidity and soluble proteids. On the addition of even cold water to a flour or meal, chemical action immediately commences, the soluble starch being dissolved out of any abraded or ruptured starch granules. As a consequence, the soluble extract varies with the time the solution is allowed to stand in contact with the flour or meal; absolute uniformity must therefore be adopted in the method employed for making this soluble extract. The following is the method employed in the writer's laboratory:—Weigh out 25 grams of the flour, and transfer to a clean dry flask of from 500—700 c.c. capacity, add 250 c.c. of distilled water, cork the flask with a clean cork, and shake up vigorously for five minutes by the clock. One or two minutes' shaking is sufficient to break up any little balls of flour, but in order to ensure perfect solution the longer time is recommended. Next, let the flask stand for 25 minutes, making half an-hour from the time of commencement. In the meantime arrange a 10-inch French filter paper, in funnel five inches in diameter, both being quite dry, and place a clean dry beaker or flask to receive the filtrate. At the end of the half-hour most of the insoluble portion of the flour will have subsided; remove the cork and carefully decant as much as possible of the supernatant liquid on to the filter *without* disturbing the sediment. The filtrate will at first be cloudy; return it to the filter until quite clear, then collect for analysis. By working in this way, there being practically none of the solid matter of the flour on the filter, any subsequent changes in the wet flour do not affect the results. As the speed of filtering varies with different filter papers, it was often found, when both flour and water were placed on the filter together, that a higher extract was yielded by the same flour, simply as a result of a slower filtering paper; there is a further disadvantage in that, when any of the solid matter of the flour was allowed to get on the filter, it greatly impeded the rapidity of filtering. Twenty-five c.c. of this clear filtrate must next be evaporated to dryness in order to ascertain the amount of matter it holds in solution. The glass dishes that were used for the moistures are also well adapted for this purpose. Having tared a clean dish against its counterpoise, and noted any difference in weight, pour 25 c.c. of the filtrate into the dish, and evaporate to dryness over the water-bath.

600. Water-Bath.—This consists of a vessel, usually of copper, about 4 inches deep, and of other dimensions, varying with the number of dishes for which it is made. In case of a bath specially prepared for flour extracts and similar work, one to hold 12 dishes is a convenient size; its actual dimensions would then be 12 in. × 15 in. × 4 in. The top contains a series of holes about 2¼ ins. diameter, one for each dish; to each of these is fitted a cover. A water supply apparatus, similar to that used with the hot-water oven, is attached to the side of the bath. It is very convenient to have a series of flanged glass rings to drop into these holes, on which the dishes are placed; they are thus prevented from coming in actual contact with the metal. These rings are similar in shape to the top of a beaker, and are about an inch deep; in fact, the tops of broken beakers are often cut off and utilised for this purpose. They must be of such a diameter that they just fit in the holes of the bath, being supported by their flanges. The reason for their use is that the outsides of the dishes are liable to pick up foreign matter from the metal of the bath, and so have their weight increased. When the dishes are allowed to come in contact with the metal of the bath, they must be carefully wiped clean before being dried. In use, the hot-water bath should have its feed apparatus so regulated as to maintain the water in the bath at a depth of about half an inch; the water must be kept boiling at a moderate rate by means of a bunsen burner. The evaporation of the fluid in the dishes then proceeds by the action of the steam.

601. Soluble Extract, continued.—On the contents of the dish having evaporated to dryness, place it in the hot-water oven for 24 hours, and then weigh. In order to calculate the percentage of soluble extract, it must be remembered that by adding 250 c.c. of water to 25 grams of flour a 10 per cent. filtered solution has been prepared. It follows that 25 c.c. of the solution contains the soluble extract of 2·5 grams of flour; the weight must therefore be multiplied by 40 in order to give the percentage. It ought to be mentioned that in strictness this is not quite correct, as no allowance is made for the moisture of the flour, so that, as 25 grams of flour contain about 3 grams of water, we really have more nearly 253 c.c. than 250 of water present. As, however, the results are only used for comparative purposes, this is not of practical importance. If wished, the soluble extract may be calculated out to the exact quantity, when the percentage of moisture has been ascertained.

602. Acidimetry and Alkalimetry.—The measurement of the amount of either free acid or free alkali in a solution is often an operation of considerable chemical importance. Thus, in flours or meals, the acidity is occasionally determined; the measure of acidity being often a useful help in deciding whether or not a sample of flour or wheat is unsound. Flours which contain bran or germ develop acidity much more rapidly than those thoroughly purified from the offal. This acidity is caused usually by the presence of lactic acid, and is produced, as has been previously stated, by the action of the lactic ferment. This organism is always found in greater or less numbers on the bran and germ of the grain, and acts by converting the sugar into lactic acid. This action is much favoured by damp and warmth.

603. Normal Solutions: Sodium Carbonate.—The process of acidimetry (acid measuring) belongs to the department of volumetric analysis, and hence it becomes necessary to explain some of the terms used in that branch of analytic work. There is required a set of standard acids and alkalies; that is, solutions of known and definite strengths, and an indicator. The standard solutions are usually made up to normal strength. It is requisite that the exact meaning of this term *normal* should be understood. Normal solutions are prepared so that one litre at 16° C. shall contain the hydrogen equivalent of the active reagent, weighed in grams. It follows that normal solutions of acids and alkalies are all of the same strength, and that equal quantities exactly neutralise each other. Decinormal solutions are prepared by diluting normal solutions to one-tenth their original strength, and are shortly designated as $\frac{N}{10}$ solutions. The acid and alkali most commonly used are sulphuric acid, H_2SO_4, and sodium hydrate (caustic soda), NaHO. Both these substances are extremely deliquescent, and so cannot be easily weighed with accuracy. It is customary, therefore, to first make up as a starting point a normal solution of sodium carbonate, Na_2CO_3. Directions follow for starting from this point and making up the necessary solutions.

Normal sodium carbonate contains 53 grams of the dry salt to the litre; as this solution is seldom employed for any other purpose than that of preparing other solutions, a quarter of a litre only need be made. Take about 18 to 20 grams of the pure dry salt, heat to dull redness in a platinum dish or crucible for about 15 minutes, allow to cool under the desiccator, and then weigh out exactly 13·25 grams. Transfer this weight to a 250 c.c. flask, and two-thirds fill with water, shake up until the whole of the salt is dissolved, and then fill up the flask to the graduation mark. Keep the solution in a clean dry stoppered bottle.

604. Indicators.—The next step is, with the aid of this solution, to make up a solution of normal sulphuric acid. From a study of elementary chemistry, the student already knows that it is usual to determine whether or not a substance is acid or alkaline by observing its action on litmus. Acids turn a solution of that body red, the blue colour being restored by excess of alkali; when the solution is neutral its colour is violet. Bodies such as litmus, which are used in order to determine the completion of any particular action, are termed "indicators."

Litmus.—To prepare the litmus solution, take some litmus grains and boil with distilled water; let the liquid stand for some hours, and decant off the clear supernatant solution. Let this solution again boil, and add nitric acid, drop by drop, until it assumes a reddish-violet colour; boil for a time, and the colour once more becomes blue. Continue this treatment with nitric acid until a violet tint is obtained that remains permanent after boiling. The reason for this boiling is that the litmus contains some earthy and alkaline carbonates; the carbon dioxide liberated, on addition of an acid, gives the litmus a reddish tint, and so requires to be expelled by boiling. The litmus solution should be kept in an open bottle supplied with a small dropping pipette, by which a small quantity can be removed when wanted. If this litmus solution be kept in a closed bottle, it is apt to become colourless; the colour may be restored by pouring the solution in an evaporating dish, and thus exposing it for a short time to the action of the atmosphere.

Phenolphthalein.—Another indicator, much more delicate than litmus, is phenolphthalein; this body, however, possesses the disadvantage of being unsuitable in the presence of carbon dioxide or ammonia. Phenolphthalein is a brownish powder, of which one part is dissolved in 30 parts of 90 per cent. alcohol, and one or two drops of the solution employed for each estimation. The addition of phenolphthalein to an acid solution produces no colour, but with the slightest excess of alkali an intense magenta red is produced.

Methyl Orange.—Under this name is prepared another body, also most useful as an indicator. Like phenolphthalein, it is a yellowish brown powder, one part of which may be dissolved in 30 parts of 90 per cent. alcohol, and two or three drops employed for each estimation. In alkaline solutions methyl orange has a yellow tint, which changes to pink or red with the slightest excess of acid. Methyl orange is absolutely unaffected by carbonic acid, and also by organic acids. On the other hand, it is sensitive to the action of ammonia, and is well adapted for titrating that body. A curious result of the action of these last two indicators is that water from chalk or limestone formations containing calcium carbonate in solution reacts alkaline to methyl orange and acid to phenolphthalein. The dissolved carbonate affects the methyl orange, which is insensible to the carbonic acid, while the phenolphthalein is caused to give an acid reaction by the excess of carbonic acid present.

605. Normal Sulphuric Acid.—Of normal and decinormal acids and alkalies, two litres of each is a convenient quantity to prepare; these solutions are best kept in stoppered Winchester quarts, which hold just over the two litres. Normal sulphuric acid contains 49 grams of H_2SO_4 to the litre. Take about 65 to 70 c.c. of pure sulphuric acid of 1·840 specific gravity (*i.e.*, strongest acid of commerce), mix this with four or five times its volume of water, allow to cool, and then make up to exactly two litres with distilled water. With acid of full strength the solution will now be too strong; it must next be tested against the normal sodium carbonate. Fill a 50 c.c. burette with the acid solution; with a pipette pour 20 c.c. of the normal sodium carbonate into a porcelain evaporating basin, and add two or three drops of methyl orange. Note the height of the acid in the burette, and proceed to add it cautiously, little by little, to the carbonate in the dish. Wait between each addition until the effervescence is over. Continue adding the acid until the neutral tint between yellow and pink is reached. Read the height of the acid in the burette, deduct the first reading; the difference is the amount of acid required to neutralise the 20 c.c. of normal sodium carbonate. Let us suppose that this amount is 18·65 c.c., then as with normal solutions equal quantities should exactly neutralise each other, it is evident that the 18·65 c.c require to be made up with distilled water to 20 c.c.; that is, 20 – 18·65 = 1·35 c.c. of water must be added. Measure the total quantity of acid solution there is, and add water to it in the above proportion. Suppose that there remain 1950 c.c., then as 18·65 : 1950 :: 1·35 to the quantity of water that must be added. Add the proper amount of water to the solution, shake up thoroughly, and once more test by filling the burette and titrating against 20 c.c. of the normal sodium carbonate, exactly as before described: 20 c.c. of the one solution should exactly neutralise 20 c.c. of the other. It should be explained that the term *titrating* is applied to the operation of testing a solution by adding to it a volumetic reagent

606. Normal Sodium Hydrate.—The next step is to prepare a solution of normal sodium hydrate; this solution contains 40 grams of pure NaHO to the litre. Weigh out about 120 grams of pure caustic soda of commerce, and dissolve up in a beaker in the smallest possible quantity of hot water. Allow the solution to stand for some time, in order that any sediment present may subside; cover the beaker during this time with a glass plate. By means of a pipette, draw off as much as possible of the clear solution, and dilute it down to two litres. Run in this solution from a burette into 20 c.c. of the normal sulphuric acid, using phenolphthalein as an indicator. With the quantity directed the solution will be too strong. Calculate the amount of water that must be added to bring the solution to its normal strength, and proceed exactly as was directed with the normal acid. After dilution, again titrate acid against alkali, when 20 c.c. of the one must exactly neutralise 20 c.c. of the other.

607. Decinormal and Centinormal Solutions.—Having succeeded in preparing with accuracy the normal sulphuric acid and sodium hydrate, decinormal solutions of these reagents must be made. Measure out by means of a 100 c.c. pipette, 200 c.c. of the normal acid, and pour it into the litre flask; fill up to the graduation mark with distilled water, and pour into a clean dry "Winchester quart," next add another litre of distilled water, and two litres of decinormal acid are prepared. In the same manner make up two litres of decinormal soda. Titrate 20 c.c. of one of these against the other; these, too, should become exactly neutral when mixed in equal quantities.

Centinormal solutions are occasionally required for certain purposes of analysis. They may be readily prepared by taking 100 c.c. of decinormal solutions, and diluting down to a litre with distilled water free from carbon dioxide.

608. Water Free from Carbon Dioxide.—In addition to the reagents already described, it is necessary to have, for determinations of acidity in flours or meals, some distilled water free from carbon dioxide. This is readily obtained by first rendering some water alkaline with caustic soda, and then distilling; the first portion of the distillate should be rejected. The caustic soda combines with the carbon dioxide that may be dissolved in the water; and so by this treatment the gas is prevented from coming over with the condensed steam. The water should be tested in order to see that no soda has been carried over mechanically by too violent boiling. The water must give no colouration on the addition of two or three drops of phenolphthalein to 100 c.c., but should strike a distinct and permanent pink on the addition of a drop of $\frac{N}{10}$ soda.

For many purposes it is sufficient to boil ordinary distilled water for some ten or fifteen minutes before use, by which most of the carbon dioxide is expelled.

609. Acidity of Meals or Flours.—When it is desired to make this estimation, the aqueous infusion should be made with the water free from carbon dioxide. Pour 100 c.c. of aqueous infusion into a white porcelain dish, add two or three drops of phenolphthalein solution, and proceed to titrate with $\frac{N}{10}$ soda. The burette must be read before the soda is run out, and then again at the completion of the reaction. After the addition of each drop of soda, stir the liquid thoroughly; the reaction is complete when the slightest pink shade remains permanent after stirring. It need scarcely be said that the dishes and other apparatus must be perfectly clean; the burette should first be rinsed with clean water, and then with a few c.c. of the soda solution; this should be allowed to run away, and then the instrument should be filled. Soda solutions tend to cause glass stopcocks to set fast; the burette must therefore be washed after use, and before being put away the stopcock should be withdrawn and wrapped round with a small piece of paper, and again put in its place; this prevents its sticking. It must of course be seen that it is not so placed as to drop out by an accident and get broken. For soda solutions it is preferable, however, to use a burette with an india-rubber tube and spring clip. Assuming that the acidity of meal or flour is due to lactic acid (as undoubtedly it is in whole or great part), then as 1 c.c. of $\frac{N}{10}$ NaHO is neutralised by 0·009 gram of lactic acid, the No. of c.c. used × 0·009 gives the weight of lactic acid in 100 c.c. of the infusion. This quantity of infusion contains the acid of 10 grams of the meal or flour, therefore No. of c.c. of $\frac{N}{10}$ soda $\times 0{\cdot}009 \times 10 =$ percentage of acid in the sample—in other words, with the quantities directed the percentage equals 0·09 times the No. of c.c. of $\frac{N}{10}$ soda used.

Balland has found that, on exhausting a good flour with alcohol and titrating the solution with turmeric paper as an indicator, the normal acidity represented as sulphuric acid varies between 0·015 and 0·040 per cent. But working with the whole flour a higher percentage of acidity is obtained. Planchon took 5 grams of the flour and gradually mixed same with 50 c.c. of cold distilled water, and added, when perfectly homogeneous, two or three drops of alcoholic phenolphthalein solution and titrated with $\frac{N}{20}$ solution of sodium hydrate. He used 0·0245 as a factor, and multiplying the number of c.c. of soda by that figure, got what was in his opinion the actual acidity of the flour.

He finds that this does not increase during the time necessary for the estimation; but on the contrary, that no variation occurs during the first two hours. Taking the same flour, and maintaining it in contact with water for varying times, he got the results which are appended. A corresponding series of tests was made with the filtered aqueous extract of such flours: the results obtained are given in the following table as soluble acidity.

	Percentage of acidity reckoned as H_2SO_4.	
	Total.	Soluble.
Titrated immediately	0·110	0·0107
,, after 1 hour	0·110	0·0225
,, ,, 2 hours	0·110	0·0230
,, ,, 4 ,, ...	0·113	0·0250
,, ,, 7 ,, ...	0·115	0·0275
,, ,, 24 ,, ...	0·126	0·0425
,, ,, 48 ,, ...	0·145	0·0830

The same flour, when extracted with alcohol (rectified spirit) for twenty-four hours, showed after filtration the presence of 0·03 per cent. of acidity soluble therein. Flour does not give up the whole of its acidity immediately to either water or alcohol. Planchon, therefore, recommends instead the titration of the whole flour in the presence of water, and gives the following as the results of such tests, still reckoning total acidity as sulphuric acid:—

	Acidity Per Cent.
Nine Roller Milled samples of fresh flour	from 0·105 to 0·122
Stone Milled sample of fresh flour	0·119
Second sample of do.	0·133
Damaged flour unfit for use	0·160
Second sample of do.	0·565

The author may state that he has for some time independently adopted the method of titration of the whole substance for both flour and bread testing, and confirms the conclusions arrived at by Balland.

The mode of titration of the mixed flour and water is performed in just the same way as with the filtered aqueous extract.

610. Analysis of Old Flours.—Balland and Planchon state that recently old flour which has reached its extreme limit of possible preservation, and thereby lost its commercial value, is being rejuvenated by passing through the mill with a proportion of fresh flour. Such mixed flour escapes detection by trade experts, and passes as genuine new flour. Very shortly, however, the newness passes off, and the whole flour becomes stale. On examination such flours are found to have both ash and water normal, but the fat will have decreased and the acidity increased. The gluten also shows signs of change, being less coherent, and having a tendency to produce frothiness in the water employed for washing it. This latter characteristic is specially noticeable in the case of the gluten being allowed to remain under water for 24 hours after being extracted. Fresh washing at the end of this period causes, in addition to frothing, much loss of weight. The following figures give the results of examination of three such samples of mixed flour compared with genuine new flours:—

	Original Gluten. Per Cent.	Gluten re-washed after 24 hours in water. Per Cent.
Sample No. 1.	29·6	18·0
,, ,, 2. ...	36·4	27·2
,, ,, 3.	36·0	26·4
New Flour A.	38·8	34·8
,, B.	36·0	32·4
,, C.	36·0	31·2

611. Separation and Identification of Acids of Sour Bread.—The acids occurring in either sour bread or dough may be divided into the two groups of fixed and volatile acids. The former consist almost entirely of lactic acid, while the latter may contain acetic or butyric acids. An approximate determination of the fixed and volatile acids may be made in the following manner:—Take 100 c.c. of the solution as directed to be prepared for determination of acidity, and evaporate to dryness in a platinum basin over a water bath, dilute again with pure distilled water, and repeat the process of evaporation. Titrate the residue with decinormal or centinormal acid, and calculate the acidity as lactic acid. Subtract the number of c.c. used for the titration from the total quantity required for the 100 c.c. of the soluble extract; the difference is the amount of volatile acidity, and may be calculated as acetic acid. It is important to make this determination in a platinum vessel, as glass imparts sufficient alkalinity to the liquid to partly, if not entirely, vitiate the results. Another objection is that an aqueous extract of either flour or bread, as shown by Balland, does not give up the whole of its acidity to its filtered aqueous extract. It is difficult on the other hand to work on the whole flour, because on boiling with water the starch would gelatinise, and thus produce an unworkable mass.

The same method may be employed on bread, in which case take 10 grams of bread, and measure out 100 c.c. of water; rub the bread into a paste in a mortar, with a little of the water, and finally add the whole. Transfer to a flask, and add 1 c.c. of chloroform (having a neutral reaction to phenolphthalein), shake up vigorously, and allow to stand over night. In the morning, decant off the clear supernatant liquid, and filter. Take a measured quantity of the filtrate, and evaporate as before in a platinum basin; calculating volatile and fixed acids respectively as acetic and lactic acid.

A more accurate method of determining the volatile acids in bread is based on distillation *in vacuo*. For this purpose the following apparatus may be employed. Select a good *round-bottom* Bohemian flask of about 1 litre capacity, A, fit to it a sound cork, through which three holes have been bored. Through one pass a tube, B, leading to the bottom of a flask, through another, the thermometer, C, registering to 200° C, and through the third, the leading tube, D. The thermometer must be so arranged that its bulb shall be about the middle of the flask. By means of a cork connect up D to the Liebig's condenser, E, and attach the lower

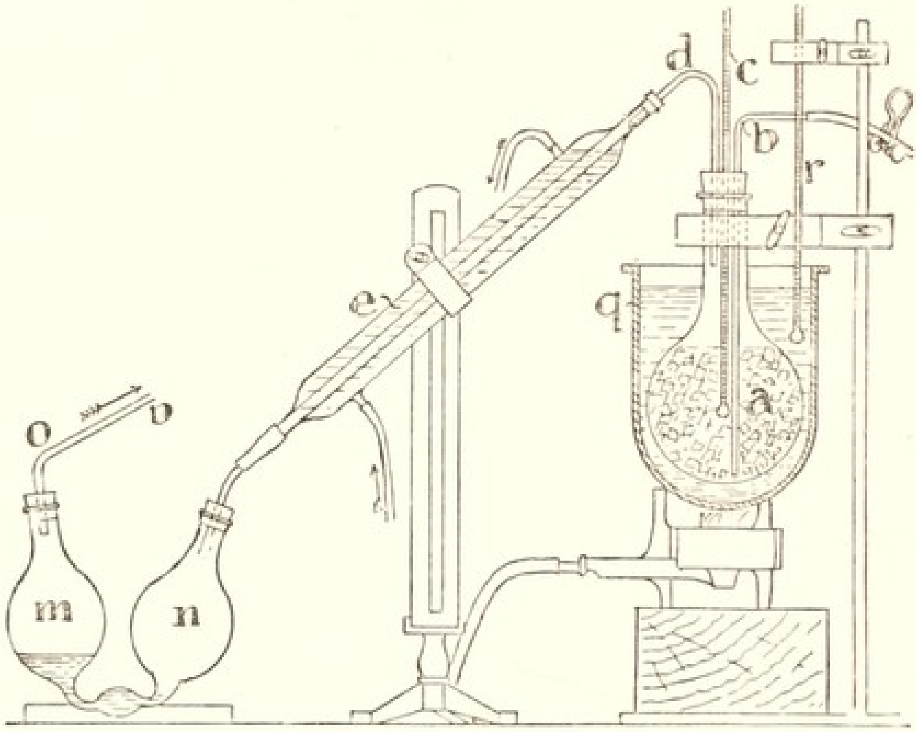

FIGURE 76.—BREAD DISTILLATION IN VACUO.

end of the condenser by means of tubing and corks to the bulbs, M N, the capacity of which should be about 250 c.c. Connect up the further bulb, M, by corks and tubing, O P, to a powerful water or mercury vacuum pump, preferably the former. Arrange the whole apparatus so that the flask, A, is fixed by means of a retort stand and clamp in the bath, Q, which in its turn is carried on a small heating burner. Close the open end of the tube, B, by means of a piece of india-rubber tubing and pinch cock, and set the vacuum pump in motion. Wait until a vacuum is obtained; stop the pump, and watch the vacuum guage to see whether the apparatus is air-tight.

Cut the bread to be tested into small dice, not more than three-eighths of an inch square; weigh off 250 grams, and transfer to the flask, A, and replace the cork, taking care that the end of the tube, B, does not get choked. Close B with the pinch cock, pour sufficient distilled water into M N to seal the connecting tube at the bottom, and connect up the whole apparatus. Fill the bath, Q, with glycerin to very nearly the top, and arrange a thermometer, R, to take the temperature of the bath. Set the vacuum pump going, and turn the water on to the condenser. Then light the burner, and raise the temperature of the glycerin bath to 150—160° C., and maintain it at that point. The moisture of the bread is volatilised, condensed in passing through the condenser, and collected in the bulbs, M N. The escape of glycerin vapour from the bath may be largely prevented by covering over the top with pieces of cardboard. When the distillation slackens, turn off the pump; admit air slowly through the tube, B, until the whole apparatus is filled, and then again exhaust. "Wash" the flask out with air in this way repeatedly. At the expiration of about 40 minutes, stop the pump, admit air through B, and disconnect the flask, A, from the condenser. Remove from the bath, and shake up, so as to thoroughly mix the bread. Again, connect up the apparatus, and recommence the process of distillation; at intervals of about half an hour, repeat the operation of disconnecting the flask and shaking up the contents, doing this altogether three times. In about two hours from the commencement, the whole of the moisture will have come over, and the thermometer inside the flask will register about 125° C. Weigh the residual dry bread, and thus determine the percentage of moisture lost: measure also the total volume of distillate. Determine acidity in the original bread, dry residue, and distillate, using for the two former, tests on the whole substance without filtration. As before, the volatile acidity may be calculated as acetic, and the fixed as lactic acid.

612. Duclaux's Method of Estimating Volatile Acids.—Duclaux finds that of the volatile acids of the acetic series, each has its own definite rate of distillation under certain fixed conditions. Thus, if 110 c.c. of a mixture of acetic acid and water be taken and distilled in a 300 c.c. flask or retort until $\frac{10}{11}$ or 100 c.c. have distilled over, it will be found that the quantity of acid in the distillate is very nearly 80 per cent. of the whole, independently of the strength of the original solution of acid. Further, if the distillate be collected in successive fractions of 10 c.c., and each titrated separately, the proportion of acid passing over in these equal volumes will in all cases be the same for each successive volume provided the acid is pure, but will vary appreciably in the presence of even traces of the other fatty acids. Foreign matters other than acids do not seem to have any very great influence on the course of the distillation. The following table gives the percentage of acid which distils over in each successive 10 c.c. for acetic and butyric acid respectively. The columns A show the percentage of the total acid in the distillate which passes over with each fraction: while in columns B the percentages of the total acid in the whole liquid operated on are given:—

FRACTIONAL DISTILLATION OF ACIDS—DUCLAUX.

	ACETIC.		BUTYRIC.	
	A. Per cent.	B. Per cent.	A. Per cent.	B. Per cent.
1st. fraction of 10 c.c.	7·5	5·9	16·8	16·4
2nd. ,, ,,	7·9	6·2	15·1	14·7
3rd. ,, ,,	8·2	6·7	13·5	13·2
4th. ,, ,,	8·6	6·9	12·3	11·8
5th. ,, ,,	9·1	7·3	10·2	10·1
6th. ,, ,,	9·6	7·6	9·3	9·1
7th. ,, ,,	10·2	8·2	7·8	7·6
8th. ,, ,,	11·5	9·2	6·4	6·3
9th. ,, ,,	12·4	9·8	5·0	4·8
10th. ,, ,,	15·1	12·1	3·6	3·5
Total distillate = 100 c.c.	100·0	79·8	100·0	97·5
Remaining in retort = 10 c.c.		20·2		2·5

DISTILLATION OF MIXTURES OF ACETIC *(a)* AND BUTYRIC ACID *(b)*—DUCLAUX.

No.	$\frac{a}{b}=\frac{560}{28}=\frac{20}{1}$		$\frac{a}{b}=\frac{10}{1}$		$\frac{a}{b}=\frac{840}{168}=\frac{5}{1}$		$\frac{a}{b}=\frac{4}{1}$		$\frac{a}{b}=\frac{2}{1}$		$\frac{a}{b}=\frac{35}{35}=\frac{1}{1}$		$\frac{a}{b}=\frac{296}{592}=\frac{1}{2}$		$\frac{a}{b}=\frac{1}{4}$	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	7·9	6·4	8·6	7·0	9·5	7·9	9·8	8·2	11·3	9·6	12·7	11·4	14·0	12·8	15·5	14·5
2	8·4	6·8	8·8	7·2	9·5	7·9	9·7	8·0	10·7	9·3	12·1	10·7	12·1	12·3	14·0	13·2
3	8·5	6·9	8·8	7·2	9·3	7·8	9·6	8·0	10·4	8·9	11·1	10·1	13·4	11·1	12·7	11·8
4	8·8	7·1	9·0	7·4	9·4	7·8	9·4	7·9	9·9	8·5	10·5	9·4	11·1	10·2	11·4	11·7
5	9·1	7·3	9·3	7·5	9·4	7·8	9·3	7·7	9·9	8·4	9·9	8·9	10·0	9·1	10·3	8·7
6	9·5	7·7	9·6	7·8	9·5	6·9	9·7	8·0	9·2	8·0	9·4	8·3	9·2	8·4	9·2	8·7
7	10·0	8·2	10·0	8·2	9·7	9·2	9·5	7·9	9·3	7·9	8·8	7·8	8·6	7·8	8·1	7·6
8	10·9	8·8	10·7	8·8	10·2	8·5	10·0	8·4	9·2	7·9	8·6	7·7	7·6	7·0	7·1	6·6
9	12·3	10·0	11·6	9·5	10·9	9·1	10·9	9·0	9·5	8·2	8·3	7·5	7·1	6·5	6·2	5·8
10	14·6	11·8	13·6	11·1	12·6	10·5	12·1	10·2	10·6	9·1	8·6	7·7	6·9	6·4	5·5	5·2
11*		19·0		18·3		16·6		16·7		14·2		10·7		8·4		6·2

* No 11 is the 10 c.c. remaining in the retort after the distillation.

Taking acetic acid solution of whatever strength, 5·9 per cent. of the whole of the acid will come over in the first 10 c.c., 6·2 per cent. in the second, and so on. The quantity of acid, which comes over, gradually increases until in the tenth 10 c.c. 12·1 per cent. is found, making altogether 79·8 of the total acid, and leaving 20·2 per cent. in the remaining 10 c.c. in the flask. With butyric acid, on the other hand, although the boiling point is higher, the acid comes over more rapidly in the earlier part of the distillation. Thus, the first 10 c.c. contain 16·4 per cent. of the whole of the acid, the last 10 c.c. 3·5 per cent. of the whole, while only 2·5 per cent. remain behind in the 10 c.c. contained in the flask. When a mixture of acids is distilled, each maintains its own rate of distillation independently of the others. It is thus possible, by fractionally distilling a solution of volatile acid, not only to identify the acid, but also to estimate the proportion of each which is present in a mixture. To do this exactly a somewhat complicated calculation is necessary, but when only the two acids, acetic and butyric, are present, the accompanying table, page 580, of rates of distillation of mixtures of the two in certain definite proportions, will serve as a guide in approximately estimating the quantity of each which is present.

The accurate estimation of volatile acids in dough and bread is fraught with special difficulties, some of which have been already recounted. It is impossible to proceed by working down the dough into a thin "cream" with water, and subjecting that to distillation, because the starch would gelatinise and the resultant paste would boil over into the condenser. An aqueous extract may be made with chloroform water, but, as shown by Balland, a large proportion of the acid does not yield itself to the filtered extract. (Out of 0·126 per cent. Balland found only 0·042 per cent., or exactly $\frac{1}{3}$, in a filtered solution after water and flour had stood together for 24 hours. Further, when working with this solution, a portion of the lactic acid it contains distils over. Bread presents less difficulties than dough, because it can be more readily submitted to distillation in vacuo. The best method of estimating will be to obtain the distillate of two lots of 250 grams each of bread, and work on that, which will give altogether about 200 c.c. of distillate. Experiment shows that by this process none of the volatile acids are lost; for on adding a second pair of bulbs between M N and the pump in Figure 76, and placing 20 c.c. of centinormal soda in these, it was found by titration at the close of the experiment that none of the soda had been neutralised by acid passing over from M N. On the other hand, the distillate obtained in this manner apparently contains traces of lactic acid. In a special experiment 500 c.c. of distillate were taken, a little zinc oxide added, and evaporated down. The concentrated solution was filtered from excess of the oxide, and evaporation continued until about 1 c.c. only remained—on cooling crystals of zinc lactate separated out. These crystals were specially tested for acetic acid, and gave no reaction.

Measure first the total quantity of distillate, and determine its acidity in 10 or 20 c.c. Then prior to starting on the estimation the following reagents are necessary:—Prepare distilled water free from carbon dioxide and neutral to phenolphthalein, and with this make up some centinormal sulphuric acid and soda. Titrate these against each other—they must exactly agree. Test a clean glass Wurtz flask for alkalinity by boiling 110 c.c. of pure distilled water down to 10 c.c. in it, and titrating the residue—this should still be neutral to phenolphthalein. If the flask gives an alkaline reaction, it must be discarded. The author finds flasks of "Jena" toughened glass very free from alkalinity, and so specially adapted for this work.

Working with such dilute solutions, the loss through imperfect condensation is sufficient to materially affect results, particularly when the rate of distillation is irregular through bumping. The following arrangement of apparatus, Figure 77, is recommended for the distillation. A is the side-tube (Wurtz) flask of 300 c.c. capacity, attached to the condenser, B. Procure some colourless glass tubes, C, about three inches high and one inch diameter, and graduated with a 10 c.c. mark, as shown. Fit up three of these with corks and leading tubes, D, and bulbs, E F (like small nitrogen bulbs). To commence the experiment, place 5 c.c. of centinormal soda in the bulbs, E F, and connect up the apparatus. Turn on the water through the condenser, and start the distillation. Meantime get another tube, C, with its bulbs charged with soda in readiness. Watch till 10 c.c. have come over, and replace the filled C tube with the empty one. Transfer the contents of both tube and bulbs to a beaker, rinsing out with a little pure distilled water, and immediately titrate with centinormal soda or acid, according to whether the solution be acid or alkaline. If acid, 5 c.c. + quantity taken for titration = the acidity. If alkaline, 5 c.c. − quantity for titration = acidity of the distillate. Remove the second distillate, and replace by another receiver, C, and charged bulbs. Titrate each in precisely the same manner, and continue until the ten distillates have been collected. Finally, titrate the 10 c.c. which remain in the flask.

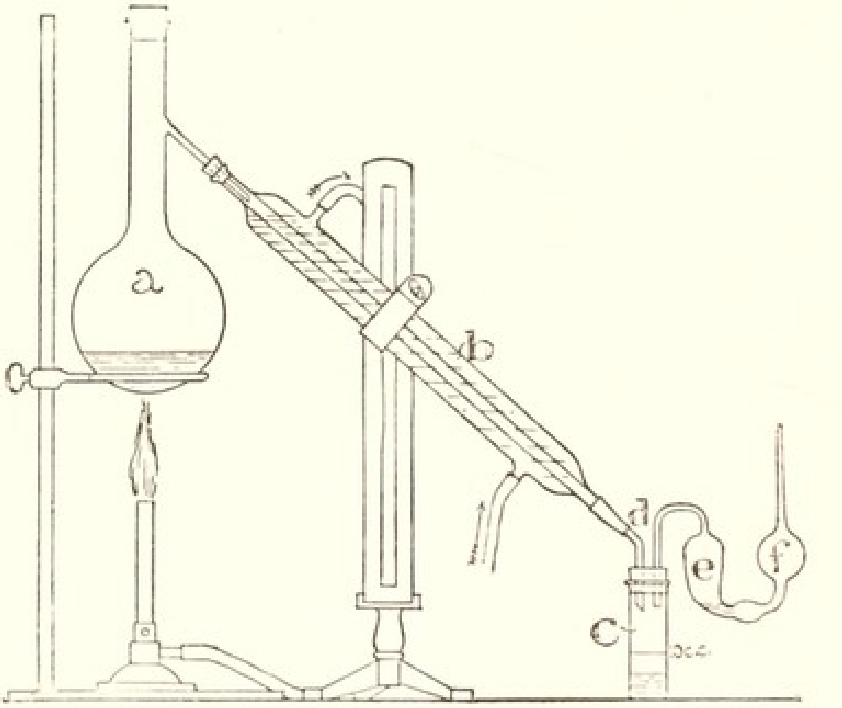

FIG. 77.—APPARATUS FOR DUCLAUX DISTILLATIONS.

The arrangement of receivers fitted with charged bulbs appears complicated; but a number of experiments have shown that with open condensation there is a very considerable loss of acid. Having obtained by titration the amount of acid reckoned as centinormal in each fraction, calculate out what percentage of the whole acid in the 110 c.c. it represents in each case: in fact, work out column B as per table for the particular experiment. In order to explain this calculation, let us assume the following to be the results of an analysis:—

Bread taken	500 grams.	
Weight of Dried Bread ...	324 ,,	= 64·8 per cent.
Volume of distillate	180 c.c.	

Acidity of 10 c.c. = 12·1 c.c. $\frac{N}{100}$ acid = 217·8 on total distillate.
Took for fractional distillation, 110 c.c. = 133·1 acidity.

	Observed Acidity in c.c. $\frac{N}{100}$ acid.	Acidity calculated in per centages of total in 110 c.c.
1st. fraction	9·4	7·0
2nd. ,, ...	9·6	7·2
3rd. ,, ...	9·7	7·2
4th. ,, ...	9·8	7·4
5th. ,, ...	10·0	7·5
6th. ,, ...	10·5	7·8
7th. ,, ...	10·9	8·2
8th. ,, ...	11·6	8·8
9th. ,, ...	12·7	9·5
10th. ,, ...	14·8	11·1
11th. residuum	24·1	18·1

The figures in the second column are simply calculated in percentages: $\frac{9·4 \times 100}{133·1} = 7·0$ per cent.

Turning next to the table (page 580) of distillation of mixtures of acetic and butyric acids, we find that these figures closely agree with those yielded by ten parts of acetic to one of butyric acid: and therefore the assumption that the volatile acids exist in these proportions to each other. Of the total acidity, therefore, $\frac{217·8 \times 10}{11} = 198$ c.c. $\frac{N}{100}$ acid are due to acetic acid, and $\frac{217·8}{11} = 19·8$ c.c. $\frac{N}{100}$ acid to butyric acid. The factors for $\frac{N}{100}$ acetic and butyric acids respectively are 0·0006 and 0·00088; and as 500 grams of bread were taken, we have $198 \times 0·0006 \times 0·2 = 0·023$ per cent. of acetic acid, and $19·8 \times 0·00088 \times 0·2 = 0·003$ per cent. of butyric acid.

This example, with hypothetical quantities, is simply given as an illustration of the mode of calculation.

613. Estimation of Proteids.—Until comparatively recently the standard method of estimating organic nitrogenous matter consisted in mixing the substance with a large excess of a mixture of lime and soda (soda-lime), and heating to redness in a tube. Destructive distillaation ensued, and the nitrogen present was evolved as ammonia, which gas was collected in an excess of acid solution, and subsequently determined by either gravimetric or volumetric processes. This mode of estimation was known as the combustion process.

For all technical purposes it has during the last few years been almost entirely replaced by what is known, after the name of the inventor, as Kjeldahl's process. This method depends on the fact that, when an organic substance is heated with a mixture of concentrated sulphuric acid and potassium sulphate, its nitrogen, if any, is (with very few exceptions) converted into ammonia, and retained by the acid as ammonium sulphate. The residuum is subsequently rendered alkaline by excess of soda, and distilled. The ammonium comes over and is collected in a known volume of decinormal acid, which is titrated, and then the amount of ammonia determined. From this the percentage of proteid matter is readily calculated. A detailed description follows of the mode of performing an organic nitrogen estimation by Kjeldahl's method.

Reagents and solutions required.—Pure concentrated sulphuric acid, as free as possible from nitrogen compounds.

Concentrated solution of caustic soda. Take 3 lbs. of commercial sodium hydrate, either in powder or sticks, and dissolve in as small a quantity of water as possible; let the solution cool, and make up to sufficient to fill a Winchester quart (about two Imperial quarts). Store in a Winchester fitted with india-rubber stopper.

Powdered potassium sulphate. Heat this for some time in an iron vessel, and store in a stoppered bottle.

Decinormal sulphuric acid and sodium hydrate.

Phenolphthalein.

Apparatus.—Bohemian round-bottom flasks, 250 c.c. capacity (or special flasks of Jena toughened glass). Wrought-iron stand to hold four of these flasks for heating purposes. This stand should consist of a stout sheet iron plate, 15 inches long by 4½ inches wide, supported on 4 legs for ordinary bunsen burners, and with 4 holes, each 2 inches diameter, through the plate. On the one long edge of the plate an upright back should be fixed about 4 inches high, and with round notches cut out so that when the flasks are resting in the holes in the plate, the necks may lie in the notches in the back. The flasks are thus supported when in use in an oblique position.

Distilling Apparatus.—Procure an ordinary two-quart oil can, A, in Figure 78. Fit this with a good two-holed rubber cork, through which pass one length of glass tube, B, sufficiently long to reach to the bottom of the can, and project about two feet above the cork. Through the other hole pass a leading tube, C. Stand the can on an ordinary tripod arranged over a burner. Procure a 1500 c.c. round-bottom Bohemian flask, D, and arrange this also on a round-top tripod stand, as shown in the figure. Fit to this flask a two-holed rubber cork, and through one hole pass a leading tube of such a length as to easily connect with C by means of a piece of india-rubber tubing, and with the other end at the bottom of the flask. Through the other hole of the cork pass the tube of the small apparatus, F J, shown in detail at the right of the figure.

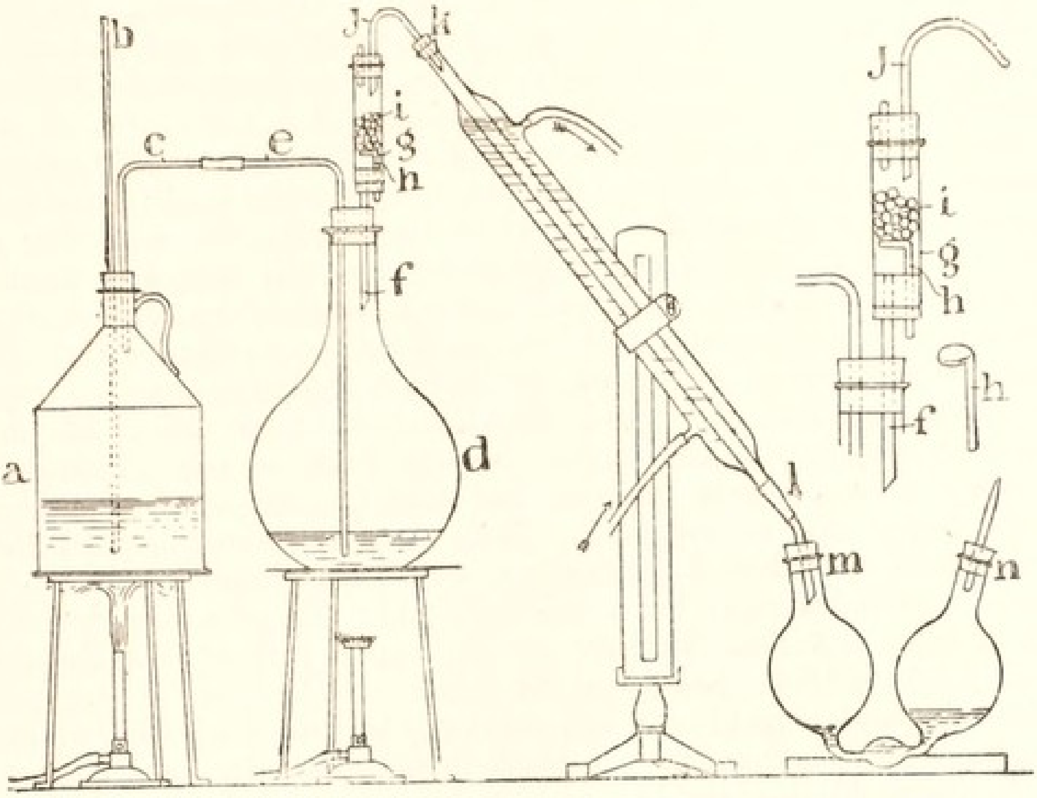

FIG. 78.—KJELDAHL DISTILLING APPARATUS.

The object of this apparatus is to provide against the possibility of splashes of soda being carried over mechanically during the distillation. It is prepared in the following manner :—Take a piece of glass tubing, G, 4 inches long and 1 inch internal diameter, round off the ends for corks in a bunsen flame, and fit with rubber corks. Through one hole of the lower cork pass a piece of glass tubing, F, $\frac{5}{16}$ inch internal diameter, and with the lower end cut obliquely : the top of this must be just level with the top of the cork in G. Take a piece of glass rod, heat one end with the foot blowpipe until a big soft drop forms on it, flatten this out into a round disc by squeezing between two pieces of wood, and bend the end over at right angles, as shown separately at H. Fix this piece of rod in the second hole of the lower rubber cork, so that the bent-over disc forms a splash guard over the upper end of the tube, F. Procure some large round glass beads about $\frac{3}{16}$ inch diameter, and pour sufficient into G to form a layer, I, about an inch deep. The splash disc, H, should be large enough to prevent any of these falling below it. To the upper cork attach a leading tube, J, also with lower end cut obliquely, for the purpose of connecting up to the condenser by means of another cork at K. By means of corks and india-rubber tubing connect to the lower end of the condenser, L, a pair of Kjeldahl bulbs, M N, and the apparatus is complete. See that all corks and rubber connections used are perfectly airtight.

Mode of Analysis.—To estimate total proteids on flours or meals, weigh off 1 gram of the sample and transfer it to a clean, dry heating flask. The weighing is best done with a pair of counterpoised horn dishes for the balance. Obtain a wide-mouthed glass funnel that will just fit the flask, and pour into it the flour or meal, carefully brushing every particle in by means of a brush kept for the purpose. By means of a pipette add 10 c.c. of the concentrated sulphuric acid and about 5 grams of the potassium sulphate. This latter may be conveniently measured, using for that purpose the end of a test tube, or what answers very well, a sewing thimble of the right size. (This may be obtained once for all by weighing out the quantity.) Rinse the acid gently round inside the flask so as to thoroughly wet it, taking care that there are no dry patches of flour between the acid and the flask. Occasionally one gets a small patch which obstinately refuses to mix with the acid, which must then be provided for in the heating. Arrange the flask stand in a stink cupboard designed so as to carry off the fumes produced, and stand the flask obliquely in one of the holes, with its neck lying in the notch. Should there be any adherent dry patches of flour, turn the flask so that they are out of the liquid and on the upper side of the flask. Turn on a very small bunsen flame; as the acid gets hot it carbonises the flour, which froths up and gradually subsides into a tarry looking liquid. The steam of the boiling acid attacks any flour patches on the upper part of the flask, and speedily brings them down into the solution. Continue to apply heat so that the acid is just below the point of ebullition, a bubble of steam escaping only occasionally: the black liquid gradually loses its colour, and in about 45 minutes has usually become colourless. As soon as this stage is reached it is allowed to cool.

When perfectly cold the next step is to arrange for the distillation; this, however, must be preceded by a blank experiment, made in order to determine the amount of ammonia present as impurity in the reagents used. Add 10 c.c of the concentrated sulphuric acid to the contents of the five-gram measure of potassium sulphate in a round-bottomed flask precisely as before: heat so as to melt the sulphate, and allow to cool. Measure off 100 c.c. of water in a graduated jar, and pour in quickly 50 c.c. of it into the flask containing the acid and sulphate—the liquid becomes very hot, but does not spurt if sufficient water is added. Having thoroughly cleaned the whole of the distilling apparatus, remove the cork from D, and pour into it the contents of the acid flask, rinse three times with the remainder of the 100 c.c. of water, pouring the rinsings into the flask, D; add one drop of methyl orange, and give the flask a shake round so as to mix the contents; replace the cork, and connect up with the condenser. Introduce by means of a pipette 25 c.c. of decinormal sulphuric acid into the bulbs, M N, and connect to the condenser. Next, take a two-inch glass funnel, and attach to it about six inches of india-rubber tubing, slip the other end over the leading tube, E. Pour 50 c.c. of the strong soda solution into a graduated measure, and pour it gradually down through the funnel, and leading tube, E, into the flask, shaking sufficiently to cause the solutions to mix. In this way make a rough titration of the acid in the flask, and note how much soda is required to produce neutralisation, and then pour in an additional 5 c.c. Rinse the glass funnel and tubing by pouring in another 50 c.c. of clear water. Disconnect the glass funnel and piece of india-rubber tubing, wash them, and reserve for this purpose. The object of adding methyl orange is to determine once for all how much soda is necessary; having done this, make a note on the label of the bottle, and simply use the same quantity, including the extra 5 c.c., for all succeeding estimations until a fresh quantity has to be made up, when it should be again titrated. The reason for first corking up the flask, D, and then adding the soda through the leading tube, is that the excess immediately liberates the ammonia, which at the high temperature is set free, and is liable to escape; operating in this manner, however, no loss is possible, as the flask is securely corked.

About two thirds fill the can, A, with water, and boil by means of the bunsen; the whole of the preceding operation being complete, turn a current of cold water through the condenser, connect up between C and E, and pass a current of steam over into D; the contents of the flask speedily come to the boil, and the steam and ammonia together are condensed, and retained in the Kjeldahl bulbs, M N. Continue the distillation until about 200 c.c. have come over; turn out the lights, disconnect the bulbs, and pour their contents into an evaporating basin, and titrate with decinormal soda and methyl orange. In the blank experiment, the quantity of ammonia evolved amounts usually from 0·3 to 0·5 c.c. of decinormal ammonia: make a note of this quantity, and repeat the blank with each new lot of concentrated acid and soda. So far as possible make these up each time in about equivalent quantities.

At the close of the experiment, thoroughly rinse out the large flask, taking particular care that no trace of the strong soda can get over into the condenser. It is a good plan to rinse the leading tube and appliance, J, of this apparatus each time by holding under a water tap, and passing a stream of water through it.

The cold contents of the acid flask, after decomposition of the flour, are transferred to the flask, D, and treated throughout in precisely the same manner as was directed for the blank experiment.

Calculation.—As 25 c.c. of acid are taken for the determination in the bulbs, that quantity, less the amount required for its titration, represents the amount of decinormal ammonia evolved, thus:

$$25 \text{ c.c.} - 13{\cdot}3 \text{ c.c. } \tfrac{N}{10} \text{ soda} = 11{\cdot}7 \text{ c.c. } \tfrac{N}{10}\ NH_3.$$

(According to blank experiment, the correction is 0·4 c.c.)

$$\text{then } 11{\cdot}7 - 0{\cdot}4 = 11{\cdot}3 \text{ c.c. from nitrogen of flour.}$$

As 1 c.c. of $\frac{N}{10}$ NH_3 equals 0·0014 of nitrogen as ammonia, then $11{\cdot}3 \times 0{\cdot}0014 = 0{\cdot}01582$ of nitrogen. But as proteids contain $\frac{1}{6{\cdot}33}$ of nitrogen, then $0{\cdot}01582 \times 6{\cdot}33 = 0{\cdot}10014$ of proteid in 1 gram of flour = 10·01 per cent.

As 6·33 and 0·0014 are constants, their product, 0·00886, may be used instead as a factor, therefore No. of c.c. of NH_3 evolved × 0·00886 = weight of proteid in quantity taken for analysis.

614. True Gluten Estimation.—For this purpose take about 0·15 gram of coarsely-powdered, dry gluten, weigh it accurately, and treat with acid and sulphate as with the whole flour. Conduct the whole estimation precisely as before; then, number of c.c. of NH_3 evolved × 0·0086 = weight of true gluten in the quantity of dry gluten taken. The following data show the mode of calculation:—

Flour yields 13·10 per cent. of dry crude gluten.
Taken for true gluten estimation = 0·152 gram.
Ammonia evolved, less correction, 14·6 c.c.
14·6 × 0·0086 = 0·129 gram true gluten.

As the whole flour contained 13·10 per cent. of true gluten, then:
As 0·152 : 13·10 :: 0·129 = 11·11 per cent. of true gluten.
Therefore:

$$\frac{\text{Percentage of crude gluten} \times \text{true gluten found in estimation}}{\text{Crude gluten used for estimation}} =$$

percentage of true gluten in whole flour.

In order to test the "True Gluten" determinations the following experiment was made:—Four glutens were extracted from the same flour, one being washed, as well as could be judged, to the right degree of purity; two of the others were purposely underwashed, and the fourth overwashed. The following were the results in wet and dry glutens:—

	Wet Gluten	Dry Gluten.	True Gluten.
No. 1, Washed correctly	53·0 per cent.	16·1 per cent.	15·0 per cent.
No. 2, Insufficiently washed	63·0 ,,	20·0 ,,	15·1 ,,
No. 3, Would pass for being washed sufficiently	56·7 ,,	16·8 ,,	15·1 ,,
No. 4, Lost weight beyond No. 1 with very great difficulty	48·5 ,,	15·1 ,,	14·7 ,,

Note No. 4 was weighed when at 51 per cent., and again washed in clean water; this water on testing gave starch colouration with iodine solution, showing that even at 51 per cent. starch was still present. Notwithstanding the wide differences in crude gluten between Nos. 1, 2, and 3, the true gluten is practically identical in all. In No. 4, however, the proteid itself is being lost. This was an exceptionally tough, hard, glutenous flour, or doubtless there would have been an appreciable difference in true gluten between Nos. 1 and 2. In true gluten estimations it is recommended that where the true gluten does not amount to 80 per cent. of the crude gluten, another estimation be made and the first one rejected.

615. Modification of Process for Estimation of True Proteids only.—The determination of proteids by the Kjeldahl process is open to the objection that other nitrogenous products which existed in the grain or flour are also reckoned as nitrogen from proteids. It is at times of service to estimate the percentage of nitrogen existing as proteids or flesh formers, as distinguished from other compounds of nitrogen.

Carbolic acid possesses the property of coagulating the soluble proteids, and thus rendering their separation from nitrates, &c., comparatively easy. Take one gram of the flour or meal and cover it in a beaker with a warm four per cent. alcoholic solution of carbolic acid: this may be prepared by taking four grams of the pure acid, and adding thereto sufficient alcohol (re-distilled methylated spirits) to make up the volume of 100 c.c. Let this stand for a quarter of an hour, then add a little boiling aqueous four per cent. solution of carbolic acid, stirring the mixture for about a minute, and then allowing it to cool. Wash the solid residue several times by decantation with the cold aqueous carbolic acid solution, pouring the washings on to a small filter, and finally transfer to it the residue itself; thoroughly dry the filter and residue. Make a Kjeldahl estimation on both the residue and filter, cutting the latter up into shreds, and treating both with the acid and sulphate in the usual manner. The percentage of nitrogen thus obtained, multiplied by 6·33, gives the quantity of true proteids.

616. Estimation of Soluble Proteids.—To make this estimation, take 50 c.c. of the filtered solution as prepared for soluble extract, and evaporate to dryness in one of the acid flasks. For this purpose the flask should be placed in the hot-water oven, as, unless the whole flask is kept hot, recondensation occurs. Even in the hot-water oven evaporation proceeds but slowly; it may be considerably hastened by immersing the flask in a glycerin bath maintained at 110—120° C. Treat the dry residue in the flask with acid and sulphate, and proceed in the usual manner. It should be remembered that 50 c.c. contain the soluble proteids of 5 grams of the flour.

617. Estimation of Proteids Soluble in Alcohol.—The albumins and globulins of flour are soluble in water and insoluble in alcohol; gliadin is insoluble in water, but soluble in 80 per cent. spirit; while glutenin is insoluble in both reagents: it is therefore possible to make an approximate analysis of the proteids of flour by determining proteids soluble in water, proteids soluble in 80 per cent. alcohol, and total proteids. Proteids soluble in alcohol may be determined in the following manner:—To 10 grams of the flour in a flask add 100 c.c. of 80 per cent. alcohol, and shake up thoroughly: weigh the flask and contents on the balance, and then raise the alcohol to boiling point by immersion of the flask in a hot-water bath. Take out, re-weigh, and if necessary make up loss of weight by adding a few drops more alcohol. Cork up and shake vigorously several times while warm. Let the flask stand over night, shake again in the morning, allow to settle and filter. Take 20 c.c. of the filtrate in an acid flask, evaporate to dryness, and determine proteids in the usual manner. Twenty c.c. will contain the proteids soluble in alcohol of 2 grams of the flour. The following table contains the result of a number of estimations made in this manner, except that the alcoholic solution was filtered hot. The results are comparative among themselves, but subsequent investigation shows that more than the gliadin proper is held in solution by the hot alcohol:—

PROXIMATE ANALYSIS OF PROTEIDS IN FLOURS.

FLOUR.	PROTEIDS.				Dry Gluten.
	Total.	Soluble in Water, Globulin, &c.	Soluble in Alcohol, Gliadin.	Insoluble. Glutenin.	
1. Spring Patent	12·64	2·60	4·81	5·23	13·05
2. Spring Bakers	14·95	1·58	6·08	7·29	14·99
3. Winter Patent	8·77	1·45	3·63	3·69	8·89
4. Winter Bakers	10·86	1·31	4·43	5·12	11·00
5. English Wheat Patent	8·78	1·38	4·33	3·07	9·15
6. Hungarian Patent	11·53	1·47	5·27	4·79	11·45

The above table gives the percentage of albumin and globulin, and also the gliadin: the glutenin may be obtained by difference, and is given in the fourth column. The few analyses made do not afford sufficient evidence on which to generalise: as might be expected from its soft, tenacious gluten, the Hungarian Patent contains a very high proportion of gliadin. But the Spring Bakers', which is as different a flour as one can well conceive, contains still more gliadin. On the other hand, the English Wheat Patent, also a totally different flour, contains more gliadin in proportion to its glutenin than does the Hungarian flour. So far as percentages of gliadin and glutenin are concerned, the Hungarian flour can be reduced to the same condition as the English by dilution with starch; but as shown in paragraph 571 on gluten valuation, such diluted Hungarian flour behaves altogether differently to English flour. Further experiments on this point are necessary before absolute conclusions can be drawn. More analytic data must first be accumulated, and then an interesting research should be made on the lines of adding gliadin and glutenin respectively to different flours, and studying how far such additions modified their characteristics. It would be necessary at first, of course, to determine whether or not the processes themselves, employed for the extraction of these proteids from flour, altered their essential properties.

CHAPTER XXIV.

ESTIMATION OF CARBOHYDRATES, AND ANALYSIS OF BODIES CONTAINING SAME.

618. Estimation of Sugar by Fehling's Solution.—The composition and properties of the sugars are fully described in Chapter VI. It is there shown that maltose is capable of forming a red precipitate of copper sub-oxide in the reagent termed Fehling's solution, while dextrin and starch cause no precipitate. This reaction is not only of service in testing for maltose and certain other sugars, but also serves the purpose of quantitatively determining the amount of sugar present in a solution.

As before, directions are first given for the preparation of the reagents, and then for the performance of the analytic operation.

619. Fehling's Standard Copper Solution.—Powder a sufficient quantity of pure re-crystallised copper sulphate, and dry it by pressure between folds of filter paper. Weigh out 69·28 grams, dissolve in water, add 1 c.c. of pure sulphuric acid, and make up the solution to 1 litre.

620. Alkaline Tartrate Solution.—Weigh out 350 grams of pure Rochelle Salt (potassium sodium tartrate), and dissolve in about 700 c.c. of water. Filter if necessary. Next dissolve 100 grams of sticks of pure caustic soda in 200 c.c. of water. If the solution is not clear, it must be filtered through a funnel fitted with a plug of glass wool. Mix the two solutions together, and make up the volume to 1 litre.

When required for use, these solutions must be mixed together in equal proportions; they then form the original Fehling's solution. This solution possessed the disadvantage of changing in character by being kept; and hence the modification in which the Rochelle salt is only added to the copper sulphate immediately before the solution is required for use. Each c.c. of the mixed solution contains 0·03464 grams of copper sulphate, and has been until recently considered equivalent to exactly 0·005 grams of pure dry grape sugar.

621. Action of Sugars on Fehling's Solution.—A careful investigation has been made by Soxhlett of the action on Fehling's solution of specially pure specimens of the various types of sugars: he finds as a result that the amount of precipitate formed depends not only on the quantity of sugar present, but also on the degree of concentration of the solution, the temperature at which the determination is made, and other conditions. Hence great care must be taken to always work in precisely the same manner, as it is only by so doing that comparative results are obtained.

Sugar may be determined by Fehling's solution either gravimetrically or volumetrically. A description of the gravimetric method is first given. The student should commence by practising the estimation on cane sugar, as this substance is easily obtained in a condition of purity. Cane sugar has no action on Fehling's solution, but when heated gently with dilute acid is changed, by hydrolysis, into a mixture of dextrose and lævulose in equal quantities, viz.:—

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water}}{H_2O} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Lævulose.}}{C_6H_{12}O_6}.$$

Dextrose and lævulose both act on Fehling's solution, precipitating copper sub-oxide, Cu_2O, in definite quantity.

622. Gravimetric Method on Cane Sugar.—Procure some of the sugar known as Finzel's crystals; this is the variety of sugar sold by the grocer for use with coffee, and consists of large, colourless, well-defined crystals of almost pure cane sugar. Select some of these free from extraneous matter, powder them, and dry for a short time in the hot-water oven. Make up a one per cent. solution by weighing out 1 gram of the pure dry sugar, dissolving it in water, and making up the volume to 100 c.c. Take 50 c.c. of this solution, and add to it 5 c.c. of pure fuming hydrochloric acid. For this purpose it is best to use a flask graduated at 50 and 55 c.c. Place the flask in a water bath, and heat until it reaches the temperature of 68° C.; this operation should be arranged so as to occupy about ten minutes. Next pour the contents of the flask into a 100 c.c. flask, and dissolve in it dry sodium hydrate in small quantities at a time until the solution is *slightly* alkaline, testing after each addition with a small strip of litmus paper. Cool the flask and make up the contents to 100 c.c. with water. The flask now contains a 0·5 per cent. alkaline solution of cane sugar converted into dextrose and lævulose. Add 25 c.c. of Fehling's standard copper solution to the same quantity of alkaline tartrate solution, and mix the two thoroughly. Take two beakers of about 6 ounces capacity, and pour into each 25 c.c. of the mixed Fehling's solution. Next add to each 50 c.c. of boiling distilled water that has been boiling for about half-an-hour. Stand the beakers in a water bath, the water of which is kept boiling by a bunsen; allow them to stand for seven minutes, and then look to see that no precipitate has formed. Should a precipitate occur, the Fehling's solution is impure, and is consequently no longer fit for use. Next add to each beaker 20 c.c. of the 0·5 per cent. sugar solution and replace in the water bath for twelve minutes. The precipitated cuprous oxide is best weighed on a counterpoised filter; prepare, therefore, beforehand, two pairs of small Swedish filters, trimmed until each one of the pair exactly counterpoises the other, when tested in the analytic balance. Fold one of the pair of counterpoised filters, and filter the copper oxide rapidly from the solution; the filtrate should still be of a deep blue colour. Collect the filtrate in a porcelain evaporating basin, and examine carefully in order to see if any traces of the precipitate have found their way through the paper; if so, pour away the supernatant liquid from the basin, and wash any precipitate back on to the filter. Moisten the other of the pair of counterpoised filters with some of the filtrate, and wash both the filters rapidly with boiling water, and dry both in the hot-water oven. The reason for treating the second paper with some of the filtrate is to cause each to be in as nearly as possible the same condition, so that it (the second) shall still counterpoise the first paper after being washed and dried. The filters should be dried for twelve hours and then weighed, the counterpoise paper being placed on the weight side.

In order to understand the calculations involved in the estimation of sugar by Fehling's solutions, it will be necessary for the student to make himself thoroughly acquainted with the properties of the sugars as already described.

The dextrose and lævulose produced by the action of dilute acid on cane sugar, as shown in the equation in a preceding paragraph, are sometimes grouped together as glucose, or grape sugar; it is then said that one molecule of cane sugar (sucrose) produces, when inverted, two molecules of glucose. From the equation it will be seen that the molecular weight of cane sugar is 342, while that of the glucose formed is 360. It was formerly supposed that an exact number of molecules of CuO of the copper sulphate was reduced to Cu_2O by the sugar; hence we find the statement that two molecules of glucose reduce 10 CuO to 5 Cu_2O. Soxhlett's researches, however, show that the reaction is not so simple, but, as before stated, varies, being dependent on the degree of the dilution of the reagent and other conditions. Different kinds of sugar, too, under the same conditions, reduce, weight for weight, different quantities of CuO to Cu_2O. Working in the manner directed, the reducing power of sugar on Fehling's solution is, according to the most recent determinations by O'Sullivan and others :—

Cane sugar has no reducing action.	1 gram produces..............	..and reduces.
Glucose, ...	1·983 grams of Cu_2O	2·205 of CuO.
Cane sugar after inversion, ...	2·087 ,, ,,	2·315 ,,
Maltose, ...	1·238 ,, ,,	1·378 ,,

The reason why the inverted cane sugar produces more Cu_2O, than does glucose is, that 1 gram of cane sugar, on inversion, yields more than a gram of glucose, the exact quantity being 1·052 grams. When only the one variety of sugar is present in a solution, the following factors may be used for calculating the amount of sugar from the weight of precipitated Cu_2O.

Glucose, ...	$\frac{1}{1·983}=0·5042.$
Cane sugar after inversion, ...	$\frac{1}{2·087}=0·4791.$
Maltose, ...	$\frac{1}{1·238}=0·8077.$

Thus, suppose that in the analysis made with the 0·5 per cent. solution, the weight of the precipitated Cu_2O was 0·1972 grams, then

$$0·1972 \times 0·5042 = 0·0794 \text{ of cane sugar.}$$

Theoretically, in 20 c.c. of the 0·5 per cent. solution there is 0·1 gram of sugar; the results of the analysis give 99·43 per cent. of chemically pure sugar. If the estimation were made with perfect accuracy, this would show that the sugar contained 0·57 per cent. of moisture or other impurity; the deficiency is doubtless in part due to error of analysis. The duplicate estimations made should agree closely.

When making an analysis of a substance, the composition of which is known approximately, a quantity should be taken that contains as nearly as can be calculated 0·1 gram of inverted cane sugar, or 0·2 gram of maltose. In case the estimation shows that the amount of sugar differs widely from these quantities, a second determination must be made in which more or less of the substance is taken.

In the presence of other carbohydrates capable of inversion by hydrochloric acid, O'Sullivan recommends that cane sugar be inverted by means of invertase, which is without action on the other sugars, &c., which may possibly be present. The method is described in detail in connection with the analysis of malt extract.

623. Volumetric Method on Cane Sugar.—When Fehling's solution is intended only to be used gravimetrically, its exact strength is not a matter of great importance, but when employed for volumetric estimations, its strength must first be accurately determined by titration with a standard solution of sugar. For this purpose the 0·5 per cent. solution of inverted cane sugar already described may be used. The sugar must be added to the Fehling's solution, and not the Fehling's solution to the sugar. The sugar solution is therefore placed in a burette, and in order that its contents may not get heated during the operation, the glass jet is attached by means of a piece of india-rubber tubing about eight or ten inches long. The burette may then be placed so as not to be vertically over the basin in which the Fehling's solution is being heated.

Measure out 5 c.c. each of the standard copper and alkaline tartrate solutions into a white porcelain evaporating basin; add 40 c.c. of well-boiled boiling water, and heat the liquid quickly to the boiling point by means of a small bunsen flame. In order to test the purity of the Fehling's solution, boil for two minutes; there should neither be a precipitate nor any alteration of colour. Next add the sugar solution in small quantities at a time, boiling between each addition. As the operation proceeds, the deep blue colour of the solution disappears; towards the end, add the sugar more cautiously, and after each boiling allow the precipitate to subside. Tilt the dish slightly over, note whether the clear supernatant liquid is still of a blue tint by observing the white sides of the dish through it. When the colour has entirely disappeared, the reaction is complete. The exact point may be determined with more exactitude by means of a dilute solution of potassium ferrocyanide, acidulated with acetic acid. With a glass rod put a series of drops of this reagent on a white porcelain tile; wash the rod, take out a drop of the clear liquid from the dish with it, and add it to one of the drops of the ferrocyanide; the slightest trace of copper produces a reddish-brown colouration.

The results of the first estimation must only be looked on as approximate, but having thus gained an idea of about how much sugar is required, the succeeding ones may be made more quickly, as almost all the sugar may be added at one time. Thus, if 9·6 c.c. of sugar solution were required in the first trial, then in the second from 8·5 to 9·0 c.c. may be run in at once, and then the solution added more carefully as the end of the reaction is reached.

Provided the Fehling's solution is of normal strength, then

10 c c. = 0·0500 grams of glucose or invert sugar.
10 c.c. = 0·0475 ,, ,, cane sugar (after inversion).
10 c c. = 0·0801 ,, ,, maltose.

The difference between the cane sugar and glucose is here again explained by the fact that cane sugar produces on inversion more than its weight of glucose; 0·0475 gram of cane sugar yields 0·05 gram of glucose. Working with a 0·5 per cent. solution of cane sugar, each c.c. contains 0·005 gram, and 9·5 c.c. contain 0·0475 gram of sugar; 10 c.c. of the Fehling's solution should therefore require for its complete reduction 9·5 c.c. of the sugar solution.

As the Fehling's solution is rarely of the exact strength, its equivalent in cane sugar must be noted so as to be used in each determination. Suppose the 10 c.c. of Fehling's solution required 9·3 c.c. of the sugar solution, then we know that 10·0 c.c. is equivalent to only $\frac{9 \cdot 3}{9 \cdot 5} =$ 0·9789 of the respective quantities of different sugars given above. The exact strength of the Fehling's solution should be noted on the bottle, together with the date when the titration was made; the solution should be frequently tested against the solution of pure sugar. The quantity of sugar found must therefore be multiplied by 0·9789. An example will make this clear. A 0·5 per cent. solution of a commercial sugar was tested volumetrically, when 11·4 c.c. of the sugar solution were required to completely reduce 10 c.c. of the Fehling's solution. By titration 10 c.c. of the Fehling's solution are known to be equivalent to 0·9789 of 0·0475 = 0·0465 of pure cane sugar; that quantity is therefore present in 11·4 c.c. of the 0·5 per cent. solution. A 0·5 per cent. solution contains 0·005 gram of sugar, so that 11·4 c.c. contains 0·0570 gram of the sugar. As 0·0570 gram of the sample contains 0·0465 gram of sugar, the percentage of pure sugar in the specimen is 81·58. The analysis would appear in the note book thus:

"Volumetric determination of pure sugar in a commercial sample of cane sugar.
Inverted and made up to 0·5 per cent. solution.
11·4 c c. required to reduce 10 c.c. of Fehling's solution,
which = 0·0465 gram of pure cane sugar.
$\frac{0 \cdot 0465 \times 100}{11 \cdot 4 \times 0 \cdot 005} =$ 81·58 per cent. of pure sugar."

624. Estimation of Maltose in Wheats or Flours.—The method of procedure is much the same as with cane sugar. The principal point is to obtain a solution of the right strength. Assuming that an aqueous infusion of wheat contains an average amount of 2·5 per cent. of maltose, then 100 c.c. of a 10 per cent. solution of the meal or flour contains 0·25 gram of maltose, so that 80 c.c. of the 10 per cent. solution are required in order to furnish an approximate amount of

0·2 gram of maltose. For each quantitative estimation, take 25 c.c. of Fehling's solution, 10 c.c. of water, and 80 c.c. of the clear 10 per cent. solution of the meal or flour. These quantities give the same degree of dilution as those directed to be used in the estimation of cane sugar; proceed exactly as in the determination of that substance. Having weighed the precipitate of Cu_2O, multiply by the factor 0·7758; the result is the quantity of maltose in 80 c.c. of a 10 per cent. solution of the meal or flour. As 80 c.c. of such a solution contains the soluble portion of 8 grams of the meal, the percentage is obtained by multiplying by $\frac{100}{8} = 12·5$.

In making this estimation the soluble proteids of the grain are kept in solution by the alkali of the Fehling's solution. They may if wished be removed by boiling and filtering the 10 per cent. solution. Put about 100 c.c. of the solution in a beaker, take the weight, and then boil for about five minutes; replace on the balance and make up to the original weight with distilled water. Filter off the coagulated proteids by passing the liquid through a dry filter; the filtrate is a 10 per cent. solution, *minus* the proteids coagulated by boiling.

If maltose is to be determined volumetrically, the solution should always be first freed from coagulable proteids in the manner just described. Take 10 c.c. of the mixed Fehling's solution, add 20 c.c. of water, and run in the clear 10 per cent. solution of the meal or flour until the reaction is complete, exactly as was done with the inverted cane sugar. The less quantity of water is added because of the maltose solution from the meal or flour being so very dilute.

In case the estimation of maltose is being made in a much stronger solution than that obtained by treating a meal with 10 times its weight of water, dilute the solution down until it contains approximately about one per cent. of maltose, and then work with exactly the same quantities as were directed for the inverted cane sugar 0·5 per cent. solution.

The estimation of maltose in wheats and flours is principally of value as a means of judging the amount of alteration which the starch has undergone: that a sugar analagous to cane sugar is also present is demonstrated by the experiment quoted in paragraph 338, page 213, in which an additional precipitate is obtained as a result of treatment with hydrochloric acid.

625. Estimation of Dextrin.—Most substances which contain maltose contain also dextrin; thus the two are both found in wort produced from malt, and also in starch solutions that have been subjected to diastasis. Dextrin has no action on Fehling's solution, but by prolonged treatment with an acid is converted into maltose, and ultimately into glucose. When maltose and dextrin are simultaneously present in a liquid, other carbohydrates being absent, the maltose is estimated in a portion as already described; another portion is treated with acid, by which both dextrin and maltose are converted into glucose. A second estimation of the copper oxide reducing power is then made. The weight of precipitate will be found to be considerably more than in the first estimation. This is due, in the first place, to the fact that glucose precipitates more Cu_2O than does maltose. The maltose originally present must be calculated into glucose, and the amount of precipitate due to it subtracted from the weight found in the second estimation: the remainder is reckoned as glucose produced by the hydrolysis of the dextrin; the percentage may be then obtained by calculation. Unfortunately, it is difficult to determine the exact point when the whole of the dextrin has been changed into glucose. When carefully worked the process is, however, sufficiently accurate for most technical purposes, and yields comparative results. The method is largely employed for the determination of dextrin in the worts made for malt assays. There follows a modification of the process adapted to the determination of dextrin in meals and flours. Having made a solution for the determination of maltose, take the same quantity of the solution as required for that estimation, viz., 80 c.c., and add to it 2 c.c. of dilute sulphuric acid (1 part concentrated acid to 8 of water), stand the mixture in a water bath, and heat to boiling for four hours. At the end of that time neutralise carefully with caustic potash solution (KHO), and proceed to estimate glucose by Fehling's solution precisely as before. The excess of glucose in the second solution over that produced by the maltose in the first requires to be calculated back to dextrin. It must be remembered that glucose is produced from dextrin according to the following equation:—

$$\underbrace{\underset{\text{Dextrin.}}{C_{12}H_{20}O_{10}} \quad + \quad \underset{\text{Water.}}{2H_2O}}_{\text{Molecular weight} = 324.} \quad = \quad \underbrace{\underset{\text{Glucose.}}{2C_6H_{12}O_6}}_{\text{Molecular weight} = 360.}$$

Therefore, every 360 parts of glucose thus produced represent 324 parts of dextrin in the original solution, or 10 of glucose = 9 parts of dextrin, so that glucose formed from dextrin $\times \frac{9}{10}$ = dextrin. As already stated, this method must only be looked on as giving results sufficiently accurate for technical purposes.

A useful alternative method of estimating dextrin depends on the fact that it is only very slightly soluble in alcohol of the strength of ordinary methylated spirits, whereas maltose, glucose, &c., are fairly soluble under the same conditions. The method is applicable to the soluble extracts of bread and flour, malt extracts, and similar preparations. When there are many such estimations to be made, a fairly large quantity of methylated spirits, say a gallon, should be redistilled (see paragraph 638), tested against purified dextrin, and reserved for this purpose. To purify dextrin, take some of the best light-coloured dextrin of commerce, and dissolve in water to about a 15 per cent. solution. Pour some of this, in small quantities at a time, in about a litre of redistilled spirit in a large flask, shaking vigorously between each addition. Dextrin will be precipitated, and should be finely divided, if in sticky lumps the solution has been used too strong, and must be diluted. Filter off this precipitate, wash with alcohol, redissolve in water, and again precipitate with a large quantity of alcohol as before. Wash and carefully dry; the resultant purified dextrin should be colourless and tasteless (save for a slight flavour from the spirit). Dissolve 0·1 gram of the dextrin, and make up to 10 c.c. in water; add this quantity to 125 c.c. of the redistilled spirit, and shake well: there should be a slight precipitate. Filter and evaporate 50 c.c. to dryness in a weighed dish, and thus determine the amount of dextrin dissolved by the particular sample of spirit. Note same in calculated weight of dextrin held in solution per 270 c.c.

In making a determination, prepare, if possible, a solution of such a strength that 20 c.c. shall contain approximately 0·2 gram of dextrin. Add this to 250 c.c. of redistilled spirit in a flask, cork, and shake up: allow to stand a few hours, then pour off the clear, supernatant liquid on to a counterpoised filter, disturbing the precipitate as little as possible. Add 100 c.c. more of redistilled spirit to the precipitate, and shake vigorously, then transfer the dextrin to the filter, washing out the paper with the clear spirit filtrate; dry and weigh against the counterpoise, which must be washed successively with the first and second spirit filtrates. Add on to the weight thus found the 270 c.c. solubility correction. (The 100 c.c. of spirit used for washing does not redissolve any weighable quantity of the precipitated dextrin.) At times the dextrin precipitate sticks somewhat to the flask: in such cases rinse first with a little alcohol, and then dissolve out with a small quantity of water, and evaporate to dryness in a weighed dish. Add the quantity thus found to the total.

As in some cases the spirits may precipitate proteids as well as dextrin, it is advisable, where special accuracy is required, to make a nitrogen determination in the dry precipitate. For this purpose fold up the filter paper, and Kjeldahlise it together with the precipitate in the usual manner. Deduct the weight of proteid from the total weight of precipitate.

Occasionally the proteids present will not separate, and produce an opalescent liquid which filters badly and extremely slowly. In this case make a fresh estimation, using stronger spirit, say 92—94 per cent., for precipitation. Let it stand at least twelve hours, or till clear, then wash the precipitate three times by decantation in the flask, shaking vigorously, and allowing to subside each time, using for this purpose *the weaker spirit.* Collect and weigh as before. In this case make a special test for the correction with some purified dextrin, operating in the same manner, and evaporating down known fractions of the lots of spirit used.

It should be added that alcohol precipitates in this manner not only dextrin, but also other gum-like bodies present, which are frequently returned in analysis as "indeterminate matters."

626. Polarimetric Estimations.—In addition to the method already described of estimating maltose and dextrin by means of Fehling's solution, there is a second process in which certain optical properties of these bodies are employed in the determination of dextrin, instead of hydrolysing that substance into glucose by means of dilute acid. This particular modification is of special value as a part of the process, to be hereafter described, of the estimation of starch, consequently it requires careful explanation.

As has been already stated, the sugars, in common with several other bodies, are capable of rotating the plane of polarisation of a ray of light. They possess this property not only in the solid state, but also when in solution; further, the amount of rotation is very nearly proportional to the degree of concentration of the solution.

627. Specific Rotatory Power.—The angular rotation of a ray of polarised light by a plate of any optically active substance, 1 decimetre (3·937 inches) in thickness, is termed its "specific rotatory power." In most substances this has to be obtained by calculation, because of the difficulty of getting transparent plates of a sufficient thickness. A solution of known strength is prepared, and from the rotatory power of this solution the specific rotatory power may be calculated. The rotatory power of solutions of the same strength may vary with the temperature, and also with the solvent employed, hence it is necessary to note the strength of the solution at the time of the estimation, and also the solvent used. The apparent or sensible specific rotatory power of a substance is found by dividing the angular rotation observed in the polarimeter (a) by the length of the tube in decimetres (l usually $=2$) in which the liquid is observed, and by the degree of concentration (c), that is the number of grams in 100 c.c. of the liquid. S being the specific rotatory power, then the above is represented by the formula—

$$S = \frac{a}{l \times \frac{c}{100}} = \frac{100a}{l \times c}$$

The rotatory power of a substance depends on the nature of the light used; as the instrument to be described is one in which the yellow monochromatic light of the sodium flame is employed, all numbers given will be for light of that description, which is often indicated by the symbol S_D.

In measuring rotatory powers of sugars it has been found convenient to take a plate of quartz, 1 millimetre in thickness, as the standard of comparison. According to the latest and most accurate measurements, such a plate produces an angular rotation of $21° \, 44' = 21·73°$ for the sodium flame (S_D). The strength of the cane sugar solution which, in a tube 2 decimetres in length, shall exercise the same rotary power, is that equal to 16·350 grams of sugar in each 100 c.c. of the solution.

$$S_D = \frac{100 \times 21·73}{2 \times 16·350} = 66·45°$$

as the specific rotatory power of cane sugar.

All sugars do not rotate the plane of polarisation in the same direction: thus, some twist it to the right, or in the direction of the hands of the clock, others twist it towards the left. The terms dextro- and lævo-rotation are applied to the right-handed and left-handed rotation respectively. Also the symbol + is used to represent dextro- and − to represent lævo-rotation. The specific rotatory power of the substances of importance in connection with the chemistry of wheat and flour is appended:

Substance.	Formula.	Specific Rotatory Power.
Cane sugar	$C_{12}H_{22}O_{11}$	+66·5°
Maltose	$C_{12}H_{22}O_{11}$	+139·2°
Dextrose	$C_6H_{12}O_6$	+51·9
Lævulose	$C_6H_{12}O_6$	−98° at 15° C.
Invert sugar	$2C_6H_{12}O_6$	−23·05° at 15° C.
Dextrin	$C_6H_{10}O_5$	+193°

628. The Polarimeter.—We will next describe one of the forms of the polarimeter, and for that purpose will select the "Jellet-Cornu Polarimeter," or "Saccharimétre a Pènombres," as manufactured by Duboscq, of Paris. This instrument is simple in construction, well made, and of reasonable price.

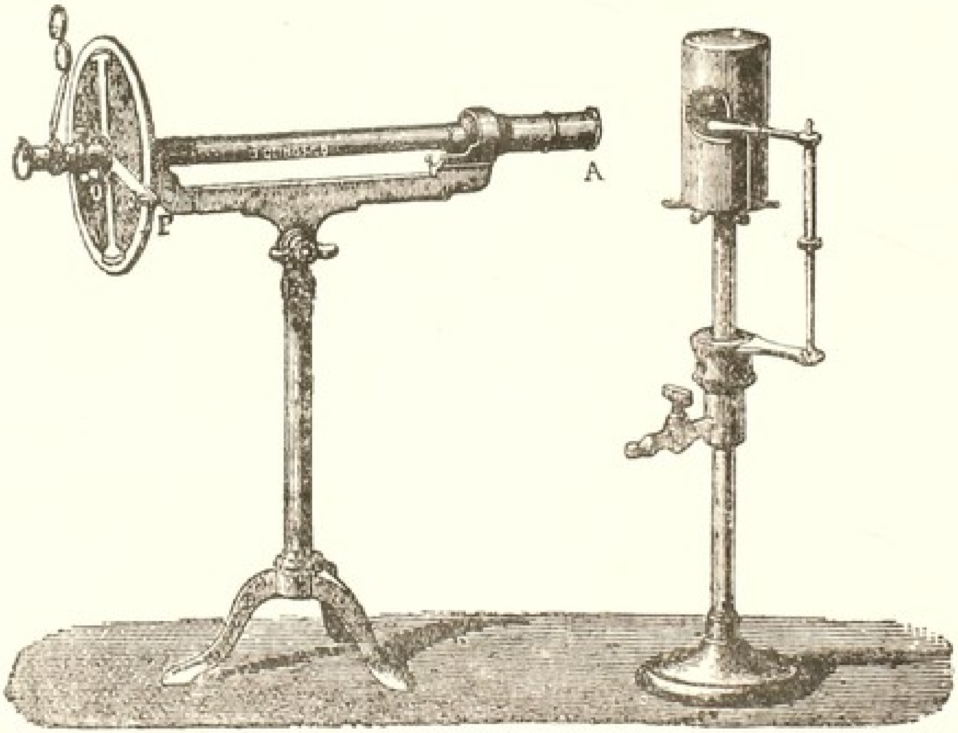

FIG. 79.—JELLET-CORNU POLARIMETER.

Figure 79 is an illustration of the instrument and the bunsen used for the production of the sodium flame. When using the polarimeter it is well to work in a room from which all light other than that of the sodium flame is excluded. The instrument consists essentially of a tripod support, carrying a horizontal frame, in which is placed the tube filled with the solution under examination, and having at the one end, A, the polarising prism, and at the other the analyser, together with a small telescopic arrangement used as an eye-piece.

629. Polarimeter Tubes.—These tubes are made of brass, lined

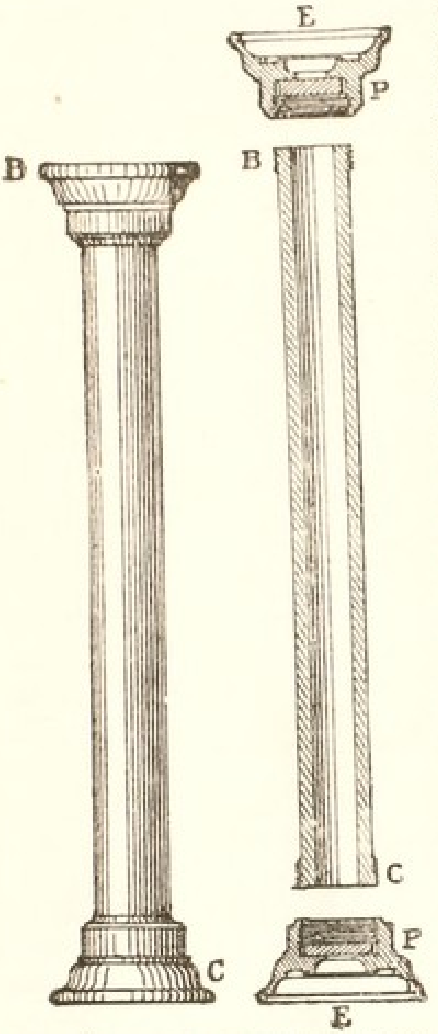

FIG. 80.—POLARIMETER TUBE.

with tin, and are exactly 20 centimetres in length from end to end inside the caps. The left-hand illustration, Figure 80, represents the tube with the ends screwed on; the other shows the tube in section. Each cap contains a glass plate which fits accurately to the end of the brass tube; above the glass plate is a washer of leather; on screwing on the cap this washer exerts an equable pressure on the glass plate, and so makes a water-tight joint. The mistake must not be made of placing the washer inside instead of outside the glass plate. When using the tube, it is first cleaned, then dried or rinsed with a few drops of the liquid under examination; one of the caps is next screwed on. The tube is then filled with the solution, any bubbles are allowed to escape, and then the second glass plate is slidden over the end and screwed tight by means of the cap. If properly filled, the tube should contain no air, neither should it leak. If there should be any tendency to leakage, it may be prevented by *very slightly* greasing the ends of the tube. It will be evident that such a tube contains a layer of the liquid exactly 20 centimetres in length.

630. Polarimeter Tube, with Thermometer.—Figure 81 shows a polarimeter tube of slightly different construction: it is in the first place lined with glass, and is 22 instead of 20 centimetres long. On the top there is a tubulure, by which a thermometer is inserted in order to determine the temperature of the solution at the time the estimation is made. The use of this particular form of tube will be described hereafter.

631. Verification of Zero of Polarimeter.—The first operation to be performed in starting work with a new polarimeter is to verify the zero of the graduated scale of the instrument. The Jellet-Cornu polarimeter is provided with two scales, both of which are engraved on the circular disc at the front of the apparatus. The upper scale is one of sugar degrees, the lower is graduated into angular degrees, namely, 90° to the right angle. The vertical arm, which shows in the figure traversing the front of the disc, is provided with a Vernier scale at each end. The edge of the disc is cut into teeth and gears into a small pinion, actuated by the milled head, P; this, on being twisted, moves the eye-piece and analysing prism, together with the Vernier scales. To make this verification of the zero, commence by placing some fused sodium chloride in the platinum spoon of the bunsen lamp, then light the bunsen, and turn the spoon into the flame, so that

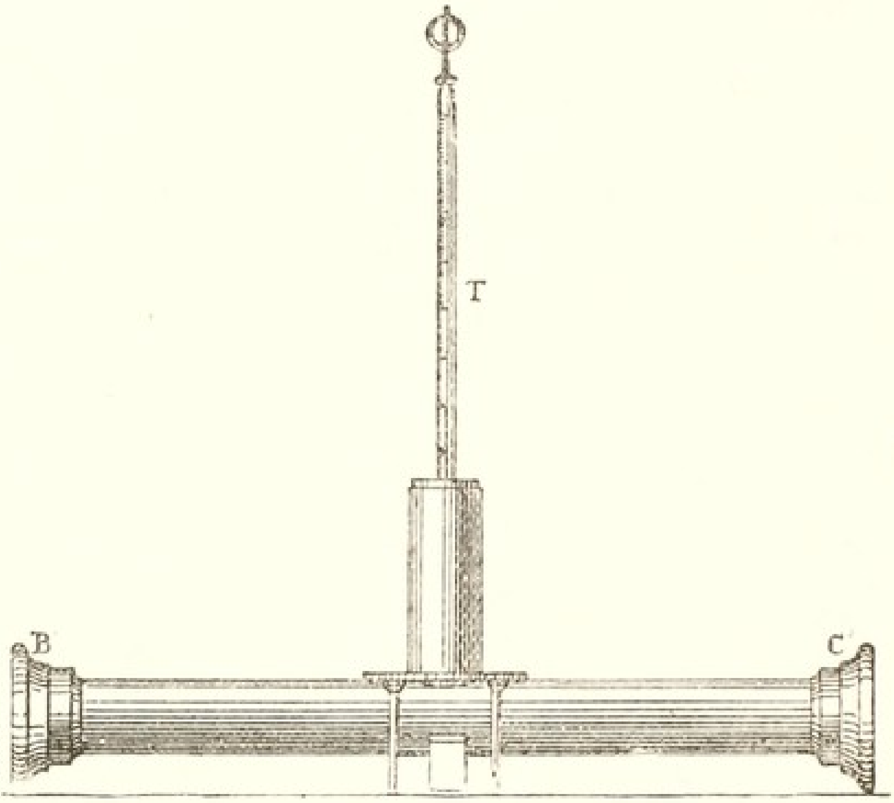

FIG. 81.—POLARIMETER TUBE, WITH THERMOMETER.

an intense yellow light is produced. Arrange the axis of the instrument in the direction of the flame, so that on looking through the eyepiece a brilliant yellow field is seen. Next fill one of the 20 centimetre tubes with distilled water, and put it in its proper position in the polarimeter. Place the zero of the Vernier in coincidence with that of the scale, and look carefully through the instrument in order to see whether both halves of the field are equally illuminated. Turn the milled head, P, very slightly in either direction; one half of the field becomes dark, and the other lighter. Now focus the eye-piece by drawing it out or pushing it in until the vertical line, dividing the two halves of the field, is sharply defined. In performing this operation see that neither of the milled heads of the instrument are touched. Having focussed the eye-piece, turn P back again until the two halves of the field are equally illuminated: note the position of the Vernier and see whether it coincides with the zero of the scale. (For reading the Vernier a small microscope is provided; this is carried on a moveable arm attached to the eye-piece.) Should the two agree, once more displace P, and again bring it back to the position in which the two halves of the field are equally bright, and read the Vernier. Observe whether the two readings of the zero are alike. If the zero of the instrument is found correct, well and good, but if not, turn P until the zero of the Vernier is exactly over that of the scale; then turn the milled head, marked O, until the two halves of the field are of the same depth of tint. Make this adjustment most carefully; when once made, the milled head must not be again moved, or the polarimeter will be thrown out of adjustment.

632. Method of Reading with Vernier.—To those not accustomed to the use of the Vernier for the purpose of accurately reading graduations on instruments of exactitude, a few words of explanation of that device will be acceptable. The Vernier is a small scale which slides over the graduations of the principal scale of the instrument. On the Vernier a length equal to nine of the graduations on the fixed scale is divided into 10 equal parts. As a consequence each division on the Vernier is exactly nine-tenths of each on the fixed scale. Bearing this in mind, let us see how the Vernier is used in actual work. Suppose that with the polarimeter a sugar solution is placed in the instrument, and the analyser turned until the two halves of the field are illuminated equally. It now becomes necessary to read off the number of degrees through which the analysing prism has been rotated. On looking at the scale we find that the zero of the Vernier is between, say 94 and 95 degrees. Look along the Vernier scale in the direction of the 95 until one of the graduations on the Vernier exactly coincides with one on the fixed scale. If this graduation on the Vernier is 7 from the zero, then the accurate reading of the polarimeter is 94·7°. In fact, whatever number graduation on the Vernier coincides with one on the other scale, the number of that particular Vernier graduation represents the fraction of a degree in decimals. This will be seen to be the case on reflection. A fuller explanation of the Vernier may be found in Ganot's "Physics."

633. Polarimetric Estimation of Cane Sugar.—As a matter of practice the student will do well to make some polarimetric estimations on pure cane sugar. For this purpose powder finely some clean Finzel's crystals, and dry for a short time at 100° C. Weigh out exactly 16·350 grams of the sugar, dissolve in distilled water, and make up to 100 c.c. Fill one of the two decimetre tubes with this solution, which must be perfectly clear and transparent. Prepare the polarimeter for working and introduce the tube. By means of the milled head, rotate the analyser to the right until the point is reached at which the change from illumination of the one side of the field to that of the other occurs with great sharpness. Turn the milled head very slowly, and observe carefully the exact point at which equal illumination is reached. Read off the number of degrees by means of the Vernier on the upper scale; then shift the analyser, once more bring it back to the neutral point, and again read. The two readings should agree to the tenth part of a sugar degree. If the sugar be absolutely pure, and the operation be made correctly, the reading should be precisely 100. This signifies that the sample under examination contains exactly 100 per cent. of pure cane sugar. Similarly, if the polarimeter stood at 97·3, we should state that the sample contained 97·3 per cent. of pure sugar.

634. Polarimetric Behaviour of Inverted Cane Sugar.—It has been already stated that the operation of treating cane sugar with an acid, and so causing it to precipitate cuprous oxide from Fehling's solution, is termed "inverting" the sample. The reason is, that a solution of sugar thus treated rotates the plane of polarisation to the left instead of to the right. Take a flask having two marks on the neck, one at 50 and the other at 55 c.c., fill up to the 50 c.c. mark with the sugar solution, and then add 5 c.c. of pure fuming hydrochloric acid. Next heat the flask in a water bath until its contents have acquired a temperature of 68° C.; this operation should be so arranged as to occupy about ten minutes. Cool the flask by immersion in cold water. Fill the 22 centimetre tube with this solution, insert the thermometer, note the temperature and read the amount of rotation, which will be left-handed, with the polarimeter. The reason for having a tube 22 centimetres in length will now be evident; the addition of 5 c.c. of acid to 50 c.c. of sugar solution will have diluted the solution to $\frac{11}{10}$ of its former volume. When the reading is taken in a 22 centimetre tube, that also is $\frac{11}{10}$ of the length of the 20 centimetre tube, consequently a depth of liquid equal to 20 centimetres of the sugar solution before inversion is looked through. Working in this manner, no calculation is necessary for the dilution resulting from the addition of the acid. Careful observation has shown that a solution of cane sugar which before inversion gave a right-handed rotation of 100°, gives after that operation a rotation of 39° to the left, provided the temperature of the inverted solution is 10° C. The plane of polarisation is therefore, by the operation of inversion, rotated through 139° on the sugar scale. As has been stated, inversion produces from the one molecule of cane sugar two molecules of glucose, one each of dextro-glucose and lævo glucose. This latter body has a diminished rotatory power at high temperatures, and hence it becomes necessary to read the temperature at which the observation is made. The rate of diminution is 1° or division for each increase of 2° C. At 0° C. the change resulting from inversion amounts to 144 divisions; for any higher temperature the value is found by

$$D = 144 - \frac{t}{2}.$$

Suppose that in the test experiment with pure cane sugar the polarimetric reading was -36, and that thermometer registered 16° C., then to find the equivalent reading at 0° C. all that is necessary is to add $\frac{t}{2}$ (in this case $= 8$) to the observed reading of total number of divisions; the result is the reading for 0° C., giving 144 in the experiment being considered, which is the theoretically correct figure. In event of the sugar containing 10 per cent. of moisture, the right hand reading would only amount to 90; similarly, the reading after inversion and calculation to 0° C. would amount to exactly $\frac{9}{10}$ of 144 divisions. If, on the other hand, some substance, as dextrose, were present which is not capable of inversion by the method adopted, then the left-hand reading would be less than the theoretical amount for cane sugar. Thus the polarimeter affords not only a means of observing the percentage of sugar present in a sample, but also gives valuable indications as to the nature of the impurity.

635. Polarimetric Determination of Dextrin and Maltose.—We must next turn our attention to the method of using the polarimeter for estimating the amount of dextrin in a liquid containing both dextrin and maltose. Should the liquid contain any coagulable proteids, they should first be removed by heating a known weight of the liquid for a few minutes in the hot water bath, making up the lost weight with distilled water, and then filtering. It may happen that the liquid is not sufficiently clear to be transparent in a layer of so much as 20 centimetres; it may then be clarified by treatment with animal charcoal in the following manner:—Add to the solution, in a flask, about one-fifth of its volume of powdered, recently ignited, pure animal charcoal. Shake up vigorously for a few minutes, and pass through a dry filter. Return the filtrate to the paper until it comes through perfectly clear. It is usually preferable, however, instead of treating with charcoal, to dilute the liquid with water, as charcoal apparently exercises an absorbent effect on some of the carbohydrates. Subject to this reservation, for the polarimetric reading, as concentrated a solution as possible should be taken, and the observation made in the 20 centimetre tube. After reading with the polarimeter, dilute down to the right strength, and estimate maltose by Fehling's solution.

Knowing the quantity of maltose present, in order to calculate the proportion of the polarimetric effect due to dextrin, the amount of rotation due to maltose must be calculated. On multiplying the number of grams of maltose in 100 c.c. of the solution by 2·71, the result is the angular rotation due to the maltose. Subtract this number from the observed angular rotation, and the remainder is the angular rotation due to dextrin. This angular rotation, on being divided by 3·86, or multiplied by 0·259, gives the grams of dextrin in 100 c.c. of the liquid. From these data the percentage of dextrin and maltose in the original substance may be calculated.

It will be of interest to mention that the most recent determinations by O'Sullivan gave, for dextrin, $S_D = 200·4°$. His factors for calculating dextrin polarimetrically are 2·78 instead of 2·71, and 4·008 for the multiplier 3·86.

As an illustration of the polarimetric estimation of dextrin, the following example of the analysis of a sample of wheat germ is given. A 10 per cent. solution of the substance was made with cold water, filtered, shaken up with animal charcoal, and again filtered until clear. The clear solution was weighed in a beaker, raised to 100° C. in the water bath, made up to original weight, and filtered from the coagulated albumin. The reading with the polarimeter was 2·00° to the right. A maltose estimation was made with 20 c.c. of the solution to 25 c.c. Fehling's solution, and 50 c.c. of water. The resulting precipitate was in this instance converted by ignition into cupric oxide (CuO) and weighed as such, then—

Wt. of CuO – 0·1515 × 0·7313 = 0·1107 gram of maltose in 20 c.c. of 10 per cent. solution.

0·1107 × 5 = 0·5539 gram of maltose in 100 c.c.

0·5539 × 10 = 5·539 per cent. of maltose in the substance.

Then, 0·5539 × 2·78 = 1·52 = angular rotation due to maltose.

Total angular rotation, 2 – 1·52 = 0·48 = angular rotation due to dextrin.

0·48 × 0·259 = 0·124 gram of dextrin in 100 c.c.

0·124 × 10 = 1·24 per cent. of dextrin present in the substance.

636. Estimation of Starch.—This estimation may be roughly made by retaining for examination the whole of the washings from the gluten test for wheat or flour. For this purpose wash the dough in small quantities of water at a time until the water remains clear, the washings being poured into a large beaker. Stir the starch and water thoroughly together, and then strain through a piece of fine silk into a second clean beaker, in order to recover any fragments of gluten that may possibly have been in the first instance forced through the silk. Having washed the whole of the starch through the silk, stand the beaker aside, in order to allow the starch to subside. Counterpoise a pair of filters and arrange them in funnels one under the other, so that the lower receives the filtrate of the upper. Remove the lower funnel and pour the supernatant liquid from the starch on to the upper filter; as soon as the filtrate runs clear, replace the second funnel and continue the filtration, finally rinsing the whole of the starch on to the filter; wash with distilled water and dry, first for a few hours at 40° C., and afterwards in the hot-water oven. The reason for first drying at a low temperature is to prevent the gelatinisation of the starch; this preliminary drying may generally be done on the top of the hot-water oven. The counterpoise filter may, of course, be dried direct in the oven, and at the end weighed against the starch and filter. This treatment gives the weight of starch cells of the wheat or flour. These, it must be remembered, contain a certain quantity of starch cellulose.

637. Estimation of Soluble Starch by Conversion into Dextrin and Maltose.—For more refined estimations the method of first converting the starch into dextrin and maltose, and then determining those bodies, is preferable. O'Sullivan gives, in the "Journal of the Chemical Society" for the year 1884, a description in detail of his method of making such estimations. The method is based on first removing dextrin, maltose, and other soluble bodies from the substance by the use of water and other solvents, then converting the starch into dextrin and maltose by the action thereon of malt diastase, and then estimating the dextrin and maltose by Fehling's solution and the polarimeter. The following special reagents are necessary:—

638. Alcohol.—This reagent is required absolutely free from water, and also mixed with water in different proportions. "Absolute" or water-free alcohol may either be purchased or prepared in the following manner:—Take two quarts of the best methylated spirits, add thereto about half its weight of recently and thoroughly burnt quicklime, shake up vigorously two or three times a day for three or four days. The quicklime will dehydrate the alcohol, by combining with the water present, to form slaked lime (calcium hydrate). The alcohol must next be separated from the lime by distillation. For this purpose arrange a glass flask, or tin or copper vessel of sufficient size, in a large saucepan to be used as a water bath. Fit a cork with leading tube to the neck of the flask, and connect this up to a condensing worm, provided with a copious supply of water. Be sure that all joints are perfectly air tight. Fill the water bath with brine, and make arrangements for securing the flask, so that, as it becomes lighter by the evaporation of the spirit, it shall not capsize. Pour off the clear alcohol from the lime into the flask, connect up the whole of the apparatus, and raise the bath to the boiling point by means of a bunsen. Collect the distilled spirit in a dry stoppered bottle. It must be remembered that alcohol is highly inflammable, and therefore every care must be taken to prevent an accident through fire. The lime used for the desiccation of the alcohol will still contain a considerable quantity of spirit; this may in great part be recovered by pouring the whole on to stout calico and squeezing as much as possible of the spirit out.

Dry potassium carbonate is perhaps frequently a more convenient agent for desiccating alcohol. The carbonate absorbs the water, and forms a heavy solution on which the alcohol floats. When distilling, both solutions may be poured into the still together, and distillation in a water-bath continued as long as anything comes over. The residual solution of potassium carbonate may then be evaporated to dryness in an ordinary iron saucepan, and used again for the same purpose.

Absolute alcohol has a specific gravity of 0·7937 at 15° C. The percentage of water is usually obtained by observing the specific gravity by means of a hydrometer. This is a glass instrument consisting of a weighted bulb and stem carrying a scale; the hydrometer, on being placed in a liquid, floats higher or lower according to its density. The specific gravity of water is often reckoned, for convenience, at 1000; absolute alcohol is then said to have a density of 793·7. A hydrometer should be procured from the instrument makers marked in single degrees from 750 to 1000.

Cool down some of the distilled alcohol to 15° C., and pour out into a hydrometer jar. (This is a tall glass vessel in which the instrument can just float.) Introduce the hydrometer, and observe the density of the liquid; should this be from 795 to 800, the alcohol may be considered for practical purposes absolute. Mixtures of alcohol and water of the following densities are also required:—820, 830, 860, 880, and 900 degrees. These may be prepared by adding water to methylated spirit.

Methylated spirit has itself a density of about 820, and, when redistilled, may be used when that strength is directed. The strength of solutions of other degrees of specific gravity is given below.

Specific gravity at 15·5° C.	Absolute Alcohol, by volume, %.	Specific gravity, at 15·5° C.	Absolute Alcohol, by volume, %.
1·0000	0·00	0·8599	81·44
0·9499	41·37	0·8299	91·20
0·9198	57·06	0·8209	93·77
0·8999	65·85	0·7999	98·82
0·8799	73·97	0·7938	100·00

In order to obtain diluted spirits of the other gravities required, water may be added in the requisite proportion to methylated spirit. As alcohol and water, on being mixed, contract in volume (*i.e.*, 50 c.c. of alcohol and 50 c.c. of water produce less than 100 c.c. of the mixture), the amount of water to be added to the methylated spirit to produce each degree of dilution cannot be calculated with absolute exactness, but still sufficiently near for present purposes. Knowing that alcohol of sp. gr. of 820 contains 93·77 of alcohol and 6·23 of water, the quantity necessary to be added is determined by the following formula :—

A = percentage of absolute alcohol in stronger spirit.
a = ,, ,, ,, weaker ,,
W = ,, water stronger ,,
w = ,, ,, weaker ,,
Q = quantity of water to be added to 100 c.c. of the lower sp. gr. spirit to produce the higher sp. gr. spirit.

Then

$$Q = \frac{A \times w}{a} - W.$$

From this formula it is found that to 100 c.c. of 820 spirit the following approximate quantities of water must be added to produce the spirits of correspondingly higher gravities :—sp. gr. 830, 3 c.c. ; 870, 21 c.c. ; 900, 43 c.c.

639. Diastase.—Take 2 or 3 kilograms (5 or 6 lbs.) of finely ground pale barley malt, add sufficient water to completely saturate it, and when saturated to slightly cover it. Allow this mixture to stand for three or four hours, and then squeeze as much as possible of the solution out by means of a filter press. Should the liquid not be bright, it must be filtered. To the clear bright solution, add alcohol of sp. gr. 830 as long as it forms a precipitate, and until the liquid becomes opalescent or milky. Wash this precipitate with alcohol of sp. gr. 860—880, and finally with absolute alcohol. Press the precipitate between folds of cloth, in order to dry it as much as possible. Then place the precipitate in a dish, and keep under the exhausted receiver of an air-pump, together with a vessel containing concentrated sulphuric acid, until the weight becomes constant. The kind of air-pump known as a mercury sprengel pump is best fitted for this purpose. Prepared and dried in this manner, diastase is a white, easily soluble powder, retaining its activity for a considerable time. Store the substance in a dry stoppered bottle, and keep in a cool and dry place.

640. Method of Performing Analysis.—The analytic operation is performed in the following manner :—Weigh out accurately 5 grams of the finely ground meal or flour ; introduce this quantity into a wide-necked flask, with a capacity of 100 to 120 c.c. (a four ounce conical flask will be found most convenient). Add sufficient alcohol of sp. gr. 820 to just saturate the flour, and then 20 to 25 c.c. of ether. Cork the flask, and set aside for a few hours, shaking up occasionally. Decant the clear ethereal solution through a filter, wash the residue three or four times with fresh quantities of ether, pouring the washings each time on the filter. To the residue add 80 to 90 c.c. of alcohol of sp. gr. of 900 ; re-cork the flask, and maintain the mixture at a temperature of 35° to 38° C. for a few hours, shaking occasionally. When the alcohol solution has become clear, decant it through the filter used for filtering the ether solution, and wash the residue a few times with alcohol of the strength and temperature directed above. Wash the residue in the flask, and any that may be on the filter, into a beaker capable of holding 500 c.c., and nearly fill the beaker with water. In about twenty-four hours the supernatant liquid becomes clear, when gradually decant through a filter. Wash the residue repeatedly with water at 35° to 38° C., and then transfer to 100 c.c. beaker. Take the filter from the funnel, open out the paper on a glass plate, and remove every particle by means of a camel-hair brush cut short, and a fine-spouted wash-bottle. Having thus transferred the whole of the residue, the beaker should not contain more than 40 to 45 c.c. of liquid. Boil for a few minutes in the water bath, care being taken to stir well in order to prevent "balling," or unequal gelatinisation of the starch. After this, cool down the beaker still in the bath to 62° to 63° C., and add 0·025 to 0·035 gram of diastase dissolved in a few c.c. of water. In a few minutes the whole of the starch is dissolved, and a trace of the liquid gives no discolouration with iodine. Continue the digestion for about an hour, then raise the bath to the boiling point, and boil for eight or ten minutes. Pour the contents on to a filter, and receive the filtrate into a 100 c.c. measuring flask; carefully wash the residue with small quantities at a time of boiling water. Cool the flask to 15·5° C., and make up its contents to 100 c.c. with distilled water. Should the washings and solution exceed 100 c.c., they must be evaporated down to that amount.

Take a polarimetric reading of this solution in the 20 centimeter tube. Five c.c. of the solution is a convenient quantity to take for the estimation of maltose. This is rather a small quantity to measure accurately; it may, if wished, be weighed instead, or 25 c.c. may be taken and diluted down to 100 c.c. with water; 20 c.c. of the diluted solution may then be taken and added to 25 c.c. of Fehling's solution and 50 c.c. of water. Proceed as before described with the estimates, and calculate the quantity of maltose from the weight of precipitated Cu_2O. Calculate the relative percentages of dextrin and maltose in the usual manner. Starch produces its own weight of dextrin and $\frac{342}{324} = 1{\cdot}0546$ its weight of maltose. To obtain the weight of starch from the dextrin and maltose it produces, the weight of the dextrin must be added to that of the maltose, divided by 1·0526 or multiplied by 0·95. These calculations will be rendered clear by the study of the following example taken from O'Sullivan's paper.

In the analysis of a sample of white wheat, 4·94 grams were taken. The 100 c.c. solution had an optical activity equivalent to 8·52° for Sᴅ, and contained 2·195 grams of maltose.
$2{\cdot}196 \times 2{\cdot}78 = 6{\cdot}10^\circ$, angular rotation due to maltose. $8{\cdot}52^\circ - 6{\cdot}10^\circ = 2{\cdot}42^\circ$, angular rotation due to dextrin. $\frac{2{\cdot}42}{4{\cdot}008} = 0{\cdot}605$ gram of dextrin in 100 c.c.

$$\begin{array}{lr} \text{Maltose, } 2{\cdot}196 = \text{starch, } 2{\cdot}196 \times 0{\cdot}95 = & 2{\cdot}086 \\ \text{Dextrin, } 0{\cdot}605 = \text{starch,} & 0{\cdot}605 \\ \hline \text{Total starch} = & 2{\cdot}691 \\ \hline \end{array}$$

$$\frac{2{\cdot}691 \times 100}{4{\cdot}94} = 54{\cdot}47 \text{ per cent. of starch present.}$$

A duplicate analysis on 6·009 grams differed only by 0·03 per cent.

In the absence of diastase, starch may usually be determined with sufficient accuracy for technical purposes in the following manner:—Remove by washing or otherwise all other carbohydrates, and gelatinise the starch by heating with water. From a known weight of the same variety of starch prepare a solution of approximately the same strength. Put 50 c.c. of each in a separate flask, and add 50 c.c. of 10 per cent. sulphuric acid. Cork the two flasks, and stand in a hot-water bath until a drop on being taken out gives no reaction with iodine solution. Then neutralise by adding solid caustic potash in small fragments, until the solution gives a faintly alkaline reaction to litmus paper; and precipitate from 10 to 25 c.c. of the solution, according to strength, with Fehling's solution. Knowing by the test with pure starch what weight of Cu_2O it precipitates under these conditions, the quantity of starch in the substance being tested can be readily calculated.

In the Analyst of 1887 is published a method by Asbóth for the determination of starch by direct precipitation with barium hydrate. The method depends on the fact that barium hydrate added to a starch solution forms a precipitate of "baryta starch," which contains definite proportions of both starch and barium oxide, BaO. With wheat starch the amount of base in the dried precipitate is 19·8 per cent. of the total, leaving 80·2 per cent. of starch. If the barium oxide in this precipitate be determined and multiplied by 4·05, the result is the weight of starch. The most convenient plan is to add excess of barium hydrate solution of known strength, and then titrate the clear filtrate, calculating barium oxide in the precipitate by difference. The standard solution of barium hydrate is kept in a bottle arranged with tubulure, to which is attached the burette. Air is admitted to both burette and bottle through tubes charged with solid caustic potash to absorb all carbon dioxide. The following method of analysis is applicable to wheaten flour:—Weigh out about 3 grams of the flour, dry, and extract the fat with petroleum spirit; evaporate off the spirit, and rub up in a mortar with small quantities of water, and transfer to a 250 c.c. flask; make up to about 100 c.c. with water, heat in the water bath for half an hour, stirring from time to time to prevent "balling." After cooling, add 50 c.c. of baryta-water, cork and shake well for two minutes. Fill up to the mark with proof spirit, and again shake. Allow to stand for ten minutes, and meantime standardise 10 c.c. of the baryta-water on $\frac{N}{10}$ hydrochloric acid. If the solution is clear, pipette off 50 c.c.; if turbid, filter through glass wool, and then pipette off from the filtrate. Titrate the solution, and deduct the quantity of acid required from that taken by 10 c.c. of the baryta-water. Calculate the difference into its equivalent of barium oxide (1 c.c. $\frac{N}{10}$ acid = 0·00765 grams of BaO). Multiply by 5 and then by 4·05, and the result is the weight of starch in the quantity taken for analysis.

The dextrin present in the flour is also precipitated, and will count as starch. This may be determined separately, and deducted from the starch as determined by this method.

641. Estimation of Dextrin and Soluble Starch.—It occasionally becomes necessary to estimate dextrin in the presence of soluble starch, as, for instance, in bread soluble extracts. The following method may then be adopted :—Take 20 c.c. of the soluble extract and add to 250 c.c. of redistilled spirits ; if the precipitate is very little, take double the quantities ; filter and proceed with the estimation precisely as previously directed for dextrin. Control the results by determining proteids in the dried and weighed precipitate—the residue is a mixture of dextrin and starch.

Proceed to estimate the starch in the following manner :—Prepare first of all the following reagents :—

0·5 per cent. solution of wheat starch.
5 per cent. solution of sulphuric acid.
Solution of iodine in potassium iodide of sherry tint.

Take two graduated Nessler glasses, and add to each 0·1 c.c. each of iodine solution and sulphuric acid ; make up to 50 c.c. with distilled water. To one add 0·5 c.c. of starch solution, and stir ; to the other add the diluted soluble extract from a burette until there is the same depth of blue tint in each. The solution to be tested is conveniently of approximately the same strength as the standard starch solution. If this first test shows it to be too concentrated, dilute, and repeat the estimation. Having read off the solution necessary to match the 0·5 c.c. of standard starch, add another 0·5 c.c. to the standard in the Nessler glass, and again run in the extract solution until the colours are of equal depth of tint. Take the reading, and add another 0·5 c.c., and repeat the titration. In this way three separate readings are obtained, which should closely agree. The following are results obtained in an actual analysis :—

Standard Starch Solution.	Diluted Bread Extract.
0·5 c.c.	0·30 c.c.
1·0 ,,	0·55 ,,
1·5 ,,	0·85 ,,
3·0 ,,	1·50 ,,

The whole of these come very closely together, and it was assumed that 1·5 c.c. of the bread extract contained as much starch as 3·0 c.c. of the standard starch solution.

To ensure success with this method of starch estimation the solutions must be dilute, and there should be no other colour-producing body than starch present. The iodine must not be in large excess, but must give a pure blue colour with starch : too much produces a dirty greenish blue. But the iodine must be in excess of the starch present. To ascertain this by trial, after a titration, add a few drops more starch and the colour should darken. Both tests must be made up with precisely the same quantity of each reagent.

Having determined the starch in this manner, deduct the amount from the total of starch and dextrin precipitated by alcohol ; the difference is dextrin.

642. Estimation of Cellulose.—The student already knows that cellulose has the same chemical composition as starch, but that it differs from that body in being insoluble in boiling water. The cellulose or woody fibre of grain has been estimated at about 10 per cent. of the whole : but of this much is soluble in the digestive secretions of animals, particularly those which ruminate, therefore an estimation of cellulose simply is not the one most valuable to the chemist whose investigation is made for the purpose of determining the food value of a substance. What for this purpose should be ascertained is that percentage of the grain or flour which is ejected from the alimentary canal in an unaltered condition. A process is therefore selected which is somewhat similar to the digestive action which proceeds in the stomach, this action being imitated by alternate treatment with dilute acid and alkali.

643. Special Reagents Necessary.—The first of these is a 5 per cent. solution of sulphuric acid. In a small beaker weigh out 100 grams of the concentrated acid, and make up to two litres. In the next place prepare a 12 per cent. solution of caustic potash by weighing out 240 grams of the pure dry sticks, dissolving, and making up to two litres with water. It is important that 20 c.c. of the acid solution should be approximately neutralised by 10 c.c. of the alkali.

644. Mode of Analysis.—Take 5 grams of the meal or flour, and mix them thoroughly with 150 c.c. of water in a beaker. Stand this in a hot-water bath, and raise to a boiling heat in order to effect the gelatinisation of the starch; stir frequently with a glass rod; add 50 c.c. of a 5 per cent. solution of sulphuric acid, and continue the boiling for an hour, stirring occasionally, and maintaining the volume at 200 c.c. by adding from time to time a little water. (The proper volume should be indicated by a mark made with the diamond on the outside of the beaker.) The acid will by this time have converted the starch into sugar. To this solution next add 50 c.c. of the solution of caustic potash; this quantity will neutralise the free acid, forming potassium sulphate, and will leave an excess of alkali in the solution approximately equivalent to the amount of acid first used. Again boil in hot-water bath for an hour, adding water to supply that lost by evaporation, and occasionally stirring. At the end of this time, dilute with cold water, stir, and allow the residue to subside. Wash by decantation, using large quantities of tap water (provided it is absolutely free from sediment), pouring as little as possible of the residue on to the paper. Stout, well-made quantitative filters of about eight or ten inches diameter should be employed: the author uses those of Schweniker's make. Next transfer the residue to the filter, and wash once with dilute hydrochloric acid, in order to dissolve any calcium carbonate that may be precipitated from ordinary water by the potash. Then wash with distilled water till free from acid, and allow the filter to drain. While still wet, remove the filter paper from the funnel, carefully spread it out flat on a sheet of glass, and with a wash bottle and short camel's hair brush, transfer the whole of the residue to a counterpoised glass dish; dry in the hot-water oven and weigh. The dry residue multiplied by 20 gives the percentage of indigestible fibre in the sample.

645. Glycerin Method of Cellulose Estimation.—A method of estimating crude fibre has been devised by Hönig, based on the fact that albumin and starch become soluble in water after heating with glycerin to 210° C., at which temperature cellulose is not attacked. The following is a modification of this method, proposed by Gabiel, in order to provide for the solution of certain substances, both nitrogenous and non-nitrogenous, other than cellulose which are unattacked by glycerin alone:—A solution of caustic alkali in glycerin is prepared by dissolving 33 grams of caustic potash in glycerin, and making up to 1 litre. For making the analysis, 2 grams of the substance are heated in a 250 c.c. flask on a piece of wire gauze over a naked flame, with 60 c.c. of the potash-glycerin. At about 130° C. a vigorous reaction occurs, and care must be taken that none of the solution is lost by foaming. At a temperature of 160° C. the reaction is for the most part finished, after which the temperature is raised to 180° C. The mixture is then poured into 200 c.c. of boiling water, well stirred, allowed to settle, and the supernatant liquid removed by upward filtration through a funnel having a piece of linen tied over the end. (The material known as swansdown answers well for such filters.) The residue is again boiled with 200 c.c. of water, allowed to settle and filtered, and a third time with the same quantity of water to which 5 c.c. of 25 per cent. hydrochloric acid have been added. The residual fibre is washed with alcohol and ether and dried. The extremely small quantity of nitrogenous substances left in the crude fibre appears to be in most cases negligible.

The centrifugal separator has been called into requisition for fibre estimations. This machine consists of a wheel making some 3000 or 4000 revolutions per minute, on the circumference of which vessels are attached; the centrifugal action acts like gravitation, only with far more intensity in separating bodies whose specific gravity is different. The quantity of material taken for analysis is 1 gram; in event of this containing any considerable quantity of fat, it is first shaken up with 20 c.c. of ether in a proper tube, and subsequently rotated in the machine. The supernatant ether is poured off, and the substance subjected twice more to the same operation with ether, being each time shaken up, and then treated in the centrifugal. The ether is driven off the residue by heating in the water-bath, 30 c.c. of hot water added, and the heating continued for about 10 minutes, the contents of the tube being stirred with a glass rod flattened at the end. Next, 10 c.c. of 5 per cent. (by volume) sulphuric acid are added, and the heating and stirring continued for another 30 minutes. The tube is now rotated in the separator, at a speed of at least 2000 revolutions per minute, for about 3 or 4 minutes. Most of the insoluble matter is separated in a compact form on the bottom of the tube; the turbid liquid is poured off on to a weighed or counterpoised filter sufficiently large to hold the contents of the tube. The tube is then refilled with 40 c.c. of hot water, stirred repeatedly during a period of from 10 to 15 minutes, the tube being meanwhile suspended in the water bath. The tube is again rotated, the clear liquid poured off on the filter, and the washing repeated in the same way. The residue is next treated with 30 c.c. of hot water, and 10 c.c. of a 5 per cent. solution of caustic potash, heated in the water-bath, and stirred repeatedly during 30 minutes. The tube is placed in the separator, and the residue washed in the same way as after the acid treatment. The fibre is next thrown on to the filter, washed in succession with alcohol and ether, and dried and weighed in the usual way.

ANALYSIS OF BODIES CONTAINING CARBOHYDRATES.

646. Malt.—It is comparatively rarely that for bakers' purposes an analysis or assay of malt is required. The principal point is the character and amount of extract it affords on being mashed; to this reference has already been made in Chapter XII, paragraph 365. A miniature mash of the same proportions may be made in the following manner:—Finely grind the sample of malt, mix thoroughly, and weigh out 158 grams; mix with about 900 c.c. of warm water, and place in a water-bath maintained at a temperature of 60° C. Let it remain until a drop taken out after stirring gives no starch or amylodextrin reaction with iodine. Then raise to the boiling point, cool, and transfer the whole to a litre flask; make up to the mark with distilled water; pour out into a larger flask or beaker, and add another 50 c.c. of water. Thoroughly mix, allow to settle, and take the density of the supernatant liquid, at a temperature of 15·5° C., by means of the hydrometer. The quantities taken are equivalent to 40 gallons of wort from 63 lbs. of malt: the extra 50 c.c. are allowed in order to provide for the average amount of "grains" resulting from this quantity of malt. There are thus 1000 c.c. of wort from 158 grams of malt. The percentage of solid extract yielded by the malt is readily calculated. Thus, supposing in a test the hydrometer density is 1035, then:

$$\frac{(1035 - 1000) \times 10}{3{\cdot}85} = 90{\cdot}9 \text{ grams of solid extract in 1000 c.c. of wort.}$$

$$\text{As } 158 : 100 :: 90{\cdot}9 = 57{\cdot}53 \text{ per cent. of solid extract}$$

The whole of the constants in the above may be reduced to one single factor, 1·644, and we then have

$$(1035 - 1000) \times 1{\cdot}644 = 57{\cdot}54 \text{ per cent. of solid extract.}$$

For a detailed description of the method for an exhaustive assay of malt, the reader is referred to Moritz and Morris' "Science of Brewing," pages 452 *et seq.*

647. Malt Extracts.—The following determinations should be made in analysing extracts of malt and similar preparations:—Reducing sugars, cane sugar, dextrin, proteids, water, phosphoric acid (P_2O_5), other mineral matter, specific rotatory power, and diastasic capacity by Lintner, or other methods hereinafter described. A ten per cent. solution of the substance should first be prepared, which, either with or without dilution, may be employed for the following estimations.

Reducing Sugars.—Take 2 c.c. of 10 per cent. solution, and precipitate as usual with Fehling's solution (30 c.c.).

Cane Sugar.—This is conveniently determined by O'Sullivan's method. Take 20 c.c. of 10 per cent. solution, make up to 100 c.c., raise to 55° C., and add 0·2 grams of solid brewers' yeast [1] (prepared by drying the liquid yeast on a towel), digest in a constant temperature water bath at 55° C. for four hours, make up loss by evaporation (or conduct the operation in a tightly corked flask), filter, and determine reducing sugars in 10 c.c. by Fehling's solution. The difference in

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[1] The author finds that compressed distillers' yeast free from starch answers equally well.

weight of Cu_2O obtained in this and the preceding determination is Cu_2O reduced by the glucose from cane sugar, and is readily calculated into the percentage of that body.

Dextrin.—Take 20 c.c. of 5 per cent. solution, add to 250 c.c. of spirit, and proceed as described under Estimation of Dextrin, paragraph 625. Should the amount of precipitate be very small, recommence the estimation, using the 10 per cent. solution. Determine proteids by Kjeldahl's process in the dried and weighed precipitate; deduct from the weight of precipitate, and calculate as dextrin.

Proteids.—Determine direct by Kjeldahl's process on 1·0 gram of the extract.

Water.—Take 5 grams of extract, dry till weight is constant in a platinum basin; about 36 hours are necessary at 100° C. When speed is an object, either a smaller quantity (1·0 gram) may be used, or an oven at 110° C. employed.

Ash.—Ignite the dried residue from 5·0 grams (residuum from water estimation) until a white ash is obtained. Note, the extract sometimes swells up enormously as it carbonises; in such cases allow to cool, and break down the carbonaceous mass so that it lies easily in the dish. (This should be done on a sheet of glazed paper.)

Phosphoric Acid.—Dissolve the ash in dilute nitric acid (1 to 3), and proceed with estimation by molybdate and "magnesia mixture" (see paragraph 591). The ash, less phosphoric acid, gives "other mineral matter."

Specific Rotatory Power.—Make up a 20 per cent. solution of the extract, and take a polarimetric reading precisely as described in paragraph 635 on Polarimetric Determination of Dextrin and Maltose. Calculate out the specific rotatory power both on the whole and the dried extract: or, if preferred, the rotatory power per gram of either whole or dried extract may be calculated. For the whole extract, with a 20 per cent. solution, this is $\frac{1}{20}$ of the total angular rotation. Supposing in the case of an extract the total solid matter to be 80 per cent., and the observed rotation 32·4°, then

$$\frac{32{\cdot}4}{20} = 1{\cdot}62^\circ \text{ rotatory power per gram of whole extract;}$$

$$\text{and } \frac{100 \times 1{\cdot}62}{80} = 2{\cdot}02^\circ \text{ rotatory power per gram of dried extract.}$$

The specific rotatory power may be obtained by multiplying by 50 in each case.

Calculation of Results.—The reducing sugar of pure malt extracts, obtained by concentrating the wort produced by total conversion of the whole malt, consists principally of maltose. On calculating it as such, and adding together the results of the whole of the determinations given, there is usually an excess of about 5 per cent. over 100: this is probably due to some of the reducing sugar being glucose instead of maltose. On the other hand, cold water extracts of malt contain only the pre-existent sugars of malt, considerable proportions of which are dextrose and lævulose: these, if worked out as maltose, give far too high a result, while if calculated as glucose, the result is too low.

Again the explanation is that in addition to glucoses there is maltose also present. It is frequently convenient to be able to estimate approximately the relative proportions of glucoses and maltose, and this may be done in the manner to be now described. It should first, however, be mentioned that doubtless malt extracts contain certain substances which escape determination in all the estimations previously given; but these cannot in any case represent a large percentage of the whole, and for present purposes may be neglected, the reservation being made that a small part of the percentage returned as sugar may consist of indeterminate bodies. Assuming that 100, less the cane sugar, dextrin, proteids, water, and ash, consists of reducing sugars, then we have

Total reducing sugar by difference in 100 grams extract = S.
Weight of cuprous oxide precipitated by 100 grams extract = W.
,, maltose in 100 grams = m.
,, glucose ,, = g.
,, cuprous oxide precipitated by 1 gram of maltose = 1·238 grams.
,, cuprous oxide precipitated by 1 gram of glucose = 1·983 grams.

$$\text{Then, } m + g = S. \quad \text{(Equation No. 1.)}$$

$$\text{and } 1{\cdot}238\ m + 1{\cdot}983\ g = W. \quad \text{(Equation No. 2.)}$$

From these the values of m and g may be determined thus:—

Multiplying equation No. 1 by 1·983, and subtracting No. 2 from the product, we get

$$\begin{aligned} 1{\cdot}983\ m + 1{\cdot}983\ g &= 1{\cdot}983\ S \\ \text{less } 1{\cdot}238\ m + 1{\cdot}983\ g &= W \\ 0{\cdot}745\ m &= 1{\cdot}983\ S - W \\ \text{and } m &= \frac{1{\cdot}983\ S - W}{0{\cdot}745.} \end{aligned}$$

$$\text{In the same way } g = \frac{W - 1{\cdot}238\ S}{0{\cdot}745.}$$

$$\text{or more simply, } g = S - m.$$

The following figures were obtained in the analysis of a sample of malt extract:—

$$S = 60{\cdot}5. \qquad W = 80.$$

$$m = \frac{(1{\cdot}983 \times 605) - 80}{0{\cdot}745} = 53{\cdot}65.$$

$$S - m = g, \text{ therefore } 60{\cdot}5 - 53{\cdot}65 = 6{\cdot}85.$$

The percentages of maltose and glucose are therefore respectively 53·65 and 6·85.

In substances sold as pure malt extracts obtained by concentration of the wort of the entire mashed malt, the percentage of glucose should not exceed from $\frac{1}{7}$ to $\frac{1}{8}$ that of maltose: any higher proportion than this should be viewed with suspicion.

The other calculations require no detailed explanation.

648. Diastasic Capacity on Lintner's Scale.—For brewing purposes diastasic capacity is now almost invariably determined by Lintner's method, and the result expressed on Lintner's standard, or in "degrees Lintner." That standard is:—"The diastasic capacity of a malt is to be regarded as 100, when 0·1 c.c. of a 5 per cent. solution reduces 5 c.c. of Fehling's solution."

For the determination, "soluble starch" and standard Fehling's solution are required. The soluble starch must be prepared according to the method described in Chapter VI., page 79. It is well to allow the digestion with acid to proceed fully as long as directed, as, unless the starch is rendered thoroughly soluble, it naturally gives apparently low diastasic results. It is well during its preparation to test a small portion at the end of seven days by thoroughly washing, and then dissolving in boiling water: the solution must be absolutely clear and limpid. When about to make an estimation, take 2 grams of the soluble starch and dissolve in hot water, cool, and make up to 100 c.c. If testing a malt or flour, take 25 grams (of course, finely ground) and digest with 500 c.c. at ordinary temperatures for five hours. Filter until perfectly bright. Arrange ten test tubes in a stand, and add to each 10 c.c. of the soluble starch solution. Then to the first add 0·1 c.c. of the solution, to the second 0·2 c.c., and so on until the last receives 1·0 c.c. Shake them thoroughly, and allow the whole to stand for one hour in a water bath maintained at the constant temperature of 70° F. During this time the diastase will have converted more or less starch, according to its strength. Next add 5 c.c. of Fehling's solution to each of the tubes, shake up, and place the whole series in boiling water for ten minutes. Allow the precipitate to subside, and note the condition of the tubes; in some the blue colour will probably have entirely disappeared, showing them to be over reduced, while others will still be more or less blue. Select the two tubes lying together in which one is slightly over and the other slightly under reduced. The number of c.c. required to give exact reduction will lie between these, and should be judged according to which it appears the nearest. Thus, suppose as nearly as possible it is exactly midway between Nos. 5 and 6, then the quantity of malt solution may be taken as 0·55; while if No. 5 is full yellow, while No. 6 is only very faintly blue, then one would give the quantity as 0·58 or 0·59, according to how near in one's judgment it appeared to be to the 0·6. With a little practice one soon gets able to judge very closely this second decimal. If the result of a test gives 0·5 c.c. as the quantity of malt solution required, then the sample is evidently only one-fifth of the standard strength of 100, or

$$\frac{0{\cdot}1 \times 100}{0{\cdot}50} = 20^\circ \text{ Lintner as diastasic capacity.}$$

But there is a certain amount of reducing sugar extracted from malt by cold water, and this also helps to reduce the Fehling's solution. The amount of this is determined in the following manner:—Take 5 c.c. of Fehling's solution, 10 c.c. of starch solution, and 10 c.c. of water, and raise to the boiling point in a small flask. To this add the malt solution from a burette until the Fehling is exactly reduced; then determine the apparent diastasic capacity of this solution. Supposing that 7 c.c. have been run in in order to reduce the Fehling, then

$$\frac{0{\cdot}1 \times 100}{7} = 1{\cdot}43^\circ, \text{ correction for reducing sugars extracted from the malt.}$$

For malts the correction 1·4 may usually be taken as a constant, and the above results become

$$20 - 1{\cdot}4 = 18{\cdot}6^\circ \text{ Lintner.}$$

Working with malt extracts, the value of the correction becomes much higher, and must be determined for each individual sample analysed, and preferably *before* the diastase estimation. Take a 5 per cent. solution of the extract, boil, make up to original volume, filter, and titrate on Fehling and starch as above described. In an actual analysis 1·25 c.c. of the 5 per cent. solution were required; the correction therefore becomes

$$\frac{0{\cdot}1 \times 100}{1{\cdot}25} = 8{\cdot}0^\circ \text{ correction for reducing sugars present.}$$

From this it will be seen that the tenth tube in the diastase determination is nearly reduced by the sugars present alone. The diastase estimation should now be made: this in the sample in question amounted to 0·73 c.c.; then

$$\frac{0{\cdot}1 \times 100}{0{\cdot}73} = 13{\cdot}7^\circ \text{ apparent diastasic capacity.}$$

$$13{\cdot}7 - 8{\cdot}0 = 5{\cdot}7^\circ \text{ Lintner, real diastasic capacity.}$$

In malt extracts and other diastasic preparations the diastasic capacity varies very widely, and either none or all of the series may be completely reduced. In the former case the diastasic capacity must be less than 10 *minus* the correction. Make another diastase estimation with a 25 per cent. solution of the extract, and multiply the correction by 5; the solution being of 5 times strength, the nett figure thus obtained for real diastasic capacity must be divided by 5 in order to give degrees Lintner. Should there be no reduction in any of the tubes, the diastasic capacity must be less than 2 *minus* the correction, which practically amounts to its total absence.

On the other hand, the whole of the series may be reduced, showing that the diastasic capacity is more than 100 *minus* the correction. In this case make up a 0·625 per cent. solution, and use it for a diastase estimation; multiply the result by 8, and take the correction as $\frac{1}{8}$ that with the 5 per cent. solution. The following is the result of an estimation on a diastase preparation made by the author:—

Correction for reducing sugars on 5 per cent. solution = 8·2°.
All tubes were reduced.
With 0·625 per cent. solution, reduction effected by 0·42 c.c.

$$\frac{0{\cdot}1 \times 8 \times 100}{0{\cdot}42} = 190{\cdot}5^\circ \text{ apparent diastasic capacity.}$$

$$190{\cdot}5 - \left(\frac{8{\cdot}2}{8} = \right)1{\cdot}02 = 189{\cdot}48^\circ \text{ Lintner, real diastasic capacity.}$$

The three diastase tests made in this manner give a total range of from 2° to 800° Lintner, and with each test overlapping the other.

In comparing extracts for bread-making purposes, it is sometimes advisable to also test on starch paste; in that case proceed exactly as with soluble starch, except that ordinary starch is substituted and carefully gelatinised without "balling."

649. Diastase Tests on Flours.—These may be made by taking a given quantity of the extract, mixing with flour and water, and digesting for a given time at some fixed temperature. The amount of matter dissolved and maltose produced may then be determined by direct estimations. Full particulars of such determinations are given in the succeeding numbered paragraph.

Baking tests afford the most valuable means of testing diastasic value of extracts for bakers. These tests should be made as directed in Chapter XXI., paragraph 582, with the extract added to the water. It is well to take the uniform quantity of the extract equivalent to 1 lb. to the sack, 2 grams = 20 c.c. of a 10 per cent. solution (the quantity of water used for dough-making must, of course, be diminished by the 20 c.c. taken with the extract). Prepare 100 c.c. of the 10 per cent. solution, place half of it in a flask, weigh, boil for five minutes, and make up to the original weight with water, and call this No. 2. Prepare duplicate loaves, using the No. 1 or unheated extract solution in the one, and No. 2 or boiled solution in the second. Make up also a plain loaf, No. 3, with the same flour; compare carefully the character of the three for volume, colour, pile, moistness, flavour, and any other points of interest to the baker. No. 2 will have had its diastase killed, and will contain only such maltose and other bodies as are contained in the extract; No. 1 will contain in addition all such substances as have been produced by the diastasic action of the extract itself.

If wished, determinations may be made of soluble extract and maltose in each of the loaves. The results may then be returned as shown in blank below:—

	Soluble Extract.	Maltose.
Normal Quantities in Plain Bread, *determined in No. 3*, - - - - - -	......	......
Quantities added in Extract, *being difference between Nos. 2 and 3*, - - - -	......	......
Quantities produced by Diastasic Action, *being difference between Nos. 1 and 2*, -	......	......
Total, - - - - -	......	......

In this way any extract can at once be valued both for added and produced maltose and other substances.

650.—Experimental Comparison of Diastase Determinations.—In order to institute a comparison between results obtained by Lintner's Method and the amount of change produced both in flour digestion and ordinary baking, the following experiments were made:—

Lintner's Determinations.—First, four extracts were selected, one of which (No. I.) had, according to Lintner, a low diastasic value; another (No. II.) was remarkably high; while the third gave practically no reading on Lintner's Scale. The fourth was another sample from the same source as No. I, but from a more active malt, and manufactured at a lower temperature. The results are in each case tabulated.

No. I. Extract, Diastasic Capacity, ... 1·2° Lintner.
No. II. " " ... 354° "
No. III. " " ... 0·8° "
No IV. Extract, not accurately determined, but slightly higher than No. I.

Another sample of No. II., same type, gave 320° Lintner on being tested. Duplicates of Nos. I and III. were in absolute agreement with those quoted

Flour Digestion Tests.—A 0·5 per cent. solution was prepared of each extract; a half of this was raised to the point of actual ebullition, cooled, and loss of weight made up with distilled water. The first part is called "Active Extract," and the second "Killed Extract." Of each, 100 c.c (=0·5 gram extract) was taken, added to 25 grams of flour in a corked flask, shaken vigorously, and all digested together for 4 hours in a water bath of 140—150° F. A blank experiment was also made with 100 c.c. water and 25 grams of flour only. The contents of the flasks were filtered, and "soluble extract" and maltose determined in the clear filtrate. The following are the results, expressed in percentages of the flour used.

SOLUBLE EXTRACT AND MALTOSE.

No. of Extract.	Percentage of Soluble Extract on Flour used.	Percentage of Extract, less total solids in malt extract = 1·6.	Percentage of Extract, less total solids in malt extract and percentage of extract with plain flour and water = 1·6 + 24·4 = 26·0, being extract due to diastasic action.
I. Active - - - -	26·28	24·68	0·28
I. Killed - - - -	24·60	23·00	Minus quantity.
II. Active - - - -	48·04	46·44	22·04
II. Killed - - - -	37·32	35·72	11·32
III. Active - - - -	31·52	29·92	5·52
III. Killed - - - -	27·08	25·48	1·08
IV. Active - - - -	34·52	32·92	8·52
IV. Killed - - - -	28·76	27·16	2·76
V. Flour and Water only	24·40		
	Percentage of Maltose.	Percentage of Maltose, less that in added malt extract, say 1·2.	Percentage of Maltose, less that in malt extract and that resulting from flour only = 1·2 + 8·88 = 10·08, being maltose due to diastasic action.
I. Active - - - -	23·75	22·55	12·47
I. Killed - - - -	14·54	13·34	3·26
II. Active - - - -	36·83	35·63	25·55
II. Killed - - - -	25·52	24·32	14·24
III. Active - - - -	19·06	17·86	7·78
III. Killed - - - -	14·86	13·66	3·58
IV. Active - - - -	22·61	21·41	11·33
IV. Killed - - - -	17·12	15·92	5·84
V. Flour and Water only	8·88	8·88	

Baking Tests.—Baking tests were then made with the first three extracts, the method being that described in the preceding paragraph, except that the "killed" solutions were simply raised to actual ebullition, without continuing the boiling for the five minutes as there directed. The quantity of extract in each case was equivalent to 1 lb. to the sack of flour. The following are the results of various determinations made on the baked loaves :—

ANALYSES OF BAKED LOAVES.

No. of Extract.	Water.	Soluble Extract.	Maltose.	Dextrin.
I. Active	43·81	6·12	5·41	3·25
I. Killed	42·24	5·62	3·31	2·75
II. Active	41·71	9·22	6·22	4·90
II. Killed	42·90	5·90	3·64	2·90
III. Active	42·21	5·04	4·70	2·45
III. Killed	42·74	4·94	3·79	2·45
V. Plain Loaf	42·25	4·74	3·15	2·40

From these data the amount of each constituent may be calculated into quantity present in plain loaf, that added in "killed" extract, and that produced by diastasic action. When thus treated the results assume the following form :—

SOURCE OF EACH CONSTITUENT IN BAKED LOAVES.

Constituent and No. of Extract.		Normal Plain Bread.	Quantity due to "Killed" Extract.	Quantity due to Diastasic Action.	Total Quantity.
Soluble Extract	I.	4·74	0·88	0·50	6·12
	II.	4·74	1·16	3·32	9·22
	III.	4·74	0·20	0·10	5·04
Maltose	I.	3·15	0·16	2·10	5·41
	II.	3·15	0·49	2·58	6·22
	III.	3·15	0·64	0·91	4·70
Dextrin	I.	2·40	0·35	0·50	3·25
	II.	2·40	0·50	2·00	4·90
	III.	2·40	0·05	0·00	2·45

Reviewing these results, the following is noticed in the flour digestions :—No. I. extract, both active and killed, gave abnormally low soluble extracts, while No. I. active yielded an exceptionally high maltose result. There were no duplicates made of these, but the results of determinations in the baked loaves are in absolute agreement with them ; thus, in the digested flour the maltose is 0·90 of the total soluble extract, while the maltose in the bread is 0·88 of the soluble extract obtained. In each case except No. I. the killed extract still exhibited considerable diastasic activity.

Turning to the bread results, the water was determined as a check on the constitution of the loaves, and not as a measure of the yielding power of the flour. There is in the case of each constituent a greater quantity present in "killed" extract treated loaves than in that which was perfectly plain, a quantity partly, but not entirely, due to the actual matter introduced by the extract itself (a lb. of extract per sack equals approximately 0·25 per cent. on the baked bread). This shows that malt extracts contain a hydrolysing constituent, the activity of which is not destroyed by momentary boiling. In each case, and with each constituent estimated, except dextrin in No. III., there is an increase due to diastasic action. In No. II., which gave by far the highest result on Lintner's scale, there is also the highest amount of change in the baked loaf, but in nothing like the same proportion. The dextrins are obtained by precipitation with alcohol, but are not corrected for proteids. The reducing sugars are throughout reckoned as maltose: but the sum of the maltose and uncorrected dextrin is uniformly in excess of the total soluble extract. No specific researches have been made, but the probable cause is that some of the sugar is glucose. Among points still requiring investigation as to the action of malt extract in bread-making are (1) the amount of heating requisite to destroy diastasic action; (2) whether any hydrolysing action is due to some other agent than diastase—acid phosphates, for example; and if so, how much? (3) the exact nature and proportions of sugars produced, whether maltose or glucose.

651. Adulterations of Malt Extract.—Malt extract may be adulterated either with molasses (treacle) or glucose syrups. The former of these may be detected by the large increase in the quantity of cane sugar present, as molasses contains from 35 to 48 per cent. of sucrose. It also usually contains considerable amounts of glucose. The so-called sirupy "glucoses" contain, when conversion has been arrested at the minimum point, large quantities of dextrin and maltose, and therefore in that particular closely resemble malt extracts. Commercial "glucose" is, however, practically devoid of proteid constituents, and in this way is detected when used as an adulterant of malt extract. A polarimetric reading affords a valuable indication as to the purity of malt extracts. The following table gives the result of a number of such readings calculated to angular rotation per gram of undried substance:—

POLARIMETRIC ESTIMATIONS ON MALT EXTRACT, ETC.

No.			Rotatory Power per Gram.
1.	Malt Extract of known purity, tested March, 1893,		1·59°
2.	Same make of Extract, sample taken April, 1893,		1·52°
3.	Sample of suspected Malt Extract, very light in colour, ...		1·99°
4.	Second sample of suspected Malt Extract, ...		1·79°
5.	Lyle's Golden Syrup, obtained personally by author,		0·52°
6.	No 1 Syrup, lightest colour,	From same Manufacturers.	1·05°
7.	No. 2 ,, intermediate,		0·81°
8.	No. 3 ,, darkest,		0·52°
9.	"Glucose" Syrup (White Confectioners'), ...		2·30°

No.		Rotatory Power per Gram.
10.	Mixture made personally by Author—	
	No. 1, 7·07 grams, No. 6, 4·79 ,, ...	1·33°
	Calculated Rotatory Power from quantities taken,	1·33°
11.	Mixture made personally by Author—	
	No. 1, 7·07 grams, No. 9, 6·26 ,, ...	1·85°
	Calculated Rotatory Power from quantities taken,	1·89°
	For comparison, Pure Maltose, ...	2·78°
	,, ,, Dextrin, ...	3·86°
	,, ,, Cane Sugar, ...	1·35°
	,, ,, Glucose (Invert Sugar),	−0·46°

Both the suspected samples had abnormally low rotatory powers, and were probably adulterated with "glucose" syrup; they agree approximately with No. 11.

652. Baking Powders, Analysis of.—Crampton, in a U.S. Department of Agriculture Bulletin, gives a detailed method of analysis of these, of which the following is a modification. In examining Baking Powders, a qualitative analysis serves to recognise whether the acid constituent is tartaric, phosphoric, or sulphuric acid, or a mixture of two or more of these. The alkalinity of the aqueous solution should be tested as a guide to the amount of excess of carbonate employed. The following are among some of the more important estimations which should be made:—

(1.) *Carbon Dioxide.*—This is the measure of the essential strength of the powder, as its value depends on the quantity of this gas liberated by the powder when used. Usually the *total* and *available* carbon dioxide are both measured, as, through deficiency in acid ingredients, the whole of the carbonates are not always decomposed when the powder is employed for baking purposes. The total carbon dioxide is obtained by treatment with excess of acid; the available by adding water and heating in as nearly as possible the same manner as in actual baking.

Many of the recognised forms of apparatus for the measurement of carbon dioxide may be used for this purpose. Thus, the well-known Schrœdter may be employed, in which the liberating acid and drying tubes, &c., are all self-contained within the same apparatus, together with the powder, which is weighed before and after the acid and powder act on each other. The loss of weight is the measure of the amount of carbon dioxide evolved. In using an apparatus of this form, from one to two grams of the powder is weighed out and transferred to the flask of the Schrœdter, previously charged with dilute liberating sulphuric acid, and concentrated acid for drying the escaping gas, weigh the whole apparatus, and allow the acid to enter very slowly. Toward the close of the reaction heat very carefully, and add the acid finally to powder when hot. Care must be taken that, owing to the gelatinisation of the starch, the whole mass does not boil over, and thus vitiate the determination. Finally draw air through in the usual manner, and weigh with the ordinary precautions. Water must *not* be added to the powder before the reaction is started. To estimate *available* carbon dioxide proceed in the same manner, except that distilled water must be used for liberating purposes, instead of dilute acid. Add the water slowly, and at the close bring it as nearly as possible to the boiling point, and maintain it at that temperature for fifteen minutes, gently agitating the apparatus occasionally.

For technical purposes, the carbon dioxide can be estimated with sufficient accuracy by a modification of the yeast apparatus described on page 203, the gas being measured volumetrically. It may be mentioned that one gram of sodium bicarbonate, $NaHCO_3$, yields on treatment with excess of acid 0·524 gram of carbon dioxide, being 267 cubic centimeters at 0° C., or 286 at 20° C. Further, 286 c.c. = 17·4 cubic inches.

Take a six-ounce flask and fit it with a good india-rubber cork, pass through the latter a right-angled delivery tube, and also a thistle funnel, provided with bulb of about 50 c.c. capacity, and a glass stop-cock. Arrange the flask on a piece of wire gauze on the retort-stand, and connect it up by means of a short length of india-rubber tubing to the end, *c*, of the T-piece, Figure 20. Stand the gas collecting jar, *f*, in a deep vessel of cold solution of calcium chloride, *sp. gr.* 1·4, preferably using for this purpose a cylinder of glass. Weigh out 25 grams of the baking powder and place it in the flask, connect up the apparatus and exhaust the air until the liquid stands at zero in the glass jar. Fill the bulb of the thistle funnel with 10 per cent. sulphuric acid, turn the stop-cock *very gently*, so as to allow the acid to enter drop by drop. Great care must be exercised in opening this stop-cock, as otherwise the column of water in the gas jar will draw the whole of the acid out of the funnel, and allow the apparatus to completely fill with air. When the reaction is over, gently heat the flask until the whole of the carbon dioxide is liberated. Allow the apparatus to cool, and read off the volume of carbon dioxide liberated. Make a deduction for the volume of acid which has been let in from the funnel; this is easily done by measuring once for all the amount it delivers. If results are immediately wanted, the apparatus may be cooled by pouring a little water over it. To determine *available* carbon dioxide proceed in exactly the same way, except that water must be used instead of acid in the funnel, and gentle boiling should be employed at the termination of the reaction for about fifteen minutes. Precisely the same remarks apply to the limits of accuracy of these tests as are made on the use of the apparatus for yeast testing in paragraph 333.

(2.) *Phosphoric Acid.*—Weigh about 0·5 gram, ignite carefully, treat with nitric acid, dilute and filter. Precipitate with ammonium molybdate, digest, filter, and wash with dilute nitric acid or ammonium nitrate solution. Dissolve the precipitate in ammonia, precipitate with magnesia mixture, filter, wash with dilute ammonia, ignite, and weigh.

(3.) *Tartaric Acid.*—Weigh out 5 grams of the powder, transfer to a 500 c.c. flask, and add 100 c.c. of water and 15 c.c. strong hydrochloric acid. When all action has ceased, make up with water to 500 c.c., and allow starch to subside. Filter and take 50 c.c. of filtrate and add thereto 10 c.c. of solution of potassium carbonate, containing 300 grams K_2CO_3 per litre; boil for half-an-hour and filter into a porcelain dish, concentrate filtrate and washings down to 10 c.c., add gradually and with constant stirring 4 c.c. glacial acetic acid, and then 100 c.c. of 95 per cent. alcohol, stirring the liquid until the precipitate floating in it assumes a crystalline appearance. After standing some hours, filter and wash with alcohol until entirely free from acetic acid. Transfer filter and precipitate to a beaker, add water and boil. Titrate the resulting solution with decinormal soda and phenol-phthalein—1 c.c. of alkali corresponds to 0·0188 grams of potassium bitartrate (cream of tartar), or 0·0150 grams of tartaric acid.

(4.) *Sulphuric Acid.*—This may be estimated without previous ignition of the powder. Weigh out 0·5 gram and digest in a beaker with strong hydrochloric acid until the whole of the powder including the starch is dissolved; then dilute with water, raise to near boiling, and add barium chloride in slight excess, allow to stand twelve hours, filter and weigh.

(5.) *Alumina.*—This body being the base of the alums, its determination should be made in all cases where sulphuric acid is found to be present. In the absence of phosphoric acid, from 0·5 gram to 1·0 gram may be ignited, extracted with acid, evaporated to complete dryness to separate silica, treated with strong hydrochloric acid, diluted with water, and alumina precipitated with ammonia, washed, dried, ignited, and weighed. In the presence of both phosphoric acid and alum, the following method may be adopted:—Weigh out five grams of the powder, in a platinum dish heat until thoroughly carbonized, digest with strong nitric acid, dilute, and filter into a 500 c.c. flask. Wash the residue slightly, transfer the filter and all back into the platinum dish, dry, burn to white ash, add mixed potassium and sodium carbonates, and fuse. Take up with nitric acid, evaporate to complete dryness, again take up with nitric acid, dilute, and filter into the 500 c.c. flask. The flask will now contain both series of filtrates; make up to the mark with water. Take 100 c.c. and precipitate with ammonium molybdate and nitric acid, digest and filter. In filtrate determine alumina by precipitation with ammonia, and estimate phosphoric acid in the precipitate in the usual manner.

(6.) *Starch.*—This may be determined by treatment with dilute acid so as to effect conversion into glucose, and then estimating by Fehling's solution. A rough determination may be made by adding water to the powder, and after cessation of the reaction washing several times on a filter, first with dilute hydrochloric acid (5 per cent.) and then with water. The residue is transferred to a platinum dish, evaporated to complete dryness at 100° C., and weighed, subsequently to which the ash is determined and subtracted from the weight at 100° C.—the remainder is taken as starch.

Other determinations may be made, but the above are the most important.

CHAPTER XXV.

BREAD ANALYSIS.

653. Having described the methods to be employed for the determination of the various constituents of wheat and flour, a short description must now be given of bread analysis.

Many of the properties by which good bread is distinguished from bad scarcely come within the range of purely chemical analysis. Among these are the colour, texture, "piling," odour and flavour of the crumb, and the colour and thickness of the crust. In the kind of bread known technically as "crumby" bread, the colour and texture of the joint between two loaves is to be observed. The analyst, in reporting on bread, should examine the loaf so far as the above characteristics are concerned, and include his opinion on the same in his report. In judging each, he may adopt the plan of employing a series of numbers, say 1 to 10, and using the lowest number for the worst possible grade, and the highest for the very best. Or he may use instead the terms V. B., very bad; B, bad; I, indifferent; M, moderate; G, good; V. G., very good; E, excellent. In either case the same term must, so far as is possible, be applied to the same grade of quality, whether of texture, colour, or other characteristic.

654. Colour.—The baker's use of this term involves a contradiction; it is the custom of the trade to speak of a loaf as "having no colour" when a dark brown, while in the purest white loaf the colour is said to be "high." This is, of course, exactly opposite to the correct use of these terms, for white is strictly no colour, while a yellow or brown body is strongly coloured. It would be a better plan if the respective terms were "lightly coloured" and "strongly or deeply coloured." Judging colour by itself alone, the loaf should be a very light yellow or creamy tint, approaching almost to whiteness. This colour is selected because the writer is of opinion that, judging bread by the eye alone, the slightest yellow hue is more agreeable than an absolute snowy whiteness. The latter, perhaps from its frequent association with absence of flavour, is unpleasant.

It must be remembered that colour, &c., are matters of individual taste and opinion, and therefore that each individual has his own standard of comparison. In forming a judgment one naturally most appreciates that in accordance with one's own standard; it does not necessarily follow that such judgment shall absolutely agree with that of another person. It is a well-known fact that in different localities the standard of taste in these matters varies.

For actual measurement of bread colour, the method of testing with the tintometer should be employed; or baked loaves may be compared against those similarly prepared from standard samples of flour.

655. Texture.—The texture of a loaf is best observed by cutting it in two with a very sharp knife. There should be an absence of large cavities, and also of dry lumps of flour. The honeycombed structure of the bread should be as even as possible. The bread should not break away easily in crumbs, but should be somewhat firm. On being gently pressed with the finger the bread should be elastic, and should spring back without showing a mark on the pressure being removed.

656. Proof.—Like many other trade terms, this is used in a somewhat different sense in different localities. It usually has reference to the degree of rise in volume a loaf undergoes before being put in the oven. In this sense, by a well-proved loaf is understood one that has risen well, both in the dough stage and after being placed in the oven. It almost goes without saying that in judging the quality of a loaf the baker likes it to be as large as possible. Such an opinion is a sound one where size of the loaf is combined with evenness of texture, and is not the result of the presence of large cavities in the bread. The opposite of a well proved loaf is a heavy one; hence this matter of the proof of a loaf is of importance. The loaf which in this particular looks the best is that which is most digestible and wholesome.

There is another sense in which the term "proof" is applied: thus, two loaves may have risen equally well, and yet the one be regarded as being better proved than is the other. The well proved loaf is, under these circumstances, viewed as that in which fermentation has proceeded until the flavour of the bread (the bouquet, if the term may be borrowed) has developed to the greatest perfection. The well proved loaf will be sweet and nutty in flavour, and have all the characteristics of being thoroughly cooked; the badly proved loaf will be lacking in flavour, and have what, for want of a better expression, may be called a "raw" taste. Undoubtedly, this use of the term "proving" refers to a difference which does exist in the two loaves, a difference which in all probability is due to the more or less perfect peptonising action of the yeast on the proteids during fermentation. The term proof is therefore used in two different senses, one as a measure of the volume of the loaf, the other as an indication of the extent to which the changes accompanying fermentation have proceeded.

657. Pile.—This is essentially a term referring to the texture of the crumb of bread, and is doubtless derived from the use of the word "pile" as indicating the texture of the surface of velvet. In a letter, of which the following is the substance, Mr. W. A. Thoms has been so kind as to explain to the author the exact sense in which the term is used in Scotland:—"By a well-piled loaf we do not understand a loaf well-risen. Pile is the gloss of the outside skin, or crumb of close packed bread, and the more unbroken the skin, the more silky in feel and glossy in sheen, the higher we rank the pile. Undoubtedly a well piled loaf must also be a well-risen loaf. They have that in common, but a well-risen loaf may be ragged, broken-skined and dark, without being over proved; such a loaf we call coarse, and say it has a bad or no pile. Proof, in dough or baked bread, refers to volume or size. These qualities, proof and pile, are due to the same factor, carbon dioxide, acting on and distending the gluten, and it is the condition of the gluten at the time in the oven, when the dough is passing into bread, that determines the pile. The condition, good or bad, of the gluten in this transition state may be due to the condition of the flour, the proportion of gluten it contains, or to the action of the yeast and its bye-products on the gluten during the entire fermentation. Unhealthy yeast will produce an abnormal proportion of acids, and acids render gluten first friable and then soluble. At the friable stage, bread may be high, badly shaped, dark and ragged, but deficient in pile."

658. Odour.—This is best judged by pulling a loaf open and burying the nose deep in the cleft. The bread should have a nutty, sweet smell; this denotes the highest degree of excellence so far as this quality is concerned. There may be an absence of smell, or what is perhaps most forcibly described as a mawkish and damp odour; these belong to the indifferent stage. The bread may smell sour, in which case an unfavourable opinion is naturally formed. Beyond these are the smells, approaching to stenches, arising from butyric, ropy, and even putrid fermentation

659. Flavour.—This of course is one of the most crucial tests to which bread can be put. It is probably the only one adopted by the vast majority of the bread-eating public. Fortunately, the judgment based on flavour is almost invariably a sound one; a bread which pleases the palate is usually one that is wholesome. Having made this statement, it may be well also to indicate one direction in which the palate test is untrustworthy; many people are extremely fond of hot rolls for breakfast. These luxuries are not, however, to be indulged in by everyone, for hot bread is not easily digestible. The reason is a simple one; the soft nature of bread, while still warm, causes it to be formed into balls in the mouth, which are swallowed without the due admixture with saliva.

When tasting bread, nothing having a strong flavour should have been eaten for some little time previously; a small piece of the bread should be put in the mouth, masticated, and allowed to remain there a short time before being swallowed. The flavour should be sweet, and of course there must be an absence of sourness or any marked objectionable taste. The physical behaviour of the bread in the mouth is also of importance. The bread should not clog or assume a doughy consistency in the mouth; neither, on the other hand, must it be dry or chippy. In addition to tasting the dry bread, a slice spread with butter may be eaten. It need not be said that in this test the butter must be unexceptionable.

660. Colour and Thickness of the Crust.—The crust should be of a rich brownish yellow tint; neither too light on the one hand, nor too dark on the other. So far as is consistent with adequate baking, the crust should be as thin as possible.

The act of baking changes the character of several of the constituents of the flour. Thus, the albumin is coagulated, and thereby rendered insoluble. The starch is partly, at least, rendered soluble by the gelatinisation consequent on heating. The fatty matters of the flour are unchanged; at times, however, bread is found to contain fat over and above that normally present in flour. In fancy bread, butter or milk is sometimes used in the dough; small quantities of lard are also employed by some bakers in order to give a special silkiness to the fracture where two loaves of crumby bread are separated from each other. The ash is not materially affected in quantity. The water varies considerably. Subjoined are the results of some analyses collected by König and quoted by Blyth. A number of others by the author are given in various parts of this work:—

	Minimum.	Maximum.	Mean for Fine Bread.	Mean for Coarse Bread.
Water	26·39	47·90	38·51	41·02
Nitrogenous substances	4·81	8·69	6·82	6·23
Fat	0·10	1·00	0·77	0·22
Sugar	0·82	4·47	2·37	2·13
Carbo-hydrates (Starch, &c.)	38·93	62·98	49·97	48·69
Woody-fibre	0·33	0·90	0·38	0·62
Ash	0·84	1·40	1·18	1·09

661. Quantity of Water in Bread.—The question may fairly be asked—On what principle is a decision to be made as to whether a bread contains too much water? In reply, the loaf having become cool, say two hours after being removed from the oven, should on being cut feel just pleasantly moist, not dry and chippy, nor on the other hand in the slightest degree sticky or clammy. A second loaf, on being examined in the same way when two days old, should answer to the same tests, and should not show the slightest signs of sourness or mustiness. Some loaves of bread containing even 40 per cent. of water would very well pass this examination; while others which might contain much less water would nevertheless be damp and sodden, rapidly turning mouldy or sour. Notwithstanding that the latter contained absolutely the less water, they would still be condemned as containing more than they ought; while the former would be returned as coming within the limit. The quantity of water permissable in a bread must depend on the nature of the flour used; the offence is not in using sufficient water to a strong flour, but in adding more to a weak flour than it can properly take.

Another question arises—Would it not be well for the public to insist on being supplied with bread made from such flours as normally require, for their conversion into bread, a low proportion of water? Again, in reply, the strongest flours—that is, those which naturally absorb the most water—are made from the soundest, best matured, and highest class wheats; so that the baker who uses a strong flour also uses a high priced flour.

662. Analytic Estimations.—In an ordinary analysis of bread, where the object is not to test for audulteration, the estimations given below may be made. A thin slice should be cut from the middle of the loaf, the crust cut off, and then the interior portion crumbled between the fingers; the crumbs must be thoroughly mixed, and at once placed in a bottle.

Moisture, Ash, and Phosphoric Acid.—Determine as directed in paragraph 647 on Malt Extracts.

Proteids.—Determine by Kjeldahl's method on 1 gram of the bread.

Acidity.—Take 10 grams of the bread, grind up in a mortar with a small quantity of water, transfer to a flask, and make up to 100 c.c. Allow to stand for an hour in a boiling-water bath, cool, and titrate with $\frac{N}{10}$ soda, using phenolphthalein as an indicator. The acidity may be calculated as lactic acid.

Fat.—Direct extraction of bread with ether or light petroleum spirit, however long continued, gives too low results, owing to the fat being enclosed by the starch and dextrin. The results are lower than those obtained from the flour from which the bread was made. The following method, slightly modified from that given by Weibull, gives trustworthy results, but it is necessary to work exactly as follows:—4 grams of new or 3 grams of stale bread or dried bread solids are put into a 70 c.c. beaker, and covered with 15 c.c. of water, after which is added 10 drops of dilute sulphuric acid (25 per cent.). The beaker is then placed in an ordinary saucepan containing a little water, the lid put on, and the contents boiled gently for at least 45 minutes, or till the solution gives no starch reaction with iodine. While still warm, the contents are carefully neutralised with slight excess of powdered marble or pure precipitated calcium carbonate. The mixture is then heated over a water bath, or by standing on the top of the hot-water oven, until concentrated to about 10 c.c., when it is spread on a strip of blotting paper (such as is used in Adam's milk process [1]), and any liquid remaining in the beaker is removed by means of a piece of cotton-wool, which is then put on to the filter paper. The latter, resting on iron gauze, is first dried for 10 minutes at 100° C. The paper is now rolled into the usual shape, and then dried for 3—4 hours at 100—103°. After this it is placed in a Soxhlet's apparatus, and extracted for about 60 times with ether or light petroleum spirit, the extraction occupying in all about five hours. The ether solution is then evaporated, and dried in a weighed dish in the usual manner. Comparative estimations of the fat in bread, and in the flour from which it was made, gave perfectly concordant results by this method.

Soluble Extract.—Take 25 grams of the bread and 240 c.c. of water, rub down with a little of the water into a perfectly uniform paste in a mortar. Transfer to a flask, add the remainder of the water and 1 c.c. of chloroform. Shake vigorously at intervals during twelve hours, or allow to stand overnight. At the end of the time shake again, and allow to stand for half an hour for the solids to settle. Filter the supernatant liquid until perfectly bright, and evaporate 25 c.c. to dry-

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[1] These consist of pieces of stout blotting paper, 22 inches long by 2½ inches wide.

ness for soluble extract. Bread contains on the average about 40 per cent. of water, and therefore there are 10 c.c. in 25 grams; this quantity, together with the 240 c.c. added, make 250 c.c. The water extract may therefore be viewed as a 10 per cent. solution of soluble matters. There is probably no generally applicable method which extracts the whole of the soluble matter of the bread, as a portion is almost certain to remain behind. If, on the other hand, the bread be subjected to prolonged boiling, some of the constituents which were not originally soluble are thereby dissolved.

It is not recommended to evaporate the bread to dryness, and make the determinations of soluble matters in the powdered dry residue, as this does not at all readily yield up its soluble matter to water.

Maltose.—Usually 10 c.c. of the soluble extract solution may be taken and precipitated with Fehling's solution in the usual manner. Should the amount of precipitate be very small, another 10 c.c. should be at once added.

Soluble Starch and Dextrin.—These may be determined as described in paragraph 641, Chapter XXIV.

Soluble Proteids.—Take 25 c.c. of the soluble extract solution, evaporate to dryness in a flask, and determine organic nitrogen by Kjeldahl's process. The difference between total and soluble proteids may be returned as insoluble proteids.

Starch.—This is usually taken as difference, after making all other determinations; but it may also be determined direct by either of the various processes given in Chapter XXIV. for estimation of starch. From the total starch, that estimated in soluble extract solution as soluble starch must be deducted.

Cellulose.—This may be determined by the method described in paragraph 642.

Digestibility.—The comparative digestibility of bread may be estimated by the method described in Chapter XXI., page 400.

CHAPTER XXVI.

ADULTERATION.

663. Standard Works on the Subject.—In giving directions for both flour and bread analysis, we have hitherto confined ourselves to such modes of testing as enable us to determine the quality and character of each, apart from any considerations as to the presence or absence of any foreign substances. This portion of our task will not, however, be complete until an outline has been given of the processes employed in the analysis of flour and bread for the purpose of detecting adulteration. This branch of chemistry applied to the arts of milling and baking has received considerable attention, and several standard works of reference have been written on the subject; among these may be mentioned those of Allen and Blyth, both of which represent the most recent and authoritative opinions of chemists on the problem. For several of the tests to be hereafter described the writer is indebted to these works, to which the student is referred for further and more detailed information.

664. Information derived from Normal Analysis.—Some of the tests already mentioned in the description of the normal analysis of flour and bread serve also as indications as to whether a sample is adulterated. Thus the moisture, if unduly high, points to the fact that the wheat has probably been damped; water added for other purposes than the sufficient softening of the bran to permit the grinding to be readily performed must be looked upon as an adulterant. It is a debated point whether even such addition of water as this is permissible; certainly there should not be enough to greatly affect the percentage of moisture in the dressed flour.

The percentage of ash in the flour affords some guide as to whether the sample has been treated with mineral substances. A flour ash, when properly burned, should amount to less than 1 per cent.; greater quantities than this are probably due to mineral adulteration.

665. Impurities and Adulterants of Flour.—The following are some of the foreign substances that are at times found in flour: seeds of other plants, as corn-cockle and darnel; blighted and ergotised grains —these are to be viewed rather as impurities than adulterants, the latter term being confined to those bodies wilfully added for purposes of fraud. Among these latter are rye, rice-meal, potato starch, meal from leguminous plants, as peas and beans, and the following mineral bodies: alum, borax, chalk, carbonate of magnesia, and bone ash.

The tests for many of these substances are in part microscopical; the chapters containing directions for practical microscopic work provide information and data as to the making of such tests. The following are the principal chemical tests for the bodies above mentioned:—

666. Darnel.—Treat a little of the flour with alcohol (rectified spirits of wine, not methylated spirits), digest at 30° C. for an hour, shaking occasionally. Filter and examine the filtrate. This should be clear and colourless, or at most should be only of a light yellow colour. In the event of the flour containing darnel, the alcoholic extract is of a greenish hue, and has an acrid and nauseous taste.

Treatment with alcohol and a small quantity of acid is a useful test for other adulterants. Extract the flour with 70 per cent. alcohol (*i.e.*, a mixture of alcohol and water, containing alcohol equivalent to 70 per cent. of absolute spirit), to which 5 per cent. of hydrochloric acid has been added. Pure wheat or rye flour yields a colourless extract; barley or oats gives a full yellow tint; pea-flour, orange-yellow, mildewed wheat, purple-red and ergotised wheat, a blood-red colouration.

667. Ergot and Mould.—To test flour for ergot, exhaust 20 grams with concentrated alcohol in a fat extraction apparatus; notice the colour, which in the presence of ergot is more or less red. Mix this solution with twice its volume of water, and shake up separate portions of this mixture with ether, amyl-alcohol, benzole, and chloroform. Ergot imparts a red colour to the whole of these solvents.

Vogel recommends the flour should be stained with aniline violet, and then examined under the microscope; should any of the starch granules have been attacked by ergot or other fungoid growths, they acquire an intense violet tint; while if they are perfectly sound, they remain comparatively colourless.

Ergotised flours evolve the peculiar fish-like odour of trimethylamine when heated with a solution of potash: the same smell is, however, evolved by flour otherwise damaged. The test is of service in distinguishing between sound and unsound flours.

The use of mouldy wheat for the manufacture of flour can readily be detected by placing the sample in a tightly stoppered bottle, damping it and placing it in a bath heated to about 30° C. Any mouldy taint can readily be detected after thus standing for two or three hours.

668. Mineral Adulterants.—The presence or absence of most foreign mineral matters will have been indicated by the percentage of ash yielded. Alum is, however, added to flour in quantities too small to be thus detected. One of the most ready means of separating mineral substances from flour is by means of what is termed the

669. Chloroform Test.—This test depends on the fact that chloroform has a density higher than that of the normal constituents of flour, but lower than that of minerals generally; consequently, on agitating a mixture of flour and chloroform, and then allowing it to rest, the flour rises to the surface, and any mineral adulterants sink to the bottom. On the small scale, for the purpose of a qualitative test, a large dry test-tube may be about one-third filled with the flour, then chloroform added to within one inch from the top. The tube must then be corked and violently shaken, after which it must be allowed to rest for some hours; the mineral matter will then be found to have sunk to the bottom. For quantitative purposes a glass "separator" is requisite. This is a cylindrical vessel some two inches in diameter, eight or ten inches in length, stoppered at the top, and furnished with a stopcock at the bottom. Introduce in this vessel 100 grams of the flour and about 250 c.c. of methylated chloroform; treat as directed for the smaller quantity. When the separation is effected, open the stopcock and allow any sediment, with as little as possible of the liquid, to run through. Treat this again with a little more chloroform in a smaller separator, and once more drain the sediment off through the stopcock into a watchglass, or small evaporating basin. Allow the chloroform to evaporate; treat the dry residue with a small quantity of water, and filter. Any plaster of Paris or other insoluble mineral matter will remain on the filter, and may be ignited and weighed. Evaporate the solution to dryness, and examine the residue carefully with a low power under the microscope for any crystals of alum.

670. Special Test for Alum.—The most convenient test for alum in flour consists in adding thereto an alkaline solution of logwood. Take 5 grams of recently cut logwood chips and digest them in a closed bottle with 100 c.c. of methylated spirit. Also make a saturated solution of ammonium carbonate. Mix 10 grams of the flour with 10 c.c. of water, then add 1 c.c. of the tincture of logwood and 1 c.c. of the ammonium carbonate solution, and thoroughly mix the whole. With pure flour the resultant mixture is of a slight pinkish tint. Alum changes the colour to lavender or full blue. The blue colour should remain on the sample being heated in the hot-water oven for an hour or two.

671. Alum in Bread.—Bread is tested for alum by first taking 5 c.c. of the tincture of logwood, 5 c.c of the ammonium carbonate solution, and diluting them down to 100 c.c. This mixture must at once be poured over about 10 grams of the crumbled bread in an evaporating basin. It is allowed to stand for five minutes, and then the superfluous liquid drained off. Slightly wash the bread and dry in the hot-water oven. Alum gives the bread treated in this manner a lavender or dark blue colour, which is intensified on drying. Pure bread first assumes a light red tint, which fades into a buff or light brown. After some practice this test gives satisfactory results, and is so sensitive that as little as 7 grains of alum to the four-pound loaf have been detected. The depth of colour affords a means of roughly estimating the quantity of alum present. It is essential that the tincture of logwood be freshly prepared, and that the test be made immediately after mixing the tincture of logwood and ammonium carbonate solution.

672. Young on Logwood Test for Alum.—In 1886 Young pointed out (The Analyst) that under certain circumstances bread which is absolutely free from alum gives the characteristic reaction with logwood. On investigation it was found that the flour used gave no indication by logwood, but that the bread gave a very distinct colouration. The sample was heavy and sour—subsequent experiments showed that the colouration was directly due to the acidity. On taking pure breads, which were absolutely negative to the logwood test, and moistening with dilute acetic acid (1 to 250 of water), and letting stand for one hour, all gave a most intense blue colour with logwood. So also did pure flour similarly treated. Young considers this effect to be due to phosphate of alumina (a body normally produced from the mineral constituents of flour), being slightly soluble in dilute acetic acid, and quotes experiments in proof of such solubility. He further found that such phosphate of alumina exists in a state of combination with the gluten, and, as a result of careful washing, was able to procure starch, which, after treatment with acetic acid and subsequent application of the logwood test, gave no colouration.

In a quantitative experiment some best quality Hungarian flour was taken, yielding 0·7 per cent. of ash and 8 per cent. of dry gluten. The gluten was washed out in a muslin bag and dried, 20 grams were taken, finely powdered, and treated with 250 c.c. of 50 per cent. acetic acid, and heated in the water bath for 28 hours. The gluten had then dissolved, leaving a sediment, from which the clear liquid was poured, and the residue again twice treated in the same manner with the diluted acetic acid. The three lots of acid extract were evaporated to dryness, and the residue burned to a perfect ash—this was treated in dilute hydrochloric acid, and the insoluble residue fused with alkaline carbonates, dissolved in dilute hydrochloric acid, filtered, and filtrate added to acid solution of ash. This was again evaporated to dryness, redissolved in small quantity of hydrochloric acid, filtered, filtrate boiled, and cautiously added to 25 c.c. of saturated solution of pure sodium hydrate, also boiling, and kept boiling for a few minutes. The precipitate was dissolved with hydrochloric acid, and precipitated with saturated solution of sodium phosphate and slight excess of ammonia. After ten minutes' boiling, the precipitate of aluminium phosphate was collected, filtered, and weighed. The 20 grams of gluten yielded 0·0185 gram of aluminium phosphate, equal to 0·01875 from 250 grams of flour, or 0·0075 per cent. Alumina was thus shown to be a natural constituent of flour, and associated with the gluten. The alumina thus normally present justifies a deduction being made of from 7 to 8 grains of alum per 4-lb. loaf from the amount corresponding to total alumina by analysis.

For further experiments by Young on the solubility of aluminium phosphate in acetic acid, the reader is referred to the Analyst for April, 1890. He there shows that the presence of ammonium acetate, and also that of ammonium chloride, prevent the complete precipitation of aluminium phosphate in the presence of acetic acid.

THE END.

NOTE ON PLATES.

To better suit the size of the page, Plates I., II., III., and V. have been slightly reduced : in consequence the magnification is only seven-eighths of that specified in each case. For example, the starches in Plate I. have only an approximate magnification of 87·5 instead of 100 diameters : the same proportionate reduction applies to the other plates mentioned.

Owing to delay caused by the difficulties encountered in obtaining a satisfactory reproduction of the Coloured Plate No. XIV., it became necessary to print off the descriptive letterpress (pp. 519—520) before the completion of the Plate. The original copy, as supplied by the author, furnished examples of the shades of sets of tintometer glasses employed in determining the colour of flours, and also of a number of representative flours. The tintometer readings given on the Plate are those of the original copy : on receipt of the printed proof, the colours as reproduced were also read by the tintometer. As some guide to the degree of accuracy of the Plate, both sets of readings are given below :—

	Tintometer Readings of	
	Original Copy.	Printed Proof.
Yellow Scale, lightest tint,	0·5 Y.	0·5 Y.
,, darkest tint,	2·5 Y.	2·3 Y.
Red Scale, lightest tint,	0·5 R.	1·1 R.
,, darkest tint,	2·5 R.	2·4 R.
Mixed Yellow and Red Scale, lightest tint,	0·28 Y. + 0·24 R.	0·30 Y. + 0·24 R.
Mixed Yellow and Red Scale, darkest tint,	1·4 Y. + 1·2 R.	1·4 Y. + 1·2 R.
No. 1. Blue Scale,	2·5 B.	2·5 B.
,, 2. Spring Bakers' Flour,	1·8 Y. + 1·4 R.	1·6 Y. + 1·2 R.
,, 3. ,, ,, 2nd sample,	1·7 Y. + 1·6 R.	1·7 Y. + 1·5 R.
,, 4. Red Dog Flour, Spring Wheat,	4·0 Y. + 4·3 R. + 1·2 B.	2·7 Y. + 3·4 R. + 1·4 B.
,, 5. Winter American Wheat Patent,	0·45 Y. + 0·2 R.	0·4 Y. + 0·2 R.
,, 6. English Patent, Blended Wheats,	0·7 Y. + 0·3 R.	0·7 Y. + 0·7 R.
,, 7. Hungarian Patent,	1·05 Y. + 0·45 R.	0·8 Y. + 0·6 R.
,, 8. Spring American Wheat Patent,	0·90 Y. + 0·6 R.	1·1 Y. + 1·0 R.

On comparing these readings, it will be observed that the Yellow Scale is reproduced with great accuracy ; so also is the lower end of the Red, but the lighter end is more than double the depth of tint it was desired to reproduce. The mixed Yellow and Red scale comes out well, all colours being as nearly as possible of the correct value. Knowing the value to be attached to each end of the various scales, the reader can estimate for himself the approximate value of the intermediate shades. The single tint from the Blue scale is also well reproduced.

Turning to the flours, Nos. 2 and 3 differ but little from the originals. No. 4 is, however, considerably lighter in the Plate than in the "copy." The Winter American Patent is closely matched. The English Patent, No. 6, is much too red : so also are the Hungarian and Spring American Patents, Nos. 7 and 8. The shade given as that of the Hungarian flour almost exactly reproduces that of the Spring American Patent, No. 8. Hungarian flour is much more yellow and "bloomy" than the Plate shows.

With these explanations the Plate affords what is hoped will be a very useful demonstration of the value to be attached to the various tintometer readings given. In all such cases there is, however, considerable difficulty in accurately reproducing delicate tints, such as those of flour, by mechanical printing processes.

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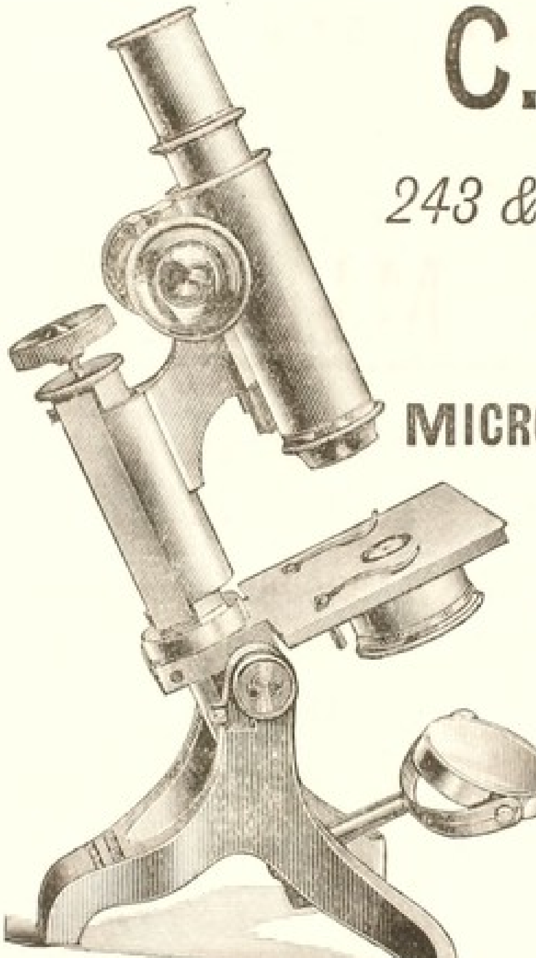


Mr. W. JAGO'S
REPORT ON COTTOLENE

BRIGHTON, *20th February*, 1895.

I have received from Messrs. BIGLAND, SONS, & JEFFREYS, of Liverpool, an ordinary 56-lb. Tub of **Cottolene** for purposes of experiment and analysis. I find this substance to consist practically of 100 per cent. Pure Fat, the following being the actual results obtained by analysis :—

Percentage of Pure Fat, - - 99·982.

I also caused to be conducted under my personal supervision in the Baking Department of my Laboratory, practical tests of the use of Cottolene both in Cake and Bread-making, with the following results :—In very rich cakes, composed entirely of flour, sugar, eggs, and Fat, I found the **"shortening" effect of 12 ozs. of Cottolene practically equal to that of 1-lb. best butter.** On the other hand, the flavour of the Cottolene Cakes was not fully equal to those which were butter-made, there being in the former rather an absence of butter flavour, than the slightest suspicion of any strong or unpleasant taste of their own.

Using the formula of 4 ounces of best butter to 8 ounces of Cottolene, the flavour is quite equal, if not superior, to that of either off-quality butter, or even good margarine, while the same shortening effect is produced by about 80 per cent. of the mixture as against butter. For fruit cakes, made from regular trade recipes, with this proportionately less quantity of shortening, the flavour is such that the general public, as distinguished from the trade expert, would have difficulty in deciding which of two cakes was made from the Cottolene mixture and which from ordinary butter.

In bread-making the employment of COTTOLENE in the proportion of from 6 to 8 ounces per bushel of flour used effects a marked improvement; the crust is shortened, and the crumb of the bread rendered moister.

The use of this article effects a saving in working, as there is no loss of either weight or time in having to wash out salt and water.

Finally, for hygienic reasons, Cottolene may with safety be used as a perfectly harmless and innocuous substitute for other fats employed for dietetic purposes.

(Signed) WILLIAM JAGO, F.I.C., F.C.S.

The vastly superior principle on which these Ovens are constructed makes their adoption by the trade generally a certainty, at no distant date.

Amongst other Advantages are the following:—

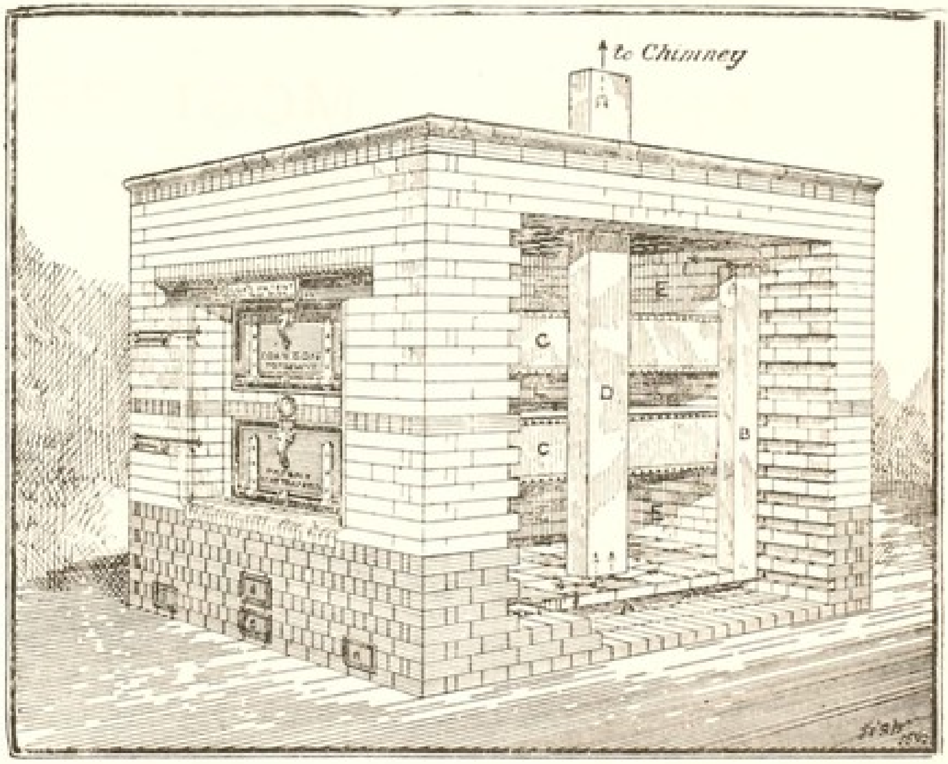
Greater Economy, Greater Durability.

Greater Cleanliness.

Absolutely continuous working with **even baking throughout.**

Absolute control over temperature.

A better bloom and **less loss of weight** than in the case of any other Oven in existence.



COPY OF TESTIMONIAL.

Messrs. Cox & Son,
4 Victoria Parade, Torquay.

MEABY'S READING BISCUIT FACTORY,
READING, *5th Nov., 1894.*

GENTLEMEN,—In reply to your enquiry, we are glad to say that the Double-Deck Ovens (10 feet by 8 feet each) you erected for us last April are doing excellent work; in fact, we wish for nothing better.

They are always ready for work, absolutely continuous, under perfect control; the two Ovens working at the same time at different temperatures. They are also extremely economical in fuel.—Yours faithfully,

(Signed) MEABY & CO., Limited.
GLOYL J. CARTER, Secretary.

FULL PARTICULARS AND ESTIMATES FREE ON APPLICATION.

COX & SON,

Engineers and Oven Builders, TORQUAY.

USERS OF THE

CLIMAX OVEN

SAY:—

Mr. C. DOWNHAM, 5, Bank Buildings, Hastings.

DEAR MR. JAGO,—In reply to your inquiry as to the CLIMAX Oven you built for me about eighteen months ago, I am pleased to say that it has from the first given me every possible satisfaction. The oven is thoroughly well built, and I feel certain from the best materials. The oven bakes a first-rate loaf of Bread, and as a Pastry and Cake oven is as good as I have yet seen. The goods have a perfect bloom, and are baked perfectly even all over the oven. For simplicity of working, economy of fuel and space, and general excellence of results, the oven is everything I could wish for in an oven. Most certainly when I want to make any additions to my baking plant, I shall certainly come to you; and if at any time you refer any one to me, I shall be very pleased to show it them.

Yours very truly,

16th October, 1891. C. DOWNHAM.

Harrow School Laundry and Bakery Co., Ltd.

The CLIMAX Oven is giving the greatest possible satisfaction. The Bread turned out is excellent.

H. STRICKLAND, *Secretary.*

Mr. A. R. WEBSTER, 2, Church Road, West Brighton.

I have much pleasure, in reply to your inquiry, to state that the Double-Decker CLIMAX Oven you built for me is giving every satisfaction. After giving much time in examining ovens built by several of the best-known builders, and also testing the work turned out by them, I finally decided on giving you the order, and am now pleased, after having used them both for Bread and Pastry for three months, to be able to write so satisfactorily of them. They give as good a bloom as the side-flue oven does, and of course much cleaner, and with proper, or perhaps I should say ordinary, management, are ready to bake two or more batches of Bread continuously one after the other, with only an interval of 15 to 20 minutes. They are decidedly economical, as they only burn about nine cwt. of coke in eight or nine days.

Should you wish at any time to show them to anyone thinking of giving you an order, I shall have much pleasure in letting them see mine.

Yours truly,

June 19th, 1891. ARTHUR R. WEBSTER.

Mr. L. HERBERT, Lion Bakery, 61, Northgate, Gloucester.

DEAR SIR,—The Three-Decker Combination CLIMAX Oven I some time ago ordered from you has now been at work about two months, and you will be glad to know is doing thoroughly well in every respect.

I have no difficulty in following batch after batch in the Drawplate Oven with

WILLIAM JAGO,

Cornwall House, 35, Queen Victoria St., LONDON, E.C.,
and 32, Clarendon Villas, BRIGHTON.

USERS OF THE

CLIMAX OVEN

SAY:—

an interval of twenty minutes between each batch. This is quite as soon as my men can get the batch ready; and as the setting and drawing of the 260 half-quartern loaves is done in less than three minutes, this means very quick work indeed. The two upper peel ovens are both admirable Bread ovens, and will bake continuously if necessary. On a Saturday as many as three batches have been baked in one of them without a break, and this could have been continued as long as was desired.

In bloom, boldness of loaf, and general characteristics, the Bread is all that could be wished, I cannot speak too highly of the quality of the workmanship, materials, and fittings used in their construction. In this respect they far excel any other oven I have seen.

In addition to my bread, I also do a large confectionery and cake trade; for this the ovens are perfectly suited.

Whether requiring drawplate or peel ovens, I can confidently recommend my fellow-bakers to place their orders with you. I am myself heartily glad that I gave the CLIMAX Oven the preference.

I shall be pleased to show my ovens to anyone thinking of building new ones, and am yours faithfully,

August 17th, 1891. LIONEL HERBERT.

Messrs. W. LEWIS & SON, Church Street, Malvern.

No doubt you have expected to hear from us *re* the CLIMAX Combination Double-Decker Oven you put in for us more than fifteen months ago. It is a perfect success, filling all our expectations, and performing all you promised for it. We find it (or them)

(i.) Saving in Fuel (about 20 per cent.)
(ii.) Saving in Weight of Bread, and consequenty a greater yield of loaves per sack.
(iii.) Splendid Advertisement on bottom of each loaf.
(iv.) No Bread spoiled by burning, "boiling," or twisted tops.
(v.) No loss of time between batches—we can bake continuously day and night with at most an interval of twenty minutes between the batches.

Besides these few advantages over other "Patent" Hot Air ovens we have used, we find that from the "CLIMAX" our Bread has that beautiful bloom so much coveted by modern bakers. They are perfectly suitable for a mixed trade, as they are quite under control, and we can bake either Pastry or Bride Cakes with an astonishing short interval between. Wishing you the success you so richly deserve,

We are, &c.,

July 12th, 1892. WM. LEWIS & SON.

WILLIAM JAGO,

Cornwall House, 35, Queen Victoria St., LONDON, E.C.,
and 32, Clarendon Villas, BRIGHTON.

USERS OF THE

CLIMAX OVEN

SAY:—

Mr. A. F. PALMER, Fishponds, Bristol.

In reply to your inquiry *re* Ovens, I am pleased to say they are working very satisfactorily. And during the short time I have used them (about six months) we have had good evidence of their efficiency and economy.

Yours truly,

February 23rd, 1893. A. E. PALMER.

Mr. J. WESTMORLAND, Bull Street, Darlaston.

DEAR SIR,—The Double-Decker CLIMAX Oven you put in for me last July is a perfect success and giving every satisfaction. It is very simple to work, gives a good solid heat, and is a first-class Bread oven, quite equal to the old flue oven in every respect, besides being perfectly clean, continuous, and solid; advantages which effect a very considerable saving of time and trouble. As regards materials and workmanship, they are the most substantially built ovens I have ever seen.

Wishing you every success, &c.,

February 16th, 1893. J. WESTMORLAND.

Mr. W. S. GOODRAM, 61, Magdalen Street, Colchester.

I have very great pleasure in letting you know how exceedingly well your CLIMAX Ovens you erected for me answer to your recommendation, doing their work quickly and well in every detail. In addition to a great saving of time, they have a perfection of cleanliness and equality of baking well nigh impossible to excel. They are in my estimation far superior to any steam ovens I have yet seen. Trusting you will meet with the success due to you,

I remain, &c.,

5th April, 1893. W. S. GOODRAM.

Mr. W. T. WAYMOUTH, Climax Bakery, St. Marychurch, Torquay.

The Three-Decker Combination CLIMAX Oven you erected for me some time ago is a perfect success. I have worked both a side-flue and steam oven, but consider yours far superior to either; it bakes Bread to perfection, and immediately after is quite ready for Pastry and Cake, which is a great boon to any baker doing a mixed trade. I should be very pleased to show my ovens to anyone in the trade, and consider they are as near perfection as can be.

Yours very truly,

17th November, 1893. W. T. WAYMOUTH.

WILLIAM JAGO,

Cornwall House, 35, Queen Victoria St., LONDON, E.C.,
and 32, Clarendon Villas, BRIGHTON.

USERS OF THE

CLIMAX OVEN

SAY:—

Mr. JOHN A. FISHER, Westgate Street, Gloucester.

I have much pleasure in stating that I am very pleased with the Double-Decker CLIMAX Oven which you built for me in May last. I consider they are an immense advance upon the old side-flue oven. They are a very great save in fuel and labour, and are very suitable for baking fancy bread, buns, pastry or cakes, giving to the goods a rich appearance not obtainable in my old oven. As regards cleanliness they are a perfect boon, and being built of the best materials I should think they would last many years. I shall have great pleasure in recommending them to anyone who intends building ovens. You may make any use of my name you wish in reference to your ovens.

Yours truly,

11th December, 1893. JOHN A. FISHER.

Mr. S. C. LUCKLY, 32, Regent Street, Clifton, Bristol.

Having now been working the CLIMAX Ovens for nearly two years, the public won't say that I give you a testimonial before giving them a trial. The drawplate is a great improvement to what I had been accustomed to for forty years, and the cleanliness in the bakehouse is a great consideration, the furnace being away at the back. But not the least to think of is the cost of fuel: my coal bill used to be £40 per year for two ovens of the old style; now for coke for the three CLIMAX Ovens, £19 per year. If any baker intends making any alteration in his ovens, I shall be glad to give any information to help him to decide for the CLIMAX.

Yours truly,

6th February, 1894. S. C. LUCKLY.

Cainscross and Ebley Co-operative Society, Ltd., Cainscross, near Stroud.

MEMO. TO MR. W. JAGO,—We find your Oven everything to be desired in an oven, doing its work admirably. It has turned out very successfully, producing a loaf that is a credit to us, and that has led to an expanding trade. The fuel burnt is less in proportion to that used by our previous ovens, and the workmanship could not be better. Your ovens are certainly the best among the many I have seen.

3rd September, 1894. B. HUDSON, *Manager.*

WILLIAM JAGO,

Cornwall House, 35, Queen Victoria St., LONDON, E.C.,
and 32, Clarendon Villas, BRIGHTON.

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LONDON: MONDAY EVENING, JANUARY 7, 1895.

ANNUAL SUBSCRIPTION
(52 NUMBERS), 12s. 6d.

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BRYAN CORCORAN,

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BASEMENT OF CORN EXCHANGE.
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BACK CHURCH LANE.

31, MARK LANE,
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See Page xxxv.

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For Dressing FLOUR in 20 different qualities, useful also for other Sifting & Straining purposes.

Manufactured & Sold at Wandsworth, LONDON, S.W. *PLAN OF MACHINE, &c., GRATIS & POST FREE.*

BEST SWISS SILKS, (SHEETS MADE TO ORDER.) EYELET HOLE & LACING TAPES, STIVE BUNTING, &c.

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SEE PAGE xxxvii.

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HENRY SIMON, 20, MOUNT STREET, MANCHESTER.

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NONPAREIL ONE AND TWO SACK ROLLER PLANTS.

Profitable Investment.

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AND

BETTER QUALITY OBTAINED

BY USING

THE 'IDEAL' BRAND

Pure Pastry Butters and Substitutes

WM. JAGO, F.C.S. and F.I.C., reports:—

"32, Clarendon Villas, Brighton, 25th March, 1895.

"I have received from Messrs. Redding & Jones, of London, samples of their 'Ideal' Margarines—cake and pastry brands respectively—for purposes of analysis and report. I find them on examination to be pure, well made, and absolutely free from objectionable matter of any description. On analysis, they gave the following results:—

	Cake Brand.	Pastry Brand.
Mineral Matter, mostly Salt, ...	0·83	0·47
Water, ...	6·29	7·29
Fat and Casein, ...	92·88	92·24
	100·00	100·00

"In the Technical Department of my Laboratory these have been subjected to an exhaustive series of tests extending over some weeks.

"The Cake Brand is of good flavour and colour, creams well, and works satisfactorily in all respects.

"The Pastry Brand is very tough and waxy, also of good flavour and colour, and works well; the paste rises well, shows no signs of pinching or falling over, but produces bold, upright goods.

"Both varieties of Margarine are of the highest class, and of exceptionally good value.

"WILLIAM JAGO."

SUBSTITUTES.

Perfection,	66/-	Cake,	50/-	Tough,	40/-
Excellent,	60/-	Pastry,	45/-	Waxy,	36/-
Superfine,	56/-	PER CWT.		Fine,	32/-

PERFECTLY PURE PASTRY BUTTERS, 58/-, 66/-, 72/-, 78/-

In all Packages. Carriage Paid.

TERMS—One Month with Two Trade References, or Cash with order.

REDDING & JONES,

16, WATER LANE, GREAT TOWER ST., LONDON, E.C.

USERS OF AMERICAN FLOUR

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A Weekly Journal,

PUBLISHED IN

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It is the representative of the American Makers of both Spring and Winter Wheat Flours, and contains all the news of the Milling Trade, and a full line of advertising of the American Exporting Millers.

Gives more information regarding American Flour than all other publications combined.

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Sent, post paid, to any address for £1 per annum.

SAMPLE COPY FREE.

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Mr. KINGSLAND SMITH,
MANAGER LONDON OFFICE,
14, Corn Exchange Chambers, Seething Lane,
LONDON, E.C.

Telegraphic Address—"BAYNARD, LONDON."

TO BAKERS.

LARGE REDUCTION IN PRICES.

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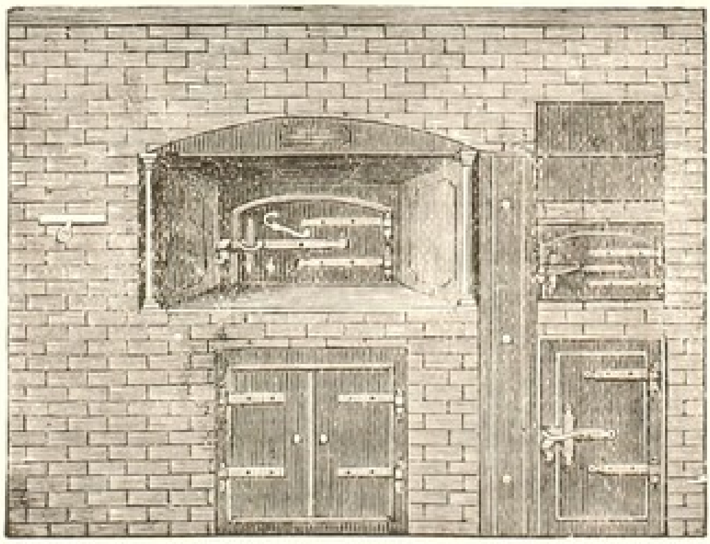
WILLIAM GRAHAM & SONS

Would draw the attention of intending builders of Ovens to their large Stock of

OVEN IRONWORK

which includes



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Special Note.—Please observe in Advertisement on page ix, the address is given as being **E.C.** instead of **S.E.**