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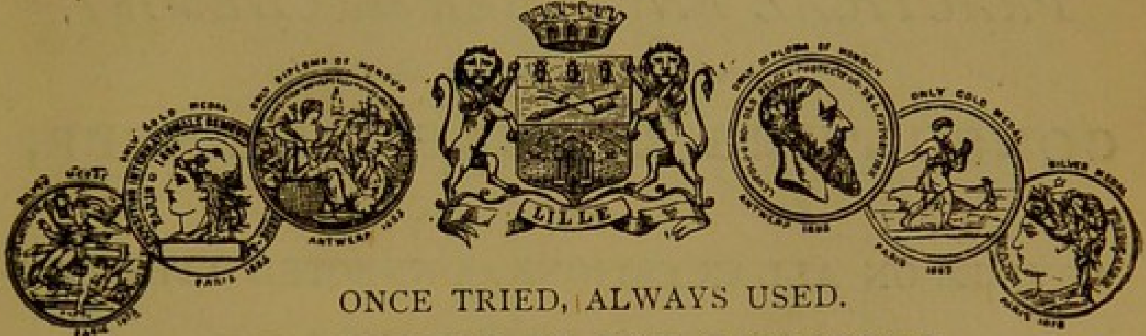
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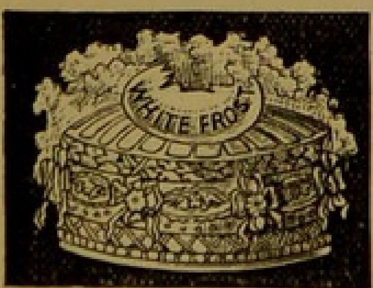
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**Commercial Organic Analysis,** by Alfred H. Allen, F.I.C., F.C.S. J. & A. Churchill. Price, Fifteen Shillings.

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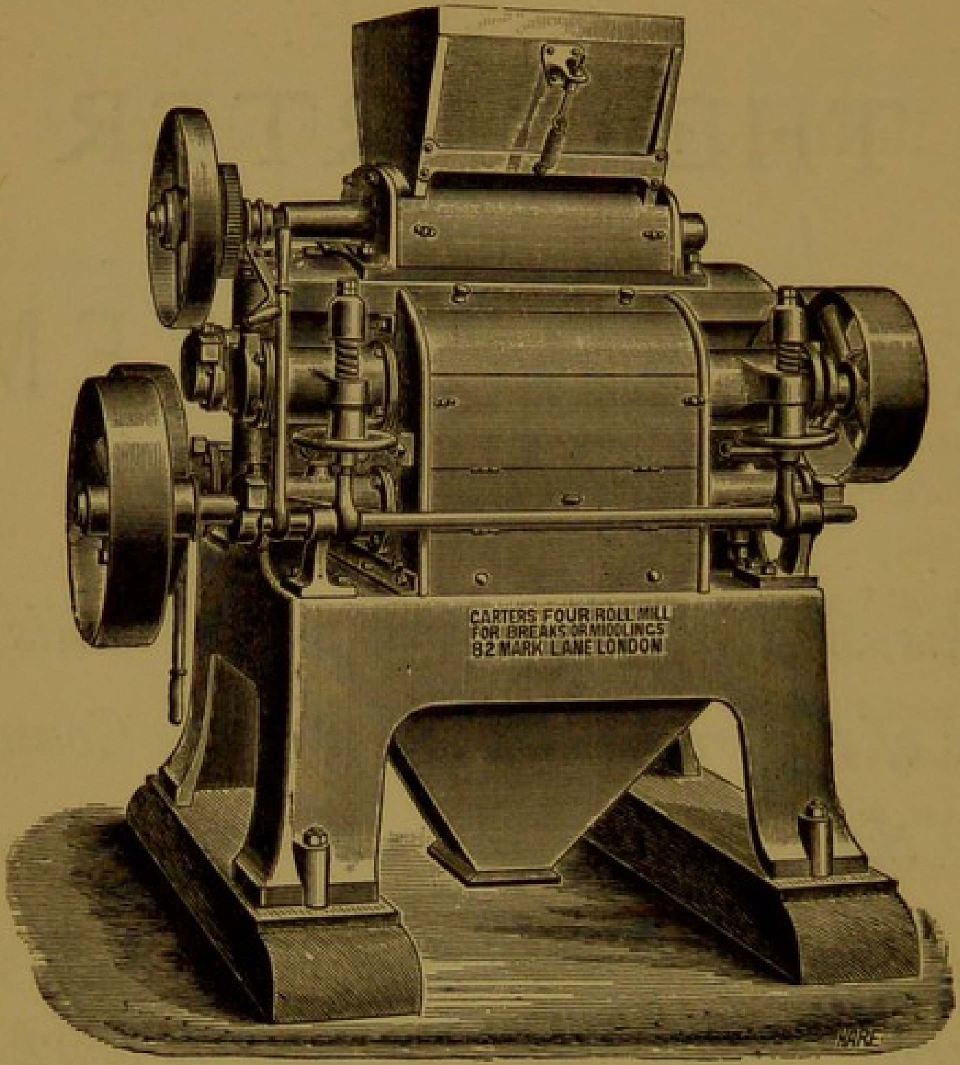
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# THE
# CHEMISTRY
# OF
# WHEAT, FLOUR, AND BREAD;
# AND
# TECHNOLOGY OF BREADMAKING.

BY

WILLIAM JAGO, F.C.S., F.I.C.,
ANALYTICAL AND CONSULTING CHEMIST,
HEADMASTER, SCIENCE SCHOOLS, BRIGHTON.

*Author of "A Confidential Report on Wheat and Flour Supply,"*
*"Inorganic Chemistry, Theoretical and Practical," &c.*

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# PREFACE.

HAVING for some time taken particular interest in the study of the Chemistry of Wheat, Flour, and Bread, in 1883, I received an invitation from Mr. J. H. Chatterton, Secretary to the "National Association of British and Irish Millers," to read a paper on that subject at the Annual Meeting of the Association. That paper was received both by the audience and the various trade journals, representing millers and bakers, in the kindliest possible fashion. As an immediate result, the Editor of the *Millers' Gazette* requested me to contribute a series of articles on the subject to that journal. The articles, to the number of sixty-four, duly appeared; and on the conclusion of the series, the Editor, and other gentlemen interested in milling and baking, strongly urged me to republish them in book form. The present work now offered to the public is the result of my having followed their advice.

My first idea was to reprint the articles almost exactly as they originally appeared; but having commenced the task of re-modelling them I found the work growing on my hands until something like three-quarters of the matter of the book was entirely re-written. Hence a task which at its commencement I had hoped to have completed in a month has extended over a year.

An inspection of the book will sufficiently show the nature of its contents: some few words of explanation of its objects are due to the reader. One of my aims has been to provide a text-book for such students as are anxious to make themselves acquainted with those departments of Chemistry and other allied sciences which have a more or less direct bearing on Milling and Baking. The earlier part of the work is devoted to an exposition of general principles, after which their application to practical work is described. I hope that in this capacity the book may be found of service by those who are preparing for the Technological Examinations of the City and Guilds of London Institute in Milling and Breadmaking. It has for some time formed the basis of the course of study through which my own milling and baking students have worked. Breadmaking is essentially a chemical operation; but in order to make my treatment of its Technology fairly complete I have introduced a chapter descriptive of modern Baking Machinery and Appliances. I have not attempted the same for Milling, because Machinery there plays so much more important a part that to have done so would altogether have altered the character of the present book: further, the subject has been already dealt with in previously written works.

But in addition to the student, there is also the practical and busy man, who finds himself without the time and opportunity necessary for studying the subject from its foundation, but who nevertheless wishes to know the conclusions that may be drawn from scientific research, and their actual bearing on milling and baking operations. I have endeavoured to so treat the subject as to place these conclusions in such a form as to be readily grasped by the general reader, who may wish to give them a practical application.

As from time to time scientific articles are quoted in the trade journals, which frequently contain chemical terms and references that are necessarily unfamiliar to those who have not had a chemical training, I have explained in appropriate parts of this book such of these terms as have come under my notice. In order to facilitate reference, the index is made somewhat more comprehensive than is usual.

In chapter XI., an account is given of some experiments I have recently made on yeast and problems connected with panary fermentation. As some of these have been suggested by discussions that have appeared in the baking and milling organs, it is hoped they may throw light on points at present in dispute.

I should like to direct the attention of both millers and bakers to the mode of Flour Testing by means of the instrument called the Viscometer, described in chapters XVI. and XX. They will notice that in various parts of the work results obtained by means of this apparatus are quoted: a study of these results will best indicate the kind of information it yields. It seems to me capable of affording very considerable help to producers and users of flour in accurately investigating and determining many of its properties. I have found in my own case that I have been able by its use to test and compare flours, not only at the same, but at different times, with a degree of precision and certainty I could not otherwise have hoped to attain.

Although primarily written for Millers and Bakers, information is supplied which it is believed will prove useful to Yeast Brewers and Merchants, Engineers, Farmers, and others, who have a more or less direct connection with the milling and baking industries.

I also venture to hope that the work may be found of service to Chemists, as affording some slight contributions to the sum total of knowledge of Chemical Science.

One of the pleasures of writing a preface to a work such as this is the opportunity it presents of expressing one's thanks for assistance rendered during its preparation. My thanks are due to Mr. Beerbohm, the proprietor, and Mr. Rush, the editor, of the *Millers' Gazette.* The production of this book is in large part due to the liberal encouragement and support I obtained from these gentlemen at the time my original articles in the *Millers' Gazette* were appearing. I have pleasure also in tendering my thanks to the proprietors and editors of the *Miller* and *British and Foreign Confectioner*, who have most readily and willingly given me any assistance in their power. Turning next to private gentlemen, I am deeply indebted to Mr. W. A. Thoms, F.R.M.S., of Alyth, N.B., for much advice and assistance. Readers of the work will see to what a great extent he has afforded me his valuable help. I also thank my assistants, and milling and baking students at the Science Schools, inasmuch as during the past three years they have at all times, "in season and out of season," cheerfully and readily helped me in the analytic work that has been necessary in order to obtain the results given in the present treatise. I append a list of the various scientific works and authorities I have consulted while preparing this book. It goes without saying that in writing the matter contained in its pages, I am greatly indebted to the various standard works on the subject. Many of these are books that ought to be in the possession of milling and baking students; I have therefore given particulars of these, together with the names of publishers, and the prices, in one of the advertising pages in the front of the book.

WORKS CONSULTED :—

Files of the Millers' Gazette, Miller, and British and Foreign Confectioner.
Journal of the Chemical Society.
Comptes Rendus.
Cantor Lectures on The Chemistry of Breadmaking ; Graham.
Studies on Fermentation ; Pasteur.
Fermentation ; Schützenberger.
Bacteria and Yeast Fungi ; Grove.
Technology of Bacteria Investigation ; Dolley.
Manual of Brewing ; Hooper.
Dictionary of Chemistry ; Watts.
Elements of Chemistry ; Miller.
Commercial Organic Analysis ; Allen.
Volumetric Analysis ; Sutton.
Analysis and Adulteration of Foods ; Bell.
Foods, Composition and Analysis ; Blyth.
Composition of American Wheat and Corn ; Clifford Richardson.
Bread Analysis ; Wanklyn.
Healthy Manufacture of Bread ; Richardson.
Materia Medica, Pereira, &c.

In dealing with so large a subject, I am conscious that I cannot hope to have altogether escaped errors, both in the analytic work and the judgment based thereon. So far as possible I have carefully checked the former, and where I have thought any result uncertain, have indicated the same. In matters of judgment, I have impartially stated the opinions that the evidence in my possession has led me to form. In the natural order of things, such opinions cannot be expected to be final: where further evidence leads me to modify any of the views I have here recorded, I shall not hesitate to express my change of opinion.

In conclusion, the generosity which has been exhibited toward my past contributions to milling and baking science gives me confidence that millers and bakers will also extend to the present work their favourable consideration.

WILLIAM JAGO.

SCIENCE SCHOOLS,
BRIGHTON, June, 1886.

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# THE CHEMISTRY,

## THEORETICAL AND PRACTICAL,

OF

# WHEAT, FLOUR, AND BREAD.

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## CHAPTER I.

### INTRODUCTORY.

1. **General Scope of Work.**—The Chemistry of Wheat, Flour, and Bread is so closely associated with certain other departments of science as to render their separation from each other almost impossible. Thus, in order that the chemical composition of a grain of wheat be understood, it is also necessary that the student shall be familiar with its physical structure. The changes which occur during fermentation cannot be mastered without a knowledge of the life-history of yeast and certain other organisms. In addition, therefore, to the purely chemical treatment of the subject, this work will comprise such references to the cognate sciences of botany and biology as will be of service to the miller, baker, and others concerned in the production and manipulation of flour. In compliance with a widely-expressed wish, a chapter will be devoted to a description of modern baking machinery and appliances

2. **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.**

3. **Study of General Chemistry 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. Technical students attending the author's lecture and laboratory classes use for this purpose, as an introductory text-book, "Jago's Elementary Chemistry,

Theoretical and Practical," published by Messrs. Longmans & Co. 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.

**4. Important Preliminary Statements and Definitions.**—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, the whole of its constituents exist as gases, and these weigh exactly the same as did the candle, *plus* the oxygen of the air with which it has combined. **Matter is indestructible, and, consequently, the same weight of material remains after any and every chemical change as there was before its commencement.**

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.

**5. 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. |
|---|---|---|---|---|
| | | 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 |

| Name. | Symbol. | Combining or Atomic Weight. | | Atomicity. |
|---|---|---|---|---|
| | | Old. | New. | |
| 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 |
| 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 |

**6. 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.

**7. 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.

**8. 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 2 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.**

**9. 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."

**10. 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 :—

$$2KI \quad + \quad HgCl_2 \quad = \quad 2KCl \quad + \quad HgI_2.$$

Potassium Iodide. Mercury Chloride. Potassium Chloride. Mercury Iodide.

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 these 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.

11. **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 particle 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 in 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.

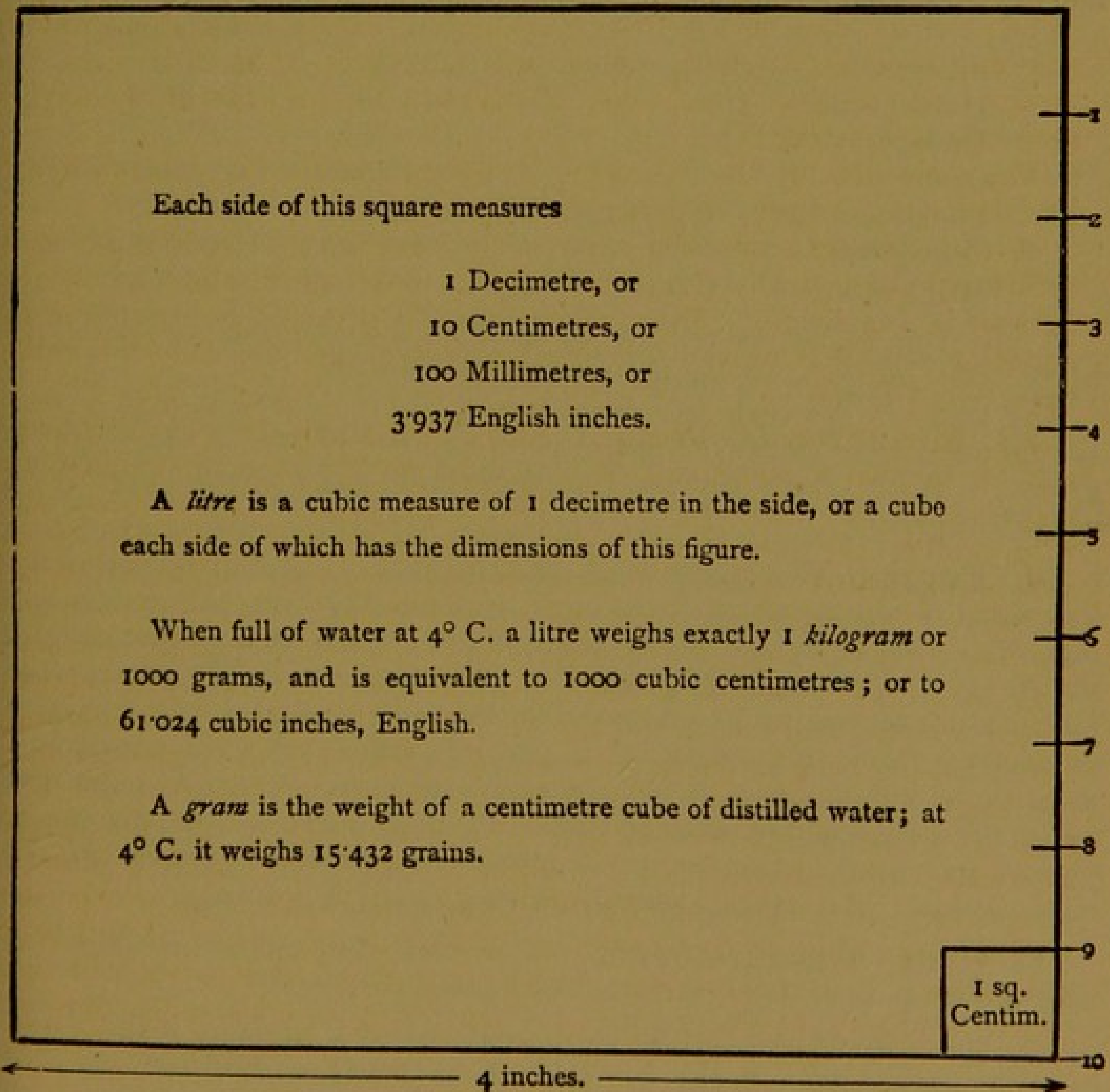
As all elements normally exist in the molecular state, it is advisable to always use equations in which the lowest quantity of any element present is a molecule. Thus, $H_2 + Cl_2 = 2HCl$, should be written as the equation representing the combination of hydrogen and chlorine, rather than, $H + Cl =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

**12. Measures of Weight and Volume.**—It will be convenient to 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 all 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.

**13. 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 ,, | = | 3937·0 ,, |
| Decametre | = | 10 ,, | = | 393·70 ,, |
| Metre | = | | | 39·370 ,, |
| 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.



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 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 ,, | = | 0·6102 | 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.

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 onnces. |
|---|---|---|---|---|
| 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. 3¼ oz., and a hectogram is very nearly 3½ 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 = weight in grams.

**14. 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.

**15. Heat Measurements.**—The most important measures of heat are its temperature, or intensity; and quantity.

**16. Temperature.—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.** 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."

**17. The Thermometer.**—The instrument used for measuring temperature is termed a "thermometer." The thermometer consists of a glass tube of very narrow bore, with a bulb blown at the end; the bulb and part of the tube are filled with mercury, all the air is then driven out, and the tube hermetically sealed by fusing its upper end. The thermometer is placed in contact with any body whose temperature it is desired to measure; if the body be the colder of the two the thermometer yields heat to it, or receives heat if it be the hotter. This transference of heat continues until the temperature of the two is equal. Mercury expands with an increase, and contracts with a decrease, of temperature, but for the same temperature has always the same volume. From the construction of the thermometer any alteration of the volume of the mercury is readily observed; the height of the mercury in the tube is therefore a measure of its volume, and secondarily of its temperature, and that of any body with which it is in contact.

**18. 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 employed. 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 arbitary 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.

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

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 :—

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

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 ,,

**19. Quantity of Heat.**—If two vessels, the one holding a pint the other a quart, are both filled with boiling water, the temperature of the water in each will be the same, but the *quantity* of heat will be double as much in the quart of water as in the pint. **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.**

**20. 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 propor-**

**tional 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.

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 abreviation, " N. T. P." is frequently used.

**21. 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.

**22. 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 $22 \times 0{\cdot}0896 = 1{\cdot}9712$ grams.

**23. 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.

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

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

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

**24. 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 "hydr-acids." 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:—

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

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 bsses 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:—

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

**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:—

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

**25. 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."**

**26. Quantivalence or Atomicity.**—Referring back to the three compounds of hydrogen mentioned in paragraph 23, it will be observed that one atom each of chlorine, oxygen, and nitrogen, combine 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 or 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 never 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 5. 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.

**27. 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. |
|---|---|---|
| $HNO_3$.<br>Nitric Acid. | $H_2SO_4$.<br>Sulphuric Acid. | $H_3PO_4$.<br>Phosphoric Acid. |
| $NaNO_3$.<br>Sodium Nitrate. | $Na_2SO_4$.<br>Sodium Sulphate. | $Na_3PO_4$.<br>Sodium Phosphate. |
|  | $HNaSO_4$.<br>Acid Sodium Sulphate. | $Na_2HPO_4$.<br>Disodic Hydrogen Phosphate. |
| $Ca(NO_3)_2$.<br>Calcium Nitrate. | $CaSO_4$.<br>Calcium Sulphate. | $Ca_3(PO_4)_2$.<br>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:—

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

**28. 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.

**29. 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

$$\begin{array}{l}\text{Na}\quad\ \ \text{H}\quad\ \ \text{S}\qquad \text{O}_4\\ 23\ +\ 1\ +\ 32\ +\ (16\ \times\ 4\ =)\ 64\ =\ 120.\end{array}$$

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

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

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

### 30. 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—

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

$$\frac{10{\cdot}22}{14} = 0.73 \text{ of Nitrogen.}$$

$$\frac{3.65}{1} = 3{\cdot}65 \text{ ,, Hydrogen.}$$

$$\frac{22{\cdot}63}{31} = 0{\cdot}73 \text{ ,, Phosphorus.}$$

$$\frac{46{\cdot}71}{16} = 2{\cdot}92 \text{ ,, Oxygen.}$$

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—

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

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

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

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

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

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 there 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.**

**31. Calculations of Quantities.**—An exceedingly common type of calculation is that in which it is required to know the quantities of one or more bodies 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:—

$$\begin{array}{ccccccc} Zn & + & H_2\,S\,O_4 & = & Zn\,S\,O_4 & + & H_2. \\ 65 & & \underbrace{2+32+64}_{98} & & \underbrace{65+32+64}_{161} & & 2. \\ \text{Zinc.} & & \text{Sulphuric Acid.} & & \text{Zinc Sulphate.} & & \text{Hydrogen.} \end{array}$$

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—

$$\begin{array}{ccccc} C_{12}\,H_{22}\,O_{11} & + & H_2\,O & = & 2\,C_6\,H_{12}\,O_6 \\ \underbrace{144+22+176}_{342} & & \underbrace{2+16}_{18} & & 2 \times \underbrace{72+12+96}_{180} = 360 \\ \text{Cane Sugar.} & & \text{Water.} & & \text{Glucose.} \end{array}$$

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.

$$\begin{array}{ccccc} 2\,C_6\,H_{12}\,O_6 & = & 4\,C_2\,H_5\,H\,O & + & 4\,C\,O_2 \\ 2 \times \underbrace{72+12+96}_{180} = 360. & & 4 \times \underbrace{24+5+1+16}_{46} = 184. & & 4 \times \underbrace{12+32}_{44} = 176. \\ \text{Glucose.} & & \text{Alcohol.} & & \text{Carbon dioxide.} \end{array}$$

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

$$\frac{14\cdot59}{1\cdot9712} = 7\cdot401 \text{ litres at N.T.P.}$$

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

$$\left.\begin{array}{l} \text{As } 273 : 293 :: 7\cdot401 \\ \quad 765 : 760 \end{array}\right\} = \frac{293 \times 760 \times 7\cdot401}{273 \times 765}$$

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

As 16·39 c.c. = 1 cubic inch, then

$$\frac{7891}{16{\cdot}38} = 481{\cdot}7 \text{ cubic inches.}$$

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. Require to know the weight of cane sugar necessary to produce 431·7 cubic inches or 7891 cubic inches of carbon dioxide gas at 20° C. and 765 m.m. pressure.

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

$$7{\cdot}401 \times 1{\cdot}9742 = 14{\cdot}59 \text{ grams of } CO_2.$$

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

**32. 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 a 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.

**33. 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 seperation 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."**

**34. 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 dialysing is termed a dialyser. The phenomena of liquid diffusion have an exceedingly important bearing on many chemical changes which occur during bread-making.

## CHAPTER II.

### DESCRIPTION OF THE PRINCIPAL CHEMICAL ELEMENTS AND THEIR INORGANIC COMPOUNDS.

**35. 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.

**36. 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.

**37. 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."

**38. 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.

**39. 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 temperature 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 atmosphere 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, 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 sufficently 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.

**40. 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 hold; 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 chapter XVII. 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.

**41. 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 with all other elements termed "Chlorides."

**42. 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.

**43. 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.

**44. 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.

**45. Carbon, C.**—This element is only known in the solid state, being incapable of liquefaction or vaporisation at the highest temperatures at our command. 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.

**46. 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 clean coke or charcoal fire. The carbon monoxide, thus produced, burns with a blue flame on the surface of the fire. The gas is inflammable, and in burning yields carbon dioxide. Carbon monoxide has no action on lime-water.

**47. 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.

**48. 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 bicarbonates, 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.

**49. 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."

**50. 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.

**51. 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 microscopic organisms.

**52. Ammonia, $N_3H$.**—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 nitrogeneous 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.

**53. 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.

**54. 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, $HNO_2$.

**55. 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.

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

**57. 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.

**58. 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 occurence in many inorganic bodies, sulphur is one of the constituents of albumin and other animal and vegetable substances.

**59. 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:—

$$\underset{\substack{\text{Sulphuretted}\\ \text{hydrogen.}}}{2SH_2} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Sulphur.}}{S_2} + \underset{\text{Water.}}{2H_2O.}$$

**60. 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.

**61. 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 salt. 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.

**62. 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 $BaSO_4$.

**63. 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.

**64. 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.

**65. 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.

**66. 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.

**67. 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.

**68. 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.

**69. 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.

**70. "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.**

**71. 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.

**72. 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.

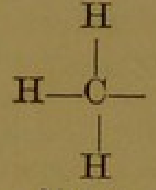
**73. Classification of Organic Compounds.**—The number of these is so bewildering that, without some classification, it would be impossible to grasp their relationship to each other: recent chemical science has succeeded in very clearly demonstrating the constitution of a vast number of these bodies. 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.

**74. 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:—

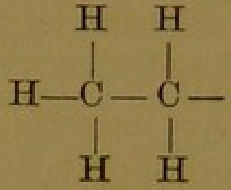
| | | |
|---|---|---|
| Methyl ... | $Me_2$ ... | $\left\{\begin{matrix}CH_3\\CH_3\end{matrix}\right.$ |
| Ethyl ... | $Et_2$ ... | $\left\{\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right.$, or $\begin{pmatrix}CH_3\\C_2H_2\end{pmatrix}_2$, or $\left\{\begin{matrix}CMeH_2\\CMeH_2\end{matrix}\right.$ |
| Propyl ... | $Pr_2$ ... | $\left\{\begin{matrix}C_3H_7\\C_3H_7\end{matrix}\right.$, or $\left\{\begin{matrix}CEtH_2\\CEtH_2\end{matrix}\right.$ |

| | | |
|---|---|---|
| Butyl ... | $Bu_2$ ... | $\left\{\begin{matrix}C_4H_9\\C_4H_9\end{matrix}\right.$ |
| Amyl ... | $Ay_2$ ... | $\left\{\begin{matrix}C_5H_{11}\\C_5H_{11}\end{matrix}\right.$ |
| Caproyl ... | $Cp_2$ ... | $\left\{\begin{matrix}C_6H_{13}\\C_6H_{13}\end{matrix}\right.$ |

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.



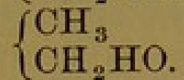
Ethyl.

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.

**75. 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."

**76. 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 :—

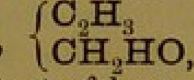
Methyl alcohol, $CH_3HO$, or  $\left\{\begin{array}{l}H\\CH_2HO.\end{array}\right.$ Butyl alcohol, $C_4H_9HO$.

Ethyl ,, , $C_2H_5HO$, or  $\left\{\begin{array}{l}CH_3\\CH_2HO.\end{array}\right.$ Amyl ,, , $C_5H_{11}HO$.

Propyl ,, , $C_3H_7HO$. Melissic ,, , $C_{30}H_{60}HO$.

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

**77. 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.

**78. Ethyl Alcohol,**  **$\left\{\begin{array}{l}C_2H_3\\CH_2HO,\end{array}\right.$ 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 "absolute" 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 degrees 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.

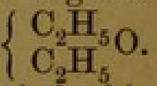
**79. Detection of Alcohol.**—Alcohol when present in any quantity is easily recognised by its smell; in liquids which contain traces only, it is best to distil and then examine the first portions of the distillate. When using a Liebig's condenser, it will be seen, at the point where the vapour begins 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.

**80. 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 portion 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.

**81. 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. Butyl alcohol occurs similarly as one of the bye-products in the preparation of spirits (rum) from the molasses of beet-root sugar. Amyl alcohol is the chief constituent of the analagous substance produced 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 whiskys, especially such as have been manufactured in "small" stills, are exceedingly deleterious; by keeping, the amyl alcohol is oxidised into harmless compounds.

**82. 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.

**83. 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. Glycerin is one of the substances produced during the normal fermentation of sugar, and also is the basic constituent of fats and oils.

**84. 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.

**85. 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.

**86. 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.

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

**88. 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.

**89. 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:—

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

Ethyl. Ethyl Oxide or Ether.

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

Ethyl Hydrate or Alcohol. Acetic Aldehyde. Acetic Acid.

By oxidising agents, two atoms of hydrogen may be removed from alcohol with the formation of acetic aldehydride. 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.

**90. Acetic Acid** 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.

**91. 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.

**92. 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.

**93. 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—

$$\underset{\text{Stearic Acid.}}{3HC_{18}H_{35}O_2} + \underset{\text{Glycerin.}}{C_3H_5(HO)_3} = \underset{\text{Glycerin Stearate.}}{C_3H_5(C_{18}H_{35}O_5)_3} + \underset{\text{Water.}}{3H_2O.}$$

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—

**94. 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.

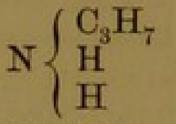
**95. Succinic Acid,** $H_2C_4H_4O_4$.—Succinic acid is a white solid body, soluble in water. It is one of the bodies produced during the normal alcoholic fermentation of sugar. On being heated, succinic acid evolves dense suffocating fumes.

**96. 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."

**97 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:—

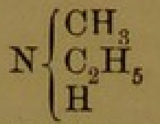
Ethylene —$C_2H_4$.
Propylene—$C_3H_6$.
Butylene —$C_4H_8$.

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 :—



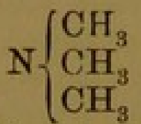
$$N\begin{cases}C_3H_7\\H\\H\end{cases}$$

Propylamine.



$$N\begin{cases}CH_3\\C_2H_5\\H\end{cases}$$

Methylethylamine.



$$N\begin{cases}CH_3\\CH_3\\CH_3\end{cases}$$

Trimethylamine.

The nature and constitution of these bodies are described in paragraph 99.

**98. 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."

**99. 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.

**100. Alkaloids.**—This name is applied to a class of organic bodies, most of which contain nitrogen, carbon, hydrogen, and oxygen. All these bodies are basic, while many are able to neutralise even the strongest acids, as sulphuric acid. They are, as a class, remarkably energetic in their action on animals ; thus, quinine and morphine are most powerful medicines, while strychnine and brucine are among the most violent poisons ; but little is understood of the constitution of the alkaloids; it is probable that they are of the same type as the compound ammonias. For the sake of uniformity in chemical nomenclature, it has been proposed to restrict the termination "ine" to the alkaloids ; for this reason, glycerin, dextrin, &c., should never be written glycerine, dextrine, &c.

**101. Pepsin and Peptones.**—Pepsin is a substance which constitutes the active digestive principle of the fluids of the stomach (gastric juice). Pepsin is soluble in water, but insoluble in alcohol or ether. A slightly acidulated aqueous solution of pepsin, especially at the temperature of the body, rapidly dissolves insoluble albuminous substances, as the white of hard boiled eggs or lean beef. The solutions, thus obtained, do not coagulate on the application of heat, and contain the substance known as "peptone." The energy of pepsin is destroyed by boiling; so also its digestive action is impeded by the presence of peptones themselves in excess. Consequently, when pepsin acts on albumin, &c., the action is at last arrested by the peptones produced. Dried pepsin, mixed with from 20 to 50 per cent. of starch, may now be procured as an article of commerce, being found of considerable value as a medicine. *Pepsin Porci* (*i.e.*, that of the pig) is the variety most generally employed. There are several modifications of peptone, hence the common use of the plural, "peptones." These compounds do not differ very greatly in percentage composition from albuminous bodies; they may be regarded as the product of one step toward their digestion. Subjoined are given the results of analyses of white of egg, and the peptone obtained therefrom :—

| | White of Egg. | Peptone. |
|---|---|---|
| Carbon, ... ... ... | 51·37 | 50·87 |
| Hydrogen, ... ... | 7·13 | 7·03 |
| Nitrogen, ... ... | 16·00 | 16·34 |
| Sulphur, ... ... ... | 2·12 | 1·64 |
| Oxygen (with traces of phosphorus), | 23·38 | 24·12 |
| | 100·00 | 100·00 |

## CHAPTER IV.

### THE MICROSCOPE, AND POLARISATION OF LIGHT.

**102. 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.

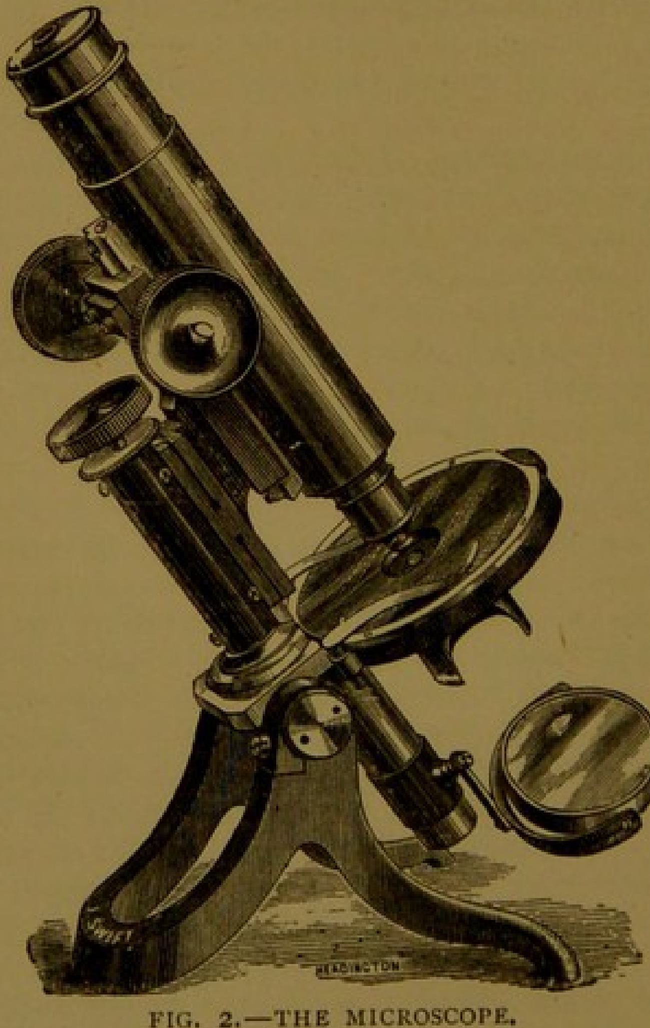


FIG. 2.—THE MICROSCOPE.

**103. 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 Swift, of 81 Tottenham Court Road, 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 actuate this pinion. The stage, which has in this particular instrument a glass surface, is provided with a pair of springs for the purpose of holding the object firmly while being examined. Underneath the stage is a plate or diaphragm, which can be rotated, and which contains a series of apertures of different diameters. Beneath this again is a concave glass mirror, so mounted as to be easily placed in any required position. The tube of the microscope, together with the stage and mirror, can be turned at any angle to the tripod stand, from the vertical to the horizontal. Within the main tube is fitted a second, known as the "draw tube," which can be pulled out if required, thus increasing the distance between the eye-piece and object glass. The lower end of this main tube is provided with an internal screw for the purpose of receiving the combinations of lenses known as "object glasses," or "objectives." The objectives of all the best makers are now cut with the same screw thread, and so are interchangeable. The "eye piece," also a lens combination, slides into the top of the draw tube. The objectives are named according to their focal length, and are consequently termed "1-in. objectives," &c. The greater the focal length the less is the magnifying power of an objective. The eye-pieces also vary in magnifying power, and are usually referred to as "A," "B" eye-pieces, and so on; the magnification increases with each successive letter of the alphabet, commencing with A. The student will require a series of these objectives, consisting of the 3-inch, 1-inch, and $\frac{1}{8}$-inch; these will be found to answer most purposes. For ordinary work the A eye-piece is sufficient, but a C eye-piece is also at times useful. The following accessories are requisite: one or two dozen glass slides, 3 inches by 1; some thin glass covers, these may be round or square, and should be about $\frac{5}{8}$ inch diameter, or square; a pair of fine forceps; one or two needles set in handles; a glass rod drawn out to a point at one end, and a small piece of glass tubing. All these may be obtained from the maker of the microscope, and are usually supplied in the case with the instrument. Other useful pieces of additional apparatus will be mentioned as necessity arises for their employment.

A word may be said in the first place about the preserving of the instrument from injury. When not in use it should either be kept in its case, or what is more convenient, under a glass shade, as then it can be readily used when required. A mounted longitudinal section of a grain of wheat should be purchased at the same time as the instrument; this is a very useful slide to possess, and will give the student an opportunity of learning how to use his microscope before he proceeds to mounting objects for himself.

**104. How to use the Microscope.**—To commence using the instrument, remove it from the case, take the 3-inch objective out of its box and screw it into the bottom of the tube; next insert the eye-piece in its place. The lenses, if dusty, may be very gently wiped with either an old silk handkerchief that has been often washed, or a piece of wash-leather. One or other of these should be kept solely for this purpose. The less, however, that the lenses require wiping the better, as being made of soft glass, they easily scratch. When working on yeast, temporarily mounted in water or other liquid substance, it is necessary to set the stage horizontal, as otherwise the liquid flows downward. But with fixed and permanent objects the microscope should be inclined to an angle of about 45 degrees, as in such a position the eye is much less fatigued during observation. The next requisite is light. In the daytime choose a room that is well lighted, if possible not by direct sunlight, but by a bright cloud. At night an argand gas lamp, especially if enclosed in a ground glass globe, makes a good source of light. Raise the microscope tube by turning the pinion until the end of the objective is about 3 inches from the stage. Place the mounted wheat-grain slide on the stage, and arrange the clips to hold it firmly. Next turn the mirror so as to throw the spot of light on the object. Now look down the eye-piece and lower the microscope tube until the object is focussed; that is, until its outlines are seen clearly without being blurred. A word may here be said about the amount of light advisable; generally speaking the rule may be laid down that it is wise to work with no more light than necessary. The light should not be bright enough to dazzle the eye in the slighest 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 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, shown just underneath the two connected with the pinion, 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 "course adjustment." For the lower powers the course 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.

**105. 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 and hundredth of a millimetre may be taken as equal to the two hundred and fiftieth, and 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. This instrument consists of a scale, which may be an arbitrary one, fixed in the eye-piece. 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 with the lowest power is equal to 0·016 m.m. (=0·00064 inch), the next 0·0064, the next 0·0038, and the highest power 0·0016 m.m. 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 0·0016 × 3·2 = 0·00602 m.m., or 0·0002 = $\frac{1}{5000}$ of an inch.

**106. 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 "$\mu$" (pronounced *mu*); its value in inches is very nearly $\frac{1}{25400}$ inch. The eye-piece measurements referred to in the preceding paragraph would have in mkms. the following values:—

0·016 m.m. = 16·0 mkms.
0·0064 m.m. = 6·4 mkms.
0·0038 m.m. = 3·8 mkms.
0·0016 m.m. = 1.6 mkms.

**107. 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.

**108. 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.

**109. Camera Lucida.**—For tracing with the microscope an ingenious appliance has been invented, which is known as a "camera lucida;" there is also a modification termed a neutral tint camera. Space does not permit our describing these, but they fit over the eye-piece, and when properly arranged either project the microscope image so that it appears to be on the sheet of paper designed for its reception, or displaces the image of the paper so as to cause it to be seen apparently in the centre of the field of the microscope. In either case the image and the surface of the paper are made to coincide. Some cameras are constructed on the principle of the image being seen by one eye and the paper with the second, while in others both the paper and the image are visible to one and the same eye. When using a camera the paper and image should, as nearly as possible, be equally illuminated.

As a preliminary to tracing with the camera, place the stage micrometer in focus, and the microscope and paper in their respective positions. These may be any that are most convenient. Then 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. 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.

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.

**110. 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."

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 direction 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.

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 polarimeters 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.

**111. Construction of Wheat Grain.**—Having given 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.

**112. 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 albuminoids. Of these substances the fats have the simplest composition, next come the starchy bodies, and lastly, the albuminoids, whose constitution is extremely complex. It may be stated as a general rule that the more complicated the constitution of a body, the more easily is it broken up into simpler compounds: this holds good in the case at present under consideration. The fats are not liable to undergo any very radical alteration in chemical constitution; starch changes more readily, while the albuminoids under favourable circumstances decompose with great rapidity.

**113. 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 perceptable 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.

**114. 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:—

| | Per Cent. |
|---|---|
| Glycerin, ... ... ... ... | 1·30 |
| Oleic acid, ... ... ... ... | 91·60 |
| 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.

Many bakers assert that the fat of flour deadens fermentation, and state that greasy flours do not rise anything like so well as do those flours from which all oily matters have been removed. It is probable that the so-called greasy nature of flours is due not to the presence of excess of fat, but to faulty milling or unsound wheats. Either of these causes would tend to produce the greasy feel referred to, and would militate against the flour behaving well during fermentation. Fat of itself has no injurious action on yeast.

### Experimental Work.

**115.** 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.

**116. 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 application 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.

**117. Fat.**—In a tightly corked or stoppered bottle, shake up together some wheat meal and ether, allow the mixture to stand for an hour, giving it an occasional shake meanwhile. At the end of that time, filter the ether 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.

**118. Definition of "Carbohydrate."**—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, together with their simplest possible formulæ:—

| | |
|---|---|
| Cellulose, ... | $C_6H_{10}O_5$. |
| Starch, ... | $C_6H_{10}O_5$. |
| Dextrin, ... | $C_6H_{10}O_5$. |
| Maltose, ... | $C_{12}H_{22}O_{11}$. |
| Cane Sugar, ... | $C_{12}H_{22}O_{11}$. |
| Milk Sugar, ... | $C_{12}H_{22}O_{11}$. |
| Glucose, or Grape Sugar, ... | $C_6H_{12}O_6$. |

### CELLULOSE, $C_6H_{10}O_5$.

**119. Occurrence and Physical Properties.**—This body constitutes the frame-work 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.

**120. 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. Francis has recently found that 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. He recommends the use of such papers for filtering bodies that have to be removed from the paper while wet. (See Chem. Soc. Jour., Vol. XLVI., p. 183.)

**121. Existence in Wheat.**—The cellulose of wheat exists principally in the bran, but is also found in small quantity disseminated throughout the whole of the grain. Flour contains very little cellulose, and that little is in an extremely finely divided state.

**122. Composition.**—The formula, $C_6H_{10}O_5$, is the simplest that can be derived from the percentage composition of cellulose, but it is extremely probable that the molecule really consists of a number of groups of $C_6H_{10}O_5$ united together.

### STARCH, $nC_6H_{10}O_5$.

**123. 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.

**124. 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.

125. **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.

## Microscopic Characters of Various Starches.

126. **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.

127. **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.

128. **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.

129 **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.

**130. 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.

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

**132. 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.

**133. 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.

For particulars given in the above table the writer is in part indebted to Muter's classification, as quoted in Blyth's Composition and Analysis of Foods.

**134. Solubility 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. The temperature at which this change occurs varies with the nature and origin of the starch.

The following table gives, on the authority of Lippman, particulars as to the gelatinising temperatures of starch from different sources:—

| Source of Starch. | Granules Swollen. | | Gelatinisation. | | | |
|---|---|---|---|---|---|---|
| | | | Commenced. | | Completed. | |
| | °C. | °F. | °C. | °F. | °C. | °F. |
| Barley, ... ... | 37·5 | 99·5 | 57·2 | 135 | 62·2 | 144 |
| Maize, ... ... | 50·0 | 122·0 | 55·0 | 131 | 62·2 | 144 |
| Rye, ... ... | 45·0 | 113·0 | 50·0 | 122 | 55·0 | 131 |
| Potato, ... ... | 46·1 | 115·0 | 58·3 | 137 | 62·2 | 144 |
| Rice, ... ... | 53·8 | 129·0 | 58·3 | 137 | 62·2 | 144 |
| Wheat, ... ... | 50.0 | 122·0 | 65·0 | 149 | 67·2 | 153 |

Wittmack disagrees with these results in so far as they concern rye flour, which he states commences to gelatinise at 60° C. (The Miller, Dec. 1, 1884; p. 798.)

**135. 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 ,, |

**136.—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.

**137. 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. Soluble starch 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 characteristic of starch. For the purpose of this test, the iodine may be dissolved in either acohol or an aqueous solution of potasium 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. 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 likely to interfere with the iodine reaction for starch are some of the dextrins; these bodies give a brown colouration with iodine, 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.

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 144, on maltose.)

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

**138. 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 gluten 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.

### DEXTRIN, $C_6H_{10}O_5$.

**139. 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.

**140. 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.

**141. 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.

**142. Chemical Character**—Dextrin almost certainly consists of a mixture of polymeric bodies of closely similar chemical character. These several dextrins are 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," strike a reddish-brown colouration on treatment with iodine; the others, which are classified as "achroo-dextrins," yield no colouration when iodine solution is added. 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.*

**143. 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 occuring both in the animal and vegetable kingdom.

**144. 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 $2\ CuO = Cu_2O + O$. 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.

**145. 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.

**146. Milk Sugar, $C_{12}H_{22}O_{11}$.**—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.

**147. 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 lœvulose or lævo-glucose.

**148. 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.

**149. Lœvulose or Lœvo-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 lœvo-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. Lœvo- and dextro-glucose both act similarly on Fehling's solution.

**150.—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 lœvulose. Cane sugar is also converted into a mixture of dextrose and lœvulose 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.

**151. Malto-dextrin,** $\left\{ \begin{array}{l} C_{12}H_{22}O_{11}. \\ (C_{12}H_{20}O_{10})_2 \end{array} \right.$ — Recent researches of Brown and Morris indicate the existence of a carbohydrate having the above composition, and which they have termed "malto-dextrin," from the supposition that it consists of a combination of maltose and dextrin. (Chemical Society's Journal, Vol. XLVI, page 527, *et seq.*).

### EXPERIMENTAL WORK.

**152. 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.

**153. 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 microscope stage, and focus the instrument, using first the inch and then a 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.

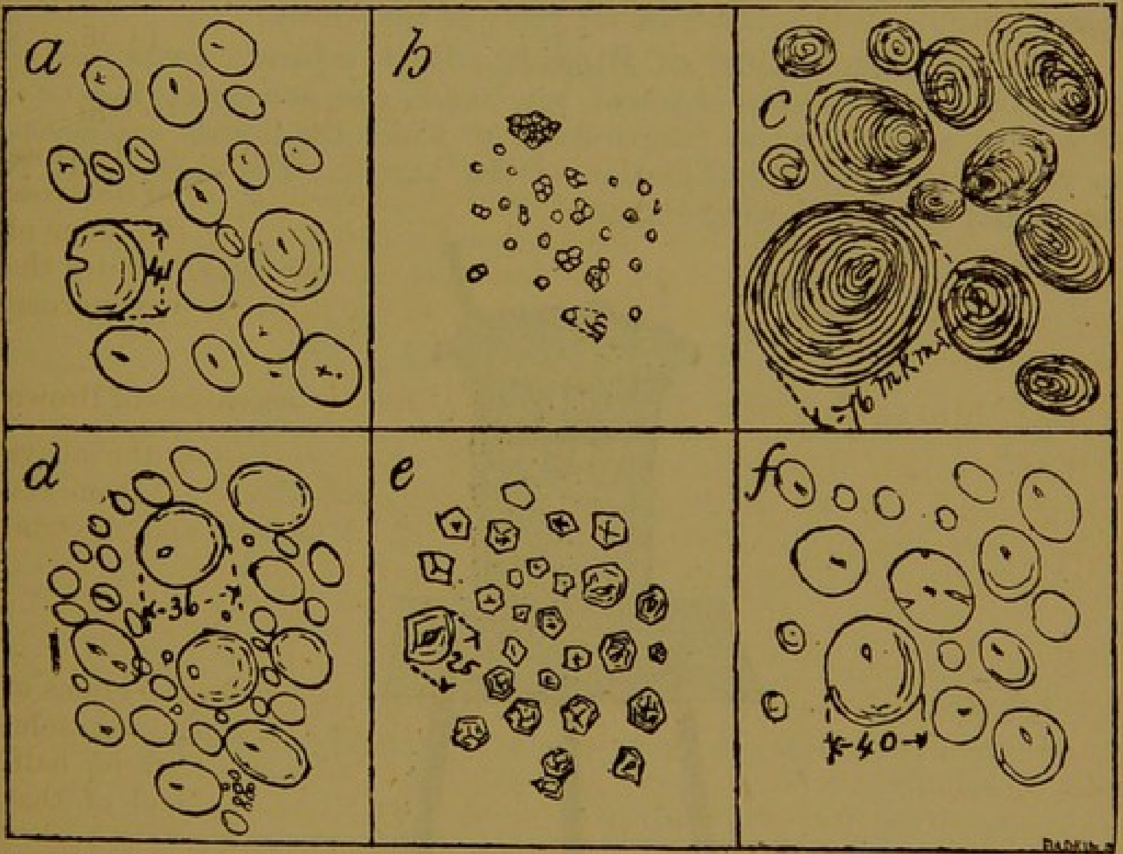


FIG. 3.—MICROSCOPIC SKETCHES OF VARIOUS STARCHES, MAGNIFIED ABOUT 87 DIAMETERS.

*a*, Barley. *b*, Rice. *c*, Potato. *d*, Wheat. *e*, Maize. *f*, Rye.

Figure 3 is a fac-simile of such a working sketch as the student should himself make while studying starches under the microscope. Most of the microscopic sketches given in this work are purposely fac-similes of actual students' drawings rather than finished engravings. It is hoped that such sketches will answer the double purpose of demonstrating to the reader the essentials of whatever is being examined, and at the same time will serve the student as examples of such drawings as should appear in his own note-book.

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 knife 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.

**154. 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.

**155. 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.

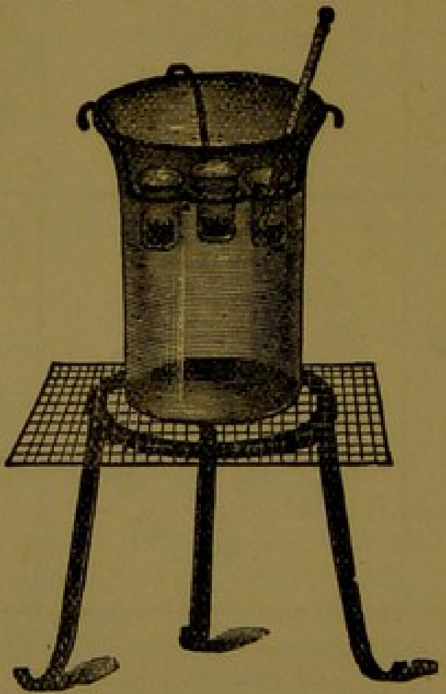


FIG. 4.—APPARATUS FOR DETERMINING TEMPERATURE OF GELATINISATION OF STARCH.

Place a moderately large beaker on a piece of wire gauze over a tripod, as in figure 4. 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. Wittnack uses this test as a means of detecting rye as an adulterant of wheat flour. He removes the beaker containing the sample as soon as it reaches 61° C.; he then finds that the heat of the sides is sufficient to raise the temperature to 62·5° C. At this temperature, Wittnack states that the rye starch granules nearly all puff up and burst, while those of wheat are scarcely affected. The appearance of each, as revealed by the microscope, is shown in figures 5 and 6.

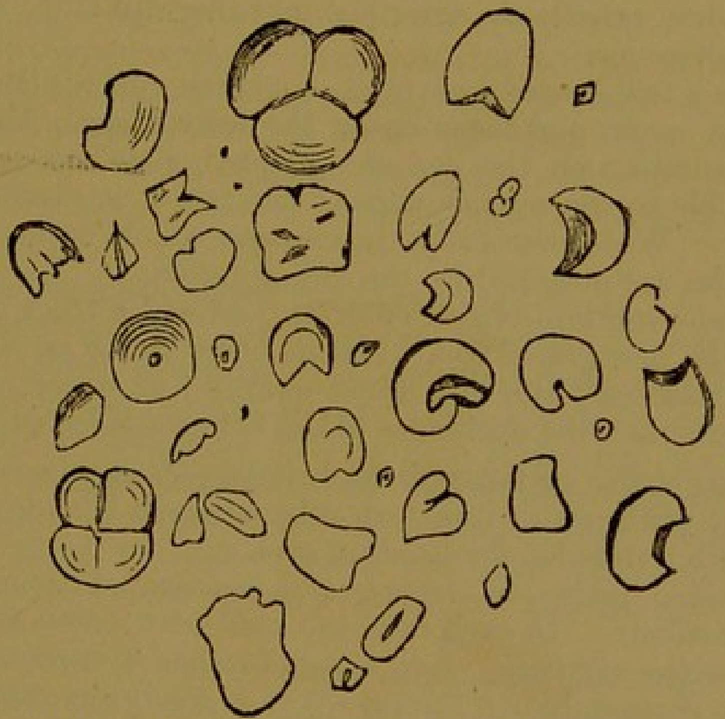


FIG. 5.—STARCH GRANULES OF RYE, NEARLY DISSOLVED AT 62·5° C.

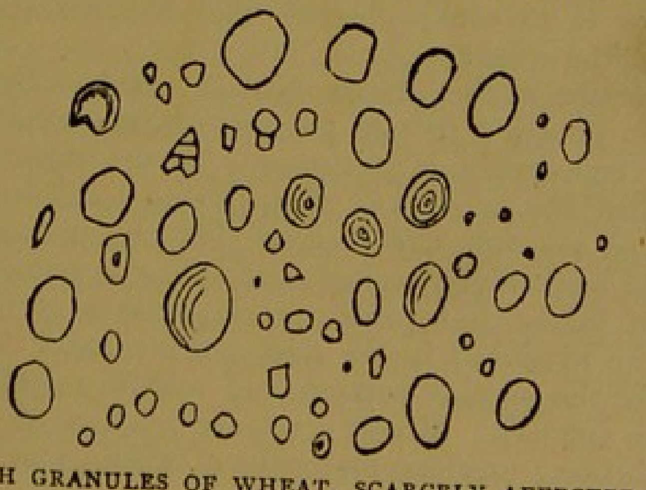


FIG. 6.—STARCH GRANULES OF WHEAT, SCARCELY AFFECTED AT 62·5° C.

For a full description of Wittnack's mode of testing, the reader is referred to his essay on rye and wheat flour, published in *The Miller* in October and following months of the year 1884. For figures 4-6, the author is indebted to the courtesy of the proprietor of that journal.

**156. Action of Caustic Alkalies, and Zinc Chloride, on Starch.**—Prepare a set of solutions of caustic soda of the strength described in paragraph 135. To do this, weigh out 10 grams of caustic soda, dissolve in a small quantity of water, and then make up the volume to 100 c.c. in a measuring flask (see chapter XIX); this gives a 10 per cent. solution. From this solution, the weaker ones are prepared by mixing with water in the requisite proportions. For the 0·6 per cent. solution, take 6 c.c. of the standard soda, pour them into the clean 100 c.c flask, add water up to the graduation mark, and shake up; for the 0·7 per cent. solution, take 7 c.c., and so on for the others. The soda solution should be measured from a burette; this also is described in chapter XIX. With these solutions, treat small quantities of the various starches exactly as described in paragraph 135, and examine under the microscope.

Next place a few granules of starch, together with a little water, on a slide under a cover, and focus under the microscope. Take a drop of caustic soda solution on the end of a pointed glass rod, and drop it as close as possible to the outside edge of the cover, so that it may freely run in under. Watch carefully the changes which occur in the starch as the granules are attacked by the soda solution.

Prepare some solution of zinc chloride, and add a trace of free iodine, as described in paragraph 136. Mount some starch on a slide with a little of this solution; run in a small quantity of water at the edge of the slide, and watch the occurence of the changes referred to.

**157. 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.

**158. 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 erythro-dextrins. 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.

**159. 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 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.

## TRANSFORMATIONS OF THE CARBOHYDRATES.

**160.** 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 occurence.

**161. Hydrolysis.**—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."

**162. 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. There is another most important group of hydrolysing agents; these consist of certain soluble bodies of organic origin, and among them may be mentioned 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. The following are the names that have been given to active principles obtained from the hydrolytics above mentioned:—

| Substance. | Name of hydrolysing constituent. |
|---|---|
| Human saliva. | Ptyalin. |
| Yeast. | Zymase or Invertin. |

| Substance. | Name of hydrolysing constituent. |
|---|---|
| Flour, Bran (more especially the latter). | Cerealin. |
| Malt. | Diastase. |

Of these substances, the active hydrolysing agent of malt has been the most carefully examined : unlike the acids, diastase is incapable of converting starch further than into dextrin and maltose. Zymase transforms both maltose and cane sugar into glucose, but has very little action on dextrin. Notwithstanding widely spread statements to the contrary, neither zymase nor yeast has any action on starch paste.

**163. 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.**

**164. Saccharification.**—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.

**165. 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.

**166. 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. With regard to the history of starch and its transformations, there is a paper of singular interest, by Brown and Heron, in Vol. XXXV., p. 596, year 1879, of the Chemical Society's Journal. Brown, in conjunction with Morris, continues the subject in a paper on "The non-crystallisable products of the action of Diastase upon Starch," in Vol. XLVI., p. 527, year 1885, of the same journal.

The following paragraphs (167-173) consist largely of a summary of the conclusions arrived at by these chemists as a result of their researches.

### Brown, Heron, and Morris' Researches.

**167. Malt Extract employed.**—It was found that a cold aqueous infusion of malt was the most convenient diastasic agent to employ, as diastase when prepared 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.

**168. 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.

**169. Action of Malt Extract on Ungelatinised Starch.**—Malt extract is incapable of acting on unaltered starch: even when contact between the two is maintained for a considerable time, not the slightest action is perceptible at ordinary temperatures.

It is well known that the starch of seeds is attacked and dissolved during the natural act of germination, but this action seems to be 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."

Brown and Heron give no particulars as to the action of malt extract on ungelatinised starch at higher temperatures; but 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 recently made a series of experiments on sound wheaten starch, obtained by washing from Hungarian flour; this at 35° C. was not acted on by an infusion of wheat germ. It is safe to state that, up to this temperature, *sound* starch cells are unacted on by diastase, whether of malt or the other cereals.

**170. Action of Malt Extract on Bruised Starch.**—It having been found that sound starch cells resisted the action of malt extract, 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.

**171. 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. Erythro-dextrin is shown to be present by the brown reaction with iodine, and does 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.

**172. 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 erythro-dextrin 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.

**173. Molecular Constitution of Starch, Dextrin, and Maltose.**—The most natural conclusion that can be derived from these varying proportions of dextrin, obtained in modifications of the hydrolysis of starch paste by malt extract, is that there are several dextrins. The evidence further points to these dextrins being polymeric, not metameric bodies (see Chapter III., paragraph 97). This view being adopted, 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 then, produced by the addition of malt extract, would 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 $C_{12}H_{20}O_{10}$ has 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, they adduce evidence in favour of a third body, malto-dextrin, being formed as an intermediate product during the hydrolysis of starch; as previously mentioned, they ascribe to this body the formula, $\left\{\begin{array}{l} C_{12}H_{22}O_{11} \\ C_{12}H_{20}O_{10}. \\ C_{12}H_{20}O_{10} \end{array}\right.$ From this it will be seen that malto-dextrin 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 now regard the following as the simplest molecular formula for starch, capable of accounting for the various reactions observed during its hydrolysis—

$$\left\{\begin{array}{l} (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \\ (C_{12}H_{20}O_{10})_3 \end{array}\right.$$

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

$$\underset{\substack{\text{One of the five ternary groups} \\ \text{constituting the starch molecule.}}}{(C_{12}H_{20}O_{10})_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Malto-dextrin.}}{\left\{\begin{array}{l} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{array}\right.}$$

Malt extract effects the complete conversion of malto-dextrin into maltose—

$$\underset{\text{Malto-dextrin.}}{\left\{\begin{matrix} C_{12}H_{22}O_{11} \\ (C_{12}H_{20}O_{10})_2 \end{matrix}\right.} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Maltose.}}{3C_{12}H_{22}O_{11}}.$$

In the change producing malto-dextrin, 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 $\zeta$. 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, make 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 :—

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

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

### Details of Hydrolysis.

**174. 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 :—

$$\underset{\text{Soluble Starch.}}{(C_6H_{10}O_5)_5} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Dextrin.}}{C_6H_{10}O_5} + \underset{\text{Maltose.}}{2C_{12}H_{22}O_{11}}.$$

**175. 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. Zymase also slowly hydrolyses this compound. 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—

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{10}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextro-glucose.}}{C_6H_{12}O_6} + \underset{\text{Lœvo-glucose.}}{C_6H_{12}O_6}.$$

**176. 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 zymase nor yeast itself is capable of effecting the hydrolysis of dextrin.

**177. Hydrolysis of Malto-dextrin.**—This change is readily effected by the action of malt extract, but not by either zymase or yeast.

**178. 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. Zymase converts maltose into glucose. The probable chemical change is—

$$\underset{\text{Maltose.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextro-glucose.}}{2C_6H_{12}O_6}.$$

**179. 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 55 to 60 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 can only proceed in the case of such starch cells whose walls are fissured. At a temperature of about 60° C. (140° F.) almost all the starch and also the erythro-dextrins 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.

**180. 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.

**181. Conditions Inimical to Diastasis.**—Diastasic action is rapidly weakened at temperatures above 65° C. ; while at 80-81° the diastasic power of malt extract is entirely destroyed. Acetic and hydrocyanic acids, strychnine, quinine, and the salts of these bases very slightly 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, choloroform, creosote, essence of turpentine, cloves, lemon, mustard, &c., exert no retarding influence.

### EXPERIMENTAL WORK.

**182. 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 subside 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 167. 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 171; 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 erythro-dextrins 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.

**183. Hydrolysis of Cane Sugar.**—Mix cane sugar solution with strong hydrochloric acid, and heat to 68° or 70° C., as described in paragraph 175. 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.

**184. 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.

**185. Substances inimical to Diastasis.** — Prepare some starch solution and malt extract as in paragraph 182. 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 VIII.

### ALBUMINOIDS OR PROTEIDS.

**186.** The most important nitrogenous substances present in wheat and flour are those classified together as albuminoids or proteids. These are substances of extremely complex constitution, and have very high molecular weights. They are non-crystallisable and highly colloid bodies. The albuminoids consist of a number of more or less allied compounds, derived from both the animal and vegetable kingdom: they are so named because of their similarity in composition and general properties to the white of egg, which may be taken as a type of the others. It is in some cases doubtful whether the albuminoids from different sources are or are not identical with each other, while in other instances, their physical characters indicate that they are distinct bodies.

**187. List of Albuminoids.**—The following is a list of the more important compounds commonly classed as albuminoids—

I. Albumin of the egg, albumin of serum (the liquid portion of coagulated blood), vegetable albumin.
II. Casein, vegetable casein, or legumin.
III. Blood fibrin, vegetable fibrin, or insoluble albumin, gliadin or glutin, and mucin or mucedin.
IV. Diastase, and cerealin.

**188. Composition of Albuminoids.**—In percentage composition, the albuminoids closely resemble each other; but still there are sufficient differences to render it improbable that they are simply isomeric or polymeric bodies. In the following table, the results of analyses of some of the more important of these bodies are given—

| | Egg Albumin. | | | Blood Fibrin. | Casein. | Gluten. | Legumin. |
|---|---|---|---|---|---|---|---|
| | Not Coagulated. | Purified. | Coagulated. | | | | |
| Carbon,......... | 53·3 | 52·9 | 52·9 | 52·8 | 53·5 | 53·1 | 53·7 |
| Hydrogen,...... | 7·1 | 7·2 | 7·2 | 7·0 | 7·1 | 6·8 | 7·2 |
| Nitrogen, ...... | 15·8 | 15·6 | 15·8 | 16·8 | 15·8 | 15·0 | 15·7 |
| Oxygen and Sulphur, | 22·1 | ... | ... | 23·4 | 23·6 | ... | 23·4 |
| Sulphur,........ | 1·8 | ... | ... | ... | ... | ... | ... |

It will be seen that in composition they are very similar, but also that differences exist, greater than can be accounted for by experimental errors in analysis. One obstacle in the way of arriving at accurate knowledge of the composition of the albuminoids is that their preparation in a state of purity is a matter of difficulty. The albuminoids contain, in addition to carbon, hydrogen, and oxygen, not only nitrogen, but also sulphur. It was at one time conjectured that this latter element was simply an accidental ingredient of albumin; further research has led to its being recognised as an essential constituent of the albuminoids. From the above quoted percentage composition of egg albumin, Lieberkühn has calculated that its simplest possible empirical formula is $C_{72}H_{112}N_{18}O_{22}S$. This being the empirical formula, it is highly probable that the actual molecule may contain several such groups. Further, if certain of the albuminoids are polymeric, their formulæ will consist of different multiples of this group.

**189. Egg Albumin.**—It was not long after the attention of chemists had been turned to the study of flour that it was found that on washing a lump of dough, enclosed in muslin, in water, an elastic body remained. It was further observed that, on being burned, this peculiar substance evolved an odour similar to that given off by many animal substances under the same circumstances. Among these bodies there was one in particular which, as more exact investigation was made, was found to possess a most remarkable resemblance to this elastic constituent of flour. The body referred to is the white of an egg, and, as the type of the bodies whose chemistry is now being studied, merits a somewhat extended description. It is frequently stated that white of egg is an almost pure form of "albumin," that being the name of the compound whose presence confers on this substance its characteristic properties. Albumin is not, however, the principal constituent of the white of egg, as it only amounts to about 12 per cent. of the whole mass, the remainder being water. Not only is albumin found in eggs, but also in blood serum and most of the organs of the body. Albumin exists in two distinct modifications, viz., in the soluble and liquid form, and also in an insoluble form, which may be produced from the soluble by the action of heat. The two forms are identical in chemical composition: instances of the both occur in respectively the raw and the boiled white of egg. The albumin, both of blood serum and white of egg, on being burned, leaves behind a residue consisting principally of sodium carbonate. This leads us to consider that these bodies really contain albumin in a state of combination, with sodium as a base, and that albumin itself may be viewed as a weak organic acid. In its purest form albumin has a slightly acid reaction with litmus.

Pure albumin may be obtained from white of egg by first beating it up with water; this treatment breaks the cell walls and liberates the soluble compound of albumin and sodium. In order to effect the separation of sodium and albumin, a lead salt (the sub acetate) is added; this produces a precipitate of lead albuminate. This precipitate is thoroughly washed and then made into a paste with water, the lead is then removed by passing carbon dioxide gas into the liquid; lead carbonate is precipitated, and albumin remains in solution. The solution, on being evaporated at low temperatures, yields a residue of pure soluble albumin. Albumin thus obtained is a pale yellowish, translucent mass, which may be easily powdered. It swells when treated with pure water, but does not dissolve freely; the addition of any alkaline salt causes its ready solution. Albumin prepared in this manner leaves no appreciable residue on being burned. On analysis it is found to possess the following percentage composition:—Carbon, 53·3; hydrogen, 7·1; nitrogen, 15·7; oxygen, 22·1; and sulphur, 1·8. A solution of albumin in water, on being heated, becomes opalescent at a temperature of 60° C. (140° F.), and at 63·3—87·7° C., (146—190° F.), the whole coagulates in a mass. When the liquid is very dilute it simply becomes turbid, and deposits "flocks" of albumin on evaporation. Albumin is insoluble in alcohol and ether; these bodies, on being added in excess to the aqueous solution, precipitate albumin in the coagulated form. Oils and fats, whether fixed or volatile, are without action on albumin. Nearly all the acids precipitate albumin from its solution; so also does mercuric chloride and other salts; nitric and picric acids are in this way specially effective, and are frequently used as tests for the presence of soluble albumin.

If a small quantity of acetic acid be added to the white of egg, so as to just neutralise the alkali; and then the liquid diluted with water, flocks of albumin are after a while deposited. This precipitate immediately dissolves on being treated with a small quantity of nitre or common salt: the solution thus obtained is coagulated on boiling.

A solution of albumin exerts a lœvo-rotary action on polarised light: it has no reducing action on Fehling's solution.

On boiling coagulated albumin with water for about sixty hours it gradually disappears, being converted into a substance soluble in water. The white of egg, when boiled, gives up a portion of its sulphur as sulphuretted hydrogen. 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.

**190. Blood Albumin.**—This body, from a chemical point of view, behaves almost exactly similarly to egg albumin.

**191. Vegetable Albumin.**—Not only is albumin found in different animal products, as white of egg, but is also a constituent of most vegetable juices; for instance, on making a cold aqueous infusion of flour, or, still better, of the germ of wheat, and then filtering the solution until properly clear, a liquid is obtained which, on being raised to the boiling point, throws down abundant flocks of albumin. The albumin, thus precipitated, is as white and pure in apearance as that from the white of egg, and is, to all intents and purposes, identical with that of egg, and blood serum. While the egg albumin always occurs in an alkaline liquid, that of vegetables is always found either in acid or neutral liquids.

**192. Legumin or Vegetable Casein.**—After the removal, by boiling, of vegetable albumin from an aqueous extract of flour, there still remains another albuminoid body in solution; the albumin having been filtered off, an addition of acetic acid produces a further precipitate of a compound known as "legumin," or vegetable casein. Peas, beans, and lentils are the principal sources of legumin, these bodies being frequently termed leguminous bodies. A solution of legumin is not coagulated by boiling, but on evaporation is covered with a film or pellicle similar to that which forms on milk on being heated. Legumin in many respects resembles the casein or nitrogenous matter of milk. Legumin, on putrefying, acquires properties very similar to those of the other wheat albuminoids.

**193. Soluble Albuminoids of Wheat.**—These consist principally of vegetable albumin and legumin; they are not distributed equally throughout the whole seed, there being certain portions of the wheat grain which are specially rich in soluble albuminoids; 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 almost entirely of starch. Bran, on being treated with dilute alcohol, in order to remove dextrin and maltose, and then with water, yields to the latter solvent an albuminoid body which may be coagulated by the action of heat. The aqueous infusion of germ, as has been already stated, also throws down an abundance of an albuminoid body on being heated; this albuminoid is very similar to that of the bran. They both possess points of very great interest to the miller and baker.

**194. Insoluble Albuminoids of Wheat, Gluten.**—Every miller and baker knows that flour, on being moistened, forms a stiff, tenacious paste or dough; he further 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 albuminoids 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, and dried, does not again swell up on being wetted. The dry gluten may be kept for a long time without change, but if when wet it is exposed to air at ordinary temperatures it gives of 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. Gluten is not a simple chemical compound, but may be split up into distinct proximate principles.

**195. Composition of Gluten.**—According to Ritthausen, gluten consists of three separate albuminoids, termed respectively—glutin, gliadin or vegetable gelatin, mucin or mucedin, and vegetable fibrin. To effect the separation of these bodies, freshly washed gluten must be cut up into small fragments and digested for several hours with alcohol of 80 or 85 per cent. strength. The alcohol is then raised to the boiling point, and maintained at that temperature for half-an-hour. The supernatant liquid is then poured off and filtered, and the residual mass of gluten heated several times with alcohol of 75 per cent. The mixed alcoholic filtrates become turbid if allowed to cool; but on their being subjected to distillation until half the alcohol has been expelled, the remainder, on cooling, deposits considerable quantities of flocculent mucin, together with glutin and fat. In order to purify the mucin, it is dissolved in 50 per cent alcohol; the solution is filtered, while hot, through fine calico, and then allowed to cool, being frequently agitated while the deposit, consisting of mucin, forms. The whole of the glutin is then contained in the clear liquid, together with traces of mucin. In order to obtain the glutin from the clear liquid, it is evaporated over the water-bath, this renders any mucin present insoluble; the glutin may then be redissolved in alcohol or dilute acetic acid, and filtered from the mucin. The portion of the gluten which remained insoluble, when digested and finally boiled with alcohol, consists of vegetable fibrin.

Günsberg is of opinion that Ritthausen's mucin is not a separate chemical compound, but simply fragments of suspended fibrin; he further considers that the gliadin obtained by Ritthausen's method is not a simple proximate principle, for cold water extracts from it a brown substance, containing nitrogen and sulphur. The residue, on treatment with boiling water, is dissolved, and on cooling deposits a sulphur free substance, containing carbon, 52·77; hydrogen, 6·79; nitrogen, 17·66; and oxygen, 22·78 per cent. Günsberg regards this substance as being true vegetable gelatin: it has nearly the same composition as animal gelatin. Ritthausen's views are, however, those most commonly held.

**196. Glutin, Gliadin, or Vegetable Gelatin.**—This body, when in the hydrated state, is either a yellowish limpid liquid, or with a less proportion of water, a soft pasty substance, capable of being drawn out into threads. On the water being removed by alcohol, and subsequent treatment with ether; glutin, on being dried *in vacuo*, forms a brittle mass. Alcohol of from 40 to 80 per cent. dissolves glutin readily, but absolute alcohol precipitates it from solutions; on evaporation of alcoholic solutions, glutin separates in a form exactly resembling animal gelatin. Glutin dissolves slightly in cold, and somewhat more readily in hot water; consequently, prolonged washing of wet gluten slowly removes the glutin. Glutin is precipitated from its solutions by mercuric chloride, and is dissolved easily and completely by tartaric, acetic, and other organic acids. Moist glutin is stained a fine red colour by mercurous nitrate. As a result of the action of heat, glutin becomes changed into forms much less soluble both in water and in alcohol. Gliadin, left in contact with water, passes into solution and putrefies.

Pure glutin yields, on analysis, carbon, 52.49; hydrogen, 6·97; nitrogen, 18·02; sulphur, 0·85; oxygen, 21·41; ash, 0·26 per cent.

Glutin is that constituent of wheaten flour which imparts to it the property of forming a stiff elastic dough, capable of retaining vesicles of gas, and thus producing a light and porous loaf. The flours of barley, rye, and oats, yield only traces of glutin on being boiled with alcohol: their insoluble albuminoids consist of only vegetable fibrin. Glutin is also absent in sensible quantity from the flours of peas, beans, and lentils. Glutin occurs in the juice of the grape.

**197. Mucin, or Mucedin.**—Mucin, when prepared according to the preceding directions, is a transparent slightly coloured flocculent body. On removal of water by absolute alcohol, and then drying *in vacuo*, mucin acquires a greyish-white colour, and becomes brittle.

Mucin dissolves in boiling alcohol, and separates out on cooling; cold acetic acid also dissolves it. Under certain circumstances, this body assumes an insoluble form, when it is scarcely distinguishable from fibrin. This change may be produced by leaving the precipitated mucin for some time in contact with cold water, or in dilute alcohol.

**198. Vegetable Fibrin, or Insoluble Albumin.**—This body constitutes about 80 per cent. of the crude gluten, and consists of that portion of the albuminous matter of flour, insoluble in water and alcohol. Vegetable fibrin occurs also in rye, barley, and the other cereals. Vegetable fibrin, when prepared according to Pitthausen's directions, before given, is a greyish-white elastic mass, still containing small quantities of starch. From these it may be purified by solution in dilute caustic potash, and filtering the liquid. Acetic acid is then added in sufficient quantity to neutralise the potash, when the fibrin is re-precipitated. Any traces of fat present may be removed by exhaustion with ether. Vegetable fibrin on being dried, forms a brownish horny mass, which slowly recovers its original condition when left in contact with water. It is dissolved by acetic, hydrochloric, and phosphoric acids, caustic potash and soda, and ammonia; it may be re-precipitated from any of these solutions by neutralisation with either dilute alkali or acid. Common salt (sodium chloride) precipitates vegetable fibrin from its solutions, and retards or arrests the action on it of dilute acids as solvents. Diastase exercises a solvent action on vegetable fibrin.

Vegetable fibrin, being insoluble in water, cannot properly be said to be capable of forming an insoluble modification; but such fibrin is sometimes found to hydrate during the doughing of flour much more slowly than at others.

**199. Mutual Relations of Glutin, Mucin, and Vegetable Fibrin.**—It will be seen that these three bodies, gliadin, mucin, and vegetable fibrin are similar in composition, and differ principally in their relative solubility. The difference in character between the glutens of various wheats depends, in part at least, on the relative proportions in which these three bodies are present, and also on whether they exist in the soluble or insoluble forms.

**200. Non-existence of Gluten as such in Flour.**—The view is in some quarters held that gluten as such does not exist in flour, but is formed when the flour is wetted, from the previously existing nitrogenous bodies. If wheaten flour be moistened with alcohol of only moderate strength, dough is not formed, but simply a damp, sandy mass, similar to moistened oat flour; the same effect is produced when a strong solution of salt is used instead of water.

While diastase is capable of transforming starch into dextrin and maltose, it is advocated by some that a body exists which hydrolyses the dry nitrogenous constituents of wheat into the moist tenacious gluten. It is well known that certain chemical changes are produced on moistening vegetable substances; thus bitter almonds, on being crushed with water, yield hydrocyanic (prussic) acid and bitter almond oil, which bodies were certainly not present previous to the treatment with water. So, too, mustard only possesses its irritating properties after being moistened: there is not a trace of the pungent mustard oil in the dry seed, but this body is formed by a special diastase on the addition of water.

The view referred to is, that gluten is also produced through the agency of a special diastase, and by hydrolysis of bodies before in the flour. In accordance with this supposition, flour, as such, contains an albuminous body termed "vegetable myosin," and this compound, by hydrolysis, through the action of a special diastase, is changed on moistening the flour into glutin. Myosin is a substance extracted from clotted muscle, and exhibits the usual reactions of albuminous substances. It is insoluble in water, alcohol, and ether, and is exceedingly soluble in dilute alkalies and very dilute acids, also in solutions of neutral salts. It is especially soluble in a 10 per cent. solution of sodium chloride. Vegetable myosin is the name given to a somewhat similar substance extracted from vegetable sources. Weyl and Bischoff treated flour with a 15 per cent. sodium chloride solution in order to remove the myosin; they then found that the residue formed no gluten, and conclude that the myosin is the gluten forming compound. They also state that flour, as a result of being heated for several hours to 60° C. loses the faculty of forming gluten; in this case they were of opinion that the non-formation of gluten was not due to the absence of a diastase, but to the coagulation of the albuminoid matter. This particular diastase has not as yet been isolated. According to this diastase hypothesis, those flours which hydrate slowly on the addition of water are deficient in this gluten-forming diastase. 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 albuminoids being in a difficultly soluble condition.

201. **Cerealin.**—Soluble albuminoids in considerable quantities are obtained from the bran and germ of wheat; these exert an action similar to that of diastase on starch paste, and have been assumed to contain a distinct proximate principle. That view will probably have to be limited to the sense in which diastase is considered a distinct substance.

**202. Putrefaction and its relation to Diastasis.**—One particular property possessed by the albuminoids is, that in the presence of moisture they speedily putrefy, or, in other words, become rotten. 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 before 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 fermentation 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 albuminoids 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. The soluble albuminoids of the different parts of the wheat grain, and also those produced by gluten during its first stages of decay, exercise a more or less decided diastasic action on starch paste, or even on starch granulose, when exposed by rupturing the outer cellulose envelope of the starch granules. Cerealin, the albuminoids of the germ, and also those produced by the incipient decomposition of gluten, are in many respects very similar to diastase.

**203. Diastase.**—It has already been found necessary to mention this body, and to describe its action on starch paste. It will now be requisite to give some further views as to its nature and composition. Diastase is a soluble albuminoid body, and can be prepared in a state of considerable purity from malt, by precipitating a cold aqueous infusion with alcohol, repeatedly washing the precipitate with the same reagent, and finally drying *in vacuo*. Prepared in this manner, diastase is a white, amorphous, easily soluble powder, retaining its activity for a considerable time. The proportion of diastase in malt does not exceed 0·002 to 0·003 per cent. One part of well-prepared diastase is stated to suffice for the conversion of 2000 parts of starch. A solution of diastase is exceedingly unstable, rapidly becoming acid, and losing the power of diastasis.

Referring again to Brown and Heron's valuable paper, these chemists find that, on heating malt extract to a temperature of about 46° C., the soluble albuminoids 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 albuminoids coagulate; this further increase of coagulation continues, as the temperature rises, up to about 95° C. The albuminoids 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 albuminoids, the diastasic power of the malt extract diminishes; also, no diminution of starch converting power has been observed without a coagulation of albuminoids. Further, at the point at which the diastasic power of malt extract is destroyed, (80-81° C.), nearly the whole of the coagulable albuminoids have been precipitated. Brown and Heron "are consequently led to conclude that **the diastasic power is a function of the coagulable albuminoids 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 albuminoids. 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 malt extract without the application of heat.

Barley contains more coagulable albuminoids than does malt, yet fresh barley extract exerts but little diastasic action. It is well known that malt is prepared by causing barley to germinate, and then kiln-drying the grain. This act of germination causes some change in the albuminoids by which they are rendered specially active in this respect. It is worthy of notice that those parts of the wheat grain of which the soluble albuminoids exert diastasic action (the bran and the germ) are those which are more or less directly concerned in the act of germination.

The comparatively inactive albuminoids 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 albuminoids 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 albuminoids, and not by the yeast itself. While *saccharomyces* act thus on wheat albuminoids, the *schizomycetes* not merely confer no diastasic power, but rapidly destroy that which the solutions may have originally possessed.

EXPERIMENTAL WORK.

**204. Soluble Albuminoids.**—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.

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.

Treat another portion of this solution with acetic acid, and afterward with salt, as described in paragraph 189. Also test another portion with Fehling's solution: notice that no reaction is produced.

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. Filter this off, and to the filtrate add a small quantity of acetic acid: notice that a further precipitate of legumin is produced; remove this also by filtration, and wash it in the filter. Heat each of these precipitates in a test-tube; notice that they evolve the same odour as did the white of egg, and that the condensed water has also an alkaline reaction due to ammonia. Repeat this experiment with pea-flour; notice the relatively large quantity of legumin precipitated.

Test portions of the clear flour infusion with alcohol and the other reagents as was done with the white of egg solution; notice the precipitation of albumin and its subsequent solution by soda or potash.

**205. Gluten and its Constituents.**—The separation of gluten will have been illustrated in the preceding experiments Moisten flour with alcohol and fold up in silk; 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.

Effect the separation of gluten into its constituents by Ritthausen's method, and test their properties as described in paragraphs 195-8. The extent to which this series of experiments is carried must depend on the time and opportunities of the student.

## CHAPTER IX.

### FERMENTATION.

**206. 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.

**207. 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. The result was a discovery that revolutionised the views previously held. It was observed 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. The whole problem of fermentation received a most careful and exhaustive examination at the hands of Pasteur, who gives 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.**"

This view is in direct antagonism to that of Liebig, who 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 albuminoid 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 albuminoids. The conclusive answer to this position of Liebig's is, that in the absence of minute organisms the decomposition of the albuminoids does not occur; it is consequently not spontaneous, and therefore fermentation must be considered as a process inseparably associated with the life of certain minute organisms.

**208. 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 signifing 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 con-**

**sequent on, and inseparable from, the life and development of certain minute microscopic organisms.**

In the chapter on the albuminoids, 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. Broadly stated, such a change is termed "fermentation" when it results in the production of some useful body, and "putrefaction" when accompanied by the transformation of a substance into useless and offensive products.

**209. Modern Theory of Fermentation.**—The following is a short statement of this theory. Maltose, albuminoids, 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. On the introduction of these, they thrive and multiply, taking the nourishment requisite for their development from the substance which is fermented. Thus yeast, in order to obtain nourishment, attacks maltose (or in strictness the glucose produced therefrom), and excretes or voids carbon dioxide gas, alcohol, and small quantities of other bodies. The digestive 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 albuminoids and produce butyric acid and other compounds. Each particular organism has its special products of fermentation. In fermentation, 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 produce a relatively large quantity of alcohol and carbon dioxide.

**210. 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.

**211. 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.

**212.** 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.

**213. Substances susceptible of Alcoholic Fermentation.**—In the strictest sense of the term, the glucoses are, of those bodies among the carbohydrates that were described in Chapter VI., the only ones capable of alcoholic fermentation. Using the term more widely, most of the sugars may be fermented; in the case of maltose and cane sugar, the first step in the change is the conversion by diastasis of these bodies into glucose. This change is effected by the soluble albuminous matter of yeast, apart from the yeast cell, and therefore is not due to fermentation. 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.

**214. Fermentation viewed as a Chemical Change.**—The conversion of glucose into alcohol and carbon dioxide may be represented very simply by the equation—

$$\underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Carbon Dioxide.}}{2CO_2.}$$

This does not, however, represent the whole of the change, for 100 parts of glucose would yield according to this equation—

| | |
|---|---|
| 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—

$$\underset{\text{Glucose.}}{4C_6H_{12}O_6} + \underset{\text{Water.}}{3H_2O} = \underset{\text{Succinic Acid.}}{H_2C_4H_4O_4} + \underset{\text{Glycerin.}}{6C_3H_5(HO)_3} + \underset{\substack{\text{Carbon}\\\text{Dioxide}}}{2CO_2} + \underset{\text{Oxygen.}}{O}$$

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 proves 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.

**215. 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 albuminoid type. There are in addition, also present, cellulose and fatty matters. Payen gives the following as the result of an analysis of yeast:—

| | |
|---|---|
| Nitrogenous matter, | 62·73 |
| Cellulose (envelopes), | 22·37 |
| Fatty matters, | 2·10 |
| Mineral ,, | 5·80 |

Nægeli 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. |
| Albuminoids, | 45 | ,, |
| Peptones, | 2 | ,, |
| Fat, | 5 | ,, |
| Extractives (leucine, cholestrine, dextrin, glycerin, succinic acid), | 4 | ,, |
| Ash, | 7 | ,, |

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, $KH_2PO_4$.

**216. 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 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 being able to derive its nutriment from inorganic bodies, is placed in the vegetable kingdom. The chemical changes produced during the growth of 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, behaves more like an animal than a plant, for during fermentation the temperature of the liquid rises considerably. Although yeast as a plant possesses and exercises the power of building up higher compounds from the simpler ones, yet it at the same time breaks down some of the compounds, with which it is in contact, into simpler bodies; and so, by the liberation of heat, raises the temperature of the containing liquid. From a chemical standpoint, yeast combines in itself the vegetable functions of synthesis, with the animal functions of analysis.

**217. 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."

**218. 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, of which the following are the most important:—

| | |
|---|---|
| *Saccharomyces Cerevisiæ*, ... | High Yeast.<br>Low Yeast. |
| ,, *Minor*, ... | Ferment of Leaven. |
| ,, *Ellipsoideus*, | Ferment of Wine. |
| ,, *Pastorianus*. | |

**219. 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. Pasteur considers these two to be distinct species; this view by later authorities is deemed untenable. 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 in all probability a sub-variety of *S. cerevisiæ*, so, too, is the kind of yeast imported so largely in this country from France and Germany, and sold as compressed yeast.

**220. High Yeast.**—This organism consists of cells, mostly round, or slightly oval, from 8 to 9 mkms. in diameter; the cells may occur either singly or grouped together in colonies. These cells have a distinct wall or envelope of cellulose, and contain within their interior a more or less gelatinous mass of 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. 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; hence these spots are termed vacuoles. A specimen of yeast is figured below:—

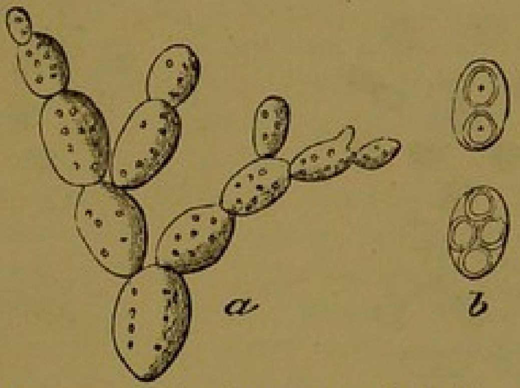


FIGURE 7.—*Saccharomyces Cerevisiæ.*

*a*, a bud-colony; *b*, two spore-forming cells (after Lürssen).

**221. 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 become less distinct, and the whole cell assumes a more transparent and distended appearance. This effect may be easily watched by first examining a few cells in water under the microscope, and then mounting a few more on a fresh slide with warm malt wort; the changes described may then be followed on the stage of 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.

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.

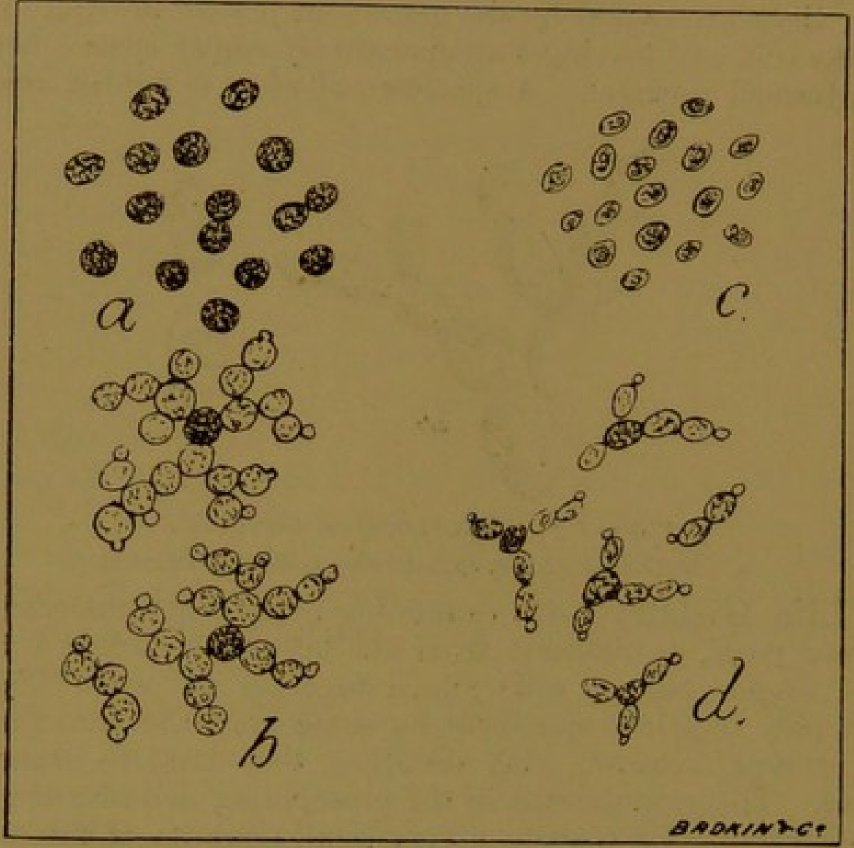


FIGURE 8.—*Saccharomyces Cerevisiæ.*

*a*, High Yeast, at rest; *b*, High Yeast, actively budding; *c*, Low Yeast, at rest; *d*, Low Yeast, actively budding.

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 syrupy 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. Thoms states that after a time, if viewed with a high power ($\frac{1}{25}$-inch objective), the contents of the cell are seen to be in rapid motion. The motion of liquids *per se* not being observable, this effect must be due to the suspended *débris* of the cell, consisting probably 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 albuminous 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.

High yeast produces a beer having a special and characteristic flavour, which distinguishes it at once from beer brewed with low yeast.

**222. 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 albuminoid 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.)

**223. 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.

**224. 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 *[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 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.

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 and maltose, they are first, however, hydrolised to glucose by the action of the zymase or soluble diastasic body secreted by the yeast cell. 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

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* The clause in brackets, [ ], is inserted by the author.

action on the albuminoids of barley or wheaten flour, transforms starch paste into dextrin and maltose, after which the yeast induces fermentation. Consequently, the two, yeast and albuminoids, 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 osmose through the cell wall, deprives the yeast of its normal proportion of water as a constituent.

**225. Nitrogenous Nutriment.**—Yeast is capable of utilising, during its growth, the nitrogen of ammoniacal salts; 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 albuminous matters present increases; therefore, by the action of yeast, the ammonium compounds are transformed into albuminous bodies. Although yeast thus acts on ammonium salts, organic nitrogenous compounds form a more suitable nutriment; among such substances, the soluble albuminoids 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 albuminoids 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 albuminoid 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 albuminoid 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.

**226. 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.

**227. 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 found 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. Further, 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 $2\frac{1}{2}$ per cent. solution of sodium chloride.

**228. Behaviour of Free Oxygen on Yeast.**—Again quoting Pasteur as an authority, he 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 conclusively proved 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. The relation between its life in free oxygen and its life when submerged in a sugar solution is extremely interesting. 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. To borrow an illustration, a working diver, enclosed in a water-tight helmet and dress, when performing his duties at the bottom of the sea, lives under difficulties. His submerged state renders breathing difficult, and any work on which he may he engaged, exhausting: after a limited time it is absolutely necessary for him to return to the fresh air. Now, during the time he is thus at rest, functioning as a fungus (if the comparison may be permitted without disrespect to those engaged in a most responsible and hazardous business), his work at the bottom is stationary; yet it on the whole profits by his rest, for shortly, with increased vigour, he is again able to resume work, and that with activity and increased effect. The comparison is obvious, and may assist to a more thorough grasping of this relation of free oxygen to fermentation.

Long before Pasteur had demonstrated the effect of oxygen in this way as a stimulant to fermentation, brewers 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.

When the object of fermentation is to produce yeast, rather than alcohol, æration of the worts should be encouraged to the fullest extent; in yeast factories, where this is one of the principal objects, fermentation is conducted in large shallow vats, whereby the surface exposed to the air is much increased.

This growth of yeast as a fungus, so clearly established as a fact by Pasteur, is of great interest as showing the close relation this organism bears to the great fungus family, not only in form, mode of growth, &c., but also in its physiological functions. To borrow his own words, "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." Such is Pasteur's admirable *resumé* of the phenomenon of fermentation as one phase of the act of vitality.

Pasteur suggests fungi, as plants living with access to air, should be called "ærobian" plants, and that the term "anærobian" should be applied to those organisms which function in the absence of air. Yeast, accordingly, is spoken of as being capable of both an ærobian (fungus-like), and an anærobian (ferment-like) existence.

**229. 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 slighest pressure; the contents of the cells are also thin and watery, instead of full of healthy granulations of gelatinous protoplasm.

**230. Reproduction of Yeast, other than by Budding.**—Some of the earlier writers on yeast maintained that the phenomena of budding seen during the growth of yeast is merely an optical illusion, and that what actually occurs is that the parent yeast cell breaks up, and that the granular contents attach themselves to the sides of other cells and then develop into full-sized cells. That this view is incorrect is proved by its being possible when yeast is budding to observe that the interior of the parent-cell and the bud is continuous, their being, at first, a direct opening from one into the other. Further, in the midst of a colony of young cells, the old or parent-cell is still seen intact. Pasteur combats the theory of the breaking up of the parent-cells most vigorously, and asserts that "this breaking is really of the most rare occurrence, and may always be explained by some abnormal circumstance affecting the yeast; being, indeed, a mechanical accident, not a physiological fact." This much may be granted to Pasteur, that the normal growth of yeast, when sown in a saccharine fluid, such as wort, or must, is by budding; and that disruption of the cells occurs most rarely. But the growth of yeast is not, either in the laboratory, or in technical operations, confined to the fermenting of fluids such as wort or must. Pasteur seems to have altogether ignored other environments in which yeast behaves far differently. Schützenberger quotes, and without contradiction, de Vauréal's opinion that the supposed budding is only an optical delusion, and that the granulations are spermatia (spores), which, when set free by the rupture of the envelope, produce new yeast cells. Schützenberger goes on to view this mode of multiplication as explaining "the facility with which the reproductive elements of yeast can be carried by the air, when we cannot distinguish in air-dust any characteristic globules of yeast." The assertion of de Vauréal's that the budding is an optical delusion cannot be maintained; but there is very strong evidence that reproduction can also take place in the manner he describes. When ale, such as Bass's, is bottled, there is always a small quantity of yeast still present; hence, if a trace of the sediment from a newly bottled sample is examined under the microscope, yeast cells can be distinguished. But if the bottle is an old one, the most careful examination only reveals the presence of isolated cells, or none at all. Instead, there are found a number of minute granules that could not be recognised as *saccharomyces*; these consist of the granular contents of the cells.

Thoms has probably devoted more time than any other living observer to the microscopic study of the functioning of yeast in dough and bakers' barms. In a review of his on Chicandard's Theory of Panary Fermentation, he makes some interesting statements which have an immediate bearing on the present topic. This theory, and Thom's reply to the same, will be dealt with fully later on; meantime there follow certain extracts from Thom's article.

" All our bread is fermented with flour barm, which is simply a modification of leaven, and I have never found *Saccharomyces* absent in such dough. But there is this difference between the barm-leaven of Scotland and the leaven of France :—The barm-leaven may be called a semi-fluid, in which, during the active stage of barm fermentation, the *saccharomyces* or yeast cells, reproduce by buds, followed slowly, during the resting or inactive stage, by a resolution of the protoplasm of the cells into spores; the French leaven, on the other hand, may be called a semi-solid, in reality a bit of old dough, in which it will be found that reproduction by budding is the exception, and reproduction by spores the rule. Now, when spore-bearing cells are, as in France, introduced direct *without* ferment—I refer to a potato, or a flour " ferment "—into semi-solid dough, the old cells are broken up, within one to three hours, in giving birth to the spores, and the search then, and for hours after, for cells having the physical features of *S. minor* or *S. cerevisiæ* may be taken as hopeless. This sporular reproduction is not confined to varieties of leaven. All the numerous varieties of yeast examined by this writer (Thoms) are subject to it, hence we see the reason for the *apparent* " gradual diminution " of the cells in yeast dough, referred to by M. Chicandard, when the examination takes place before the young spores have had time to acquire the physical features and size of the parent cells. This phase of the subject M. Chicandard has either not known or overlooked.

" Proof of my statements may be obtained by placing a trace of, say Paris-pressed yeast, 24 to 36 hours old, or after packing by the manufacturer, on a glass slide, diluting it with water and keeping at a temperature 70° to 76° F. under continuous microscopic observation for from one to three hours with eye-piece and objective—immersion, used without cover-glass—amplifying from 1000 to 2000 diameters. At first nothing but the yeast cells (and too often starch granules in excess) in the water can be seen. The cells are motionless, containing sporules of various sizes and in varying numbers in each cell, and if healthy, with only traces of undifferentiated protoplasm in some of the cells. As the observation is continued, the cells are seen to increase in size by the absorption of water, the sporules to begin a more or less active movement within the cells, which continues and may become more active, the cell walls grow thinner, till, within one to three hours, they are dissolved or disappear, and the active sporules are free. These are then seen to be mostly single; but some few in pairs, rolling about with an active Brownian movement—little more than rolling from side to side, very slightly translative—and when freed from unhealthy cells (*i.e.* cells with none, or one or two small sporules and the rest of the protoplasm in seething, boiling motion), they are seen accompanied by numerous small organisms, motile, of variable length, some single, some in pairs; in other words, the organisms seen by M. Chicandard in leaven and yeast doughs, and which he considers like *bacteria*, and in this I agree with him. The released sporules from healthy cells are so small, and with protoplasm so transparent and non-granular that, seen in diluted or filtered yeast or leaven doughs, they would not be recognised as *Saccharomyces.* But we see, nevertheless, that they are the endogenous offspring or spores of yeast. I reaffirm spores of yeast, because, continuing the observation, we find within the second and third hour the whole microscopic field of view covered with these minute active cells; the difficulty then is to find a large old cell, the earlier released spores have become larger, slightly oval, with minute buds in process of formation. They are budding *saccharomyces*, requiring only time and a medium, such as sterilised malt wort, to acquire the functions, size, and appearance of their parents. The old cells die in giving birth to a progeny six to eight times their number, but the young do not die in the dough if properly treated; on the contrary, they, in due course, live their short lives, assimilating, excreting, respiring, growing big, then resting a little, and finally resolving their protoplasm into spores." (Thoms, British and Foreign Confectioner, March, 1885.)

This observation of Thoms', be it noted, is in substantial agreement with those of de Vauréal and Schützenberger, so far as the possibility of the reproduction of yeast in the absence of normal yeast cells is concerned.

Huxley fully recognises that yeast reproduces by spores—"No Torula (yeast cell) arises except as the progeny of another; but, under certain circumstances, multiplication may take place in another way. The Torula does not throw out a bud, but its protoplasm divides into (usually) four masses, termed *ascospores*, each of which surrounds itself with a cell-wall, and the whole are set free by the dissolution of the cell-wall of the parent. This is multiplication by *endogenous* division." (Practical Biology, Huxley and Martin, p. 4.) In the same work are given directions for the study of endogenous division. Some dried yeast is to be first washed, then allowed to subside: the supernatant liquid is poured off, and the creamy deposit, spread with a camel's hair brush in a thin layer on either freshly cut potato slices or on a plate of plaster of Paris. It is then placed under a bell jar, together with wet blotting paper. Usually, on about the eighth or ninth day, ascospores make their appearance, and may be detected by examination with a power of about 800 diameters. Cells containing ascospores are shown in Figure 7.

With sound yeast to start with, Thoms' estimate of the time before sporulation occurs is extremely short: the author finds that cells of yeast sown in either water or an unfermentable medium, and maintained for some three or four days at a temperature of 25° C., still maintain their cell walls intact.

In Huxley's experiment, the wet blotting paper is used in order to keep the atmosphere of the bell jar saturated with moisture, and so prevent the yeast drying up.

The breaking up of yeast with the liberation of granules occurs when the cells are in an exhausted medium, as finished beer; or one in which there is little yeast nutriment, as in dough. In dough, too, the difficulty of growth is increased by its semi-solid condition. These granules, if sufficiently developed, before the breaking of the parent cell, to maintain an independent existence, grow and bud as ordinary yeast in a suitable medium. Endogenous division also ensues when the yeast is exposed to air, or moist surfaces, whether of potato or plaster of Paris. Further, when yeast is allowed to dry the cell envelopes also disappear, and spores are liberated. To sum up, in all these instances of sporulation, the yeast is functioning in the absence of nutriment, it then resolves itself into minute spores which, on being sown into malt wort or other favourable medium, reproduce yeast cells, which grow in the ordinary manner. It is interesting to notice that in Huxley and Martin's method, the yeast is exposed to air, and is in what Pasteur deems the fungus condition. Schützenberger asserts that the sporulation of yeast cannot occur without the presence of free oxygen. In Thom's experiment he also provides for free access of air by using no cover glass. The amount of air present must be very limited in the case of dough: probably under such circumstances, the act of sporulation goes no further than the premature breaking up of the cell wall, with the liberation of comparatively undeveloped sporules, which, under favourable conditions, may develop into cells. Further investigation on this point is needed.

**231. 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.

**232. 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, paragraph 221, gives illustrations of low yeast.

**233. 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. 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.

**234. Low Yeast not used for Bread-making.**—An exceedingly prevalent error is, that the continental pressed yeasts now being so extensively employed in this country for bread-making are the prepared sedimentary yeast of lager beer. 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. Compressed yeasts are obtained from fermentations for distilling and not for beer brewing purposes, and the yeast is invariably culled from the top of the fermenting liquid.

**235. Convertibility of Low and High Yeasts.**—Students who approach this subject with a previous knowledge of the laws of the origin of species as a result of evolution, so ably 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, as the result of personal investigations, believes that the two yeasts are 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 ingenious 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. Schützenberger, however, states that, although with great difficulty, he is able by changing the conditions of existence, to transform the one into another. Grove, in "Bacteria and Yeast Fungi," refers to Pasteur's view as to these being distinct species, but affirms his position to be untenable.

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" (for illustrations and descriptions see his "Studies on Fermentation,") Pasteur introduces wort, then sterilises the same by boiling it, and afterward sows therein a small quantity of the yeast he wishes to cultivate in the pure state. 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.

Descriptions follow of methods for the absolute isolation of single organisms and their subsequent culture. The application of such methods to yeast would place beyond doubt the problem of convertibility, or otherwise, of high and low yeast.

**236. Method for the Isolation of Yeast and other Organisms.**—Much still remains to be done in the way of isolating and examining in detail the functions of the different organisms that normally occur in bakers' yeasts. As such research will probably follow on the lines that have been adopted in other investigations having a similar object, the most authoritatively recognised methods will be described in detail.

"Nægeli's Dilution Method" 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 an 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 successive drops are then placed in ten separate tubes of culture fluid, which may be sterilised wort. Some one or two will probably remain unimpregnated, one or two others may have more than one form of organism present; but the majority will contain but one growth only. The isolation of mixed organisms is thus effected. Hansen, in his admirable researches on alcoholic ferments, adopted this method. To Koch is due the chief credit of bringing this method of investigation to its present comparative perfection. When one examines samples of impure yeast, or still more, certain forms of putrefying matter, a multitude of different organisms may be detected. The problem of separating these from each other, and observing their action one by one, seems difficult, yet Nægeli's method just described shows its possibility. Koch, in his world-famed experiments on *Bacteria* (certain minute organisms to be hereafter described), used specially prepared gelatin as a cultivating medium. This 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.

But while *bacteria* are capable of functioning in this semi-solid gelatin, yeast would find itself unable to do so: the author suggests the following slight modification of Koch's method for yeast investigation. Let a small quantity of the yeast under examination be mixed precisely as Koch directs with the gelatin, and pour the mixture out in a thin layer on the surface of a clean glass plate (a microscopic slide). Carefully protect this until solid, then examine with the microscope until an isolated yeast cell is discovered of the kind which it is wished to further investigate. Cut the small piece of gelatin containing this one cell out, transfer it to another slide, examine again in order to see that it is the only one present, and then wash it into a flask containing sterilised wort, there to develope and reproduce its kind.

Lankaster most significantly writes—"It is only by such *monosporous* cultivations, that we can arrive at solid conclusions in reference to the forms and activities of *Bacteria*, *e.g.*, as to whether one form can give rise to progeny of another form, when its food and conditions of growth are changed, and again as to whether fermentative powers can be lost or acquired in the course of generations derived from one parent germ, but subjected to different conditions as to food, temperature, and oxygen. The method of gelatin cultivation devised by Dr. Koch places the means of following out these inquiries in the hands of every skilful microscopist."

**237. Pasteur's "New High Yeast."**—Pasteur relates that in 1873, he accidentally met with a form of yeast that before was unknown to him. Its distinguishing characteristics were that in the mode of budding and size and shape of cells, it closely resembled the ordinary low yeast of lager beer, but differed in the essential particular that it rose to the surface during fermentation. He further speculates as to whether or not this variety of yeast is known commercially, and opines that it is. At the close of the Franco-German war in 1870, some Viennese traders established a factory near Paris for the manufacture of yeast for bakers. This yeast, Pasteur states to be a "high" one, differing from the yeast of ordinary high fermentation, and closely resembling normal "low" yeast in microscopic appearance. He suggests the probable identity of this yeast with his "new high yeast." The description Pasteur gives of this yeast of Viennese origin accords closely with the well-known facts concerning the "French yeast" so largely imported for bakers' use in this country.

**238. 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.

**239. 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."

**240. 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.

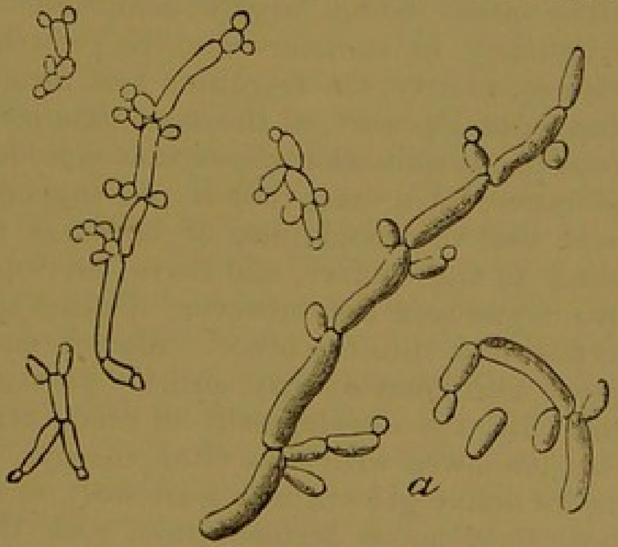

FIG. 9.—*Saccharomyces Pastorianus.*
a, The same more highly magnified (after Pasteur).

*S. Pastorianus* occurs in the after-fermentation of wine and beer, and also in baker's "patent" yeasts. As it is found in English beers which have been kept 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 dextrins cannot be either fermented or hydrolysed by ordinary yeast; but that *S. pastorianus* is capable of hydrolysing dextrin 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*.

**241. 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 yeast is capable of functioning in air, growing after the manner of a fungus, that is not, however, the normal method of development of yeast, whereas the fungi proper luxuriate rapidly when growing with free access to air; but 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. Viewed under the microscope, the mycelium is found to consist of extending branches of elongated cells closely felted or intertwined together. 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 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. On submerging this mould during its active 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*.

**242. Saccharomyces Albicans.**—Except for its very close resemblance in form to ordinary yeast, this species is scarcely of sufficient importance for mention. The cells are either round, oval, or cylindrical. Round cells are 4 mkms. in diameter; oval, 3·5 to 5 mkms. long. It forms both spores and buds, the latter usually consisting of strings of cylindrical cells. This organism occurs on the mucous membrane of the mouth, causing the disease known as "thrush." It functions as a fungus, forming a mycelium, and when submerged sets up a very limited alcoholic fermentation.

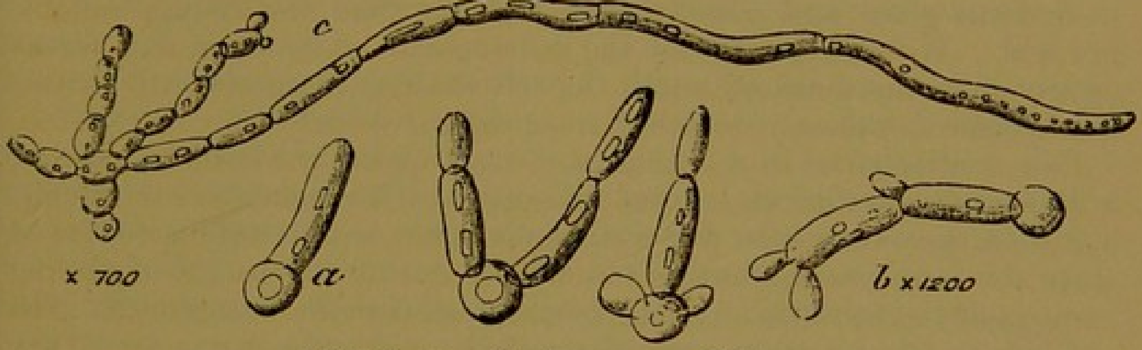

FIGURE 10.—*Saccharomyces Albicans.*

*a*, beginning of growth; *b*, further advanced; *c*, formation of mycelium (after Grawitz).

### Experimental Work.

**243. Substances produced by Alcoholic Fermentation.**—Prepare some ten or twelve ounces of malt wort, by mashing ground malt in five times its weight of water; and take its density by a hydrometer. To the wort add a small quanity 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 buble 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 shewing 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 79, 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.

**244. Microscopic Study.**—Mount a few cells of yeast on a slide, with water, and examine with the eighth of an inch objective; notice the shape of the cells; whether single or joined, whether the protoplasm is granular, and whether there are any vacuoles. Measure a few of the cells and carefully draw them to scale. Next mount a few cells in iodine solution, notice that this reagent produces no colouration; any starch granules present will be stained blue. Next mount a few cells in magenta solution, and examine; the interior contents are stained, while the envelope remains uncoloured. Burst the cells by placing a few folds of blotting paper on the top of the cover, and then sharply pressing with the end of a penholder or pencil. Again examine, and note the empty colourless sacs, and crushed stained protoplasm. To prepare magenta solution, dissolve 1 part of crystallised magenta in 10 parts of alcohol, and add 1600 parts of distilled water: 0·1 gram of magenta is a convenient quantity to take.

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.

Cultivate some yeast on thin slices of potato, as described in paragraph 230, in order to observe the production of ascospores.

# CHAPTER X.

## LACTIC AND PUTREFACTIVE FERMENTATIONS.

**245. 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.

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.

**246. 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.

**247. Bacterium Termo.**—This is essentially the ferment of putrefaction. 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.

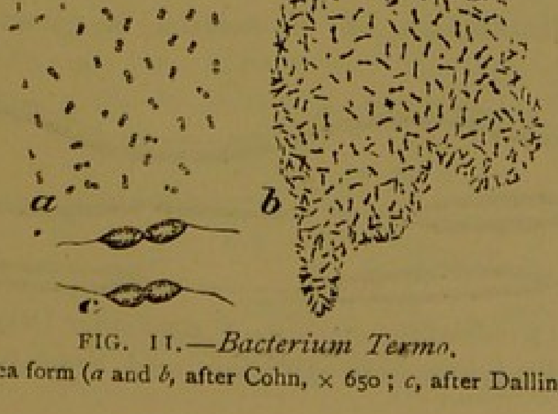

FIG. 11.—*Bacterium Termo*.
*b*, The zooglœa form (*a* and *b*, after Cohn, × 650; *c*, after Dallinger, × 4000)

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.

**248. 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 sometimes 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*."

**249. Bacillus Subtilis.**—This organism is also termed "*Vibrio subtilis*:" 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 in figure 12.

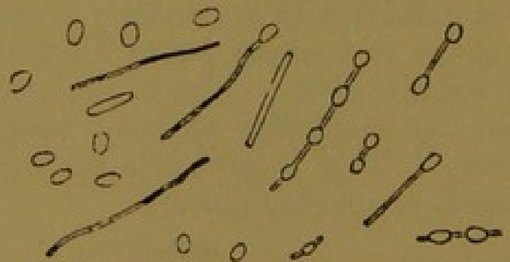

FIGURE 12.—*Bacillus Subtilis*, with spores (after Cohn).

An enlarged illustration of *B. subtilis* is given in the following figure, 13—

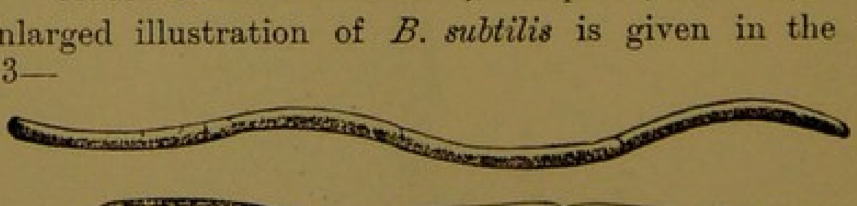

FIG. 13.—*Bacillus Subtilis*, × 4000 (after Dallinger).

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. Cohn states that *B. subtilis* causes butyric fermentation; that is, a fermentation which produces butyric acid. Lister states that *Bacterium lactis*, the ferment which turns milk sour by the formation of lactic acid, closely resembles *B. subtilis*, and may possibly be identical with it. In case the latter supposition be correct, it follows that these organisms are capable of pleomorphism; that is, that the one variety can exist as two distinct forms, and functioning differently, induce distinct types of fermentation. Van Tieghem states that butyric fermentation is produced by another *bacillus*, termed *B. amylobacter*, which view Frankland also adopts. *B. amylobacter* is morphologically very similar to *B. subtilis*, but is distinguished by containing, at times, starch within its cells. This latter organism always produces butyric acid, carbon dioxide, and hydrogen, whatever substance it operates on.

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.

**250. 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:—

$$\underset{\text{Lacto-Glucose.}}{C_6H_{12}O_6} = \underset{\text{Lactic Acid.}}{2\ HC_3H_5O_3}.$$

Ordinary glucose is also susceptible of the same transformation. As previously stated, some doubt exists as to the exact place in the order of *schizomycetes* of the lactic ferment, as to whether it belongs to the *bacteria* or *bacilli*. It 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:

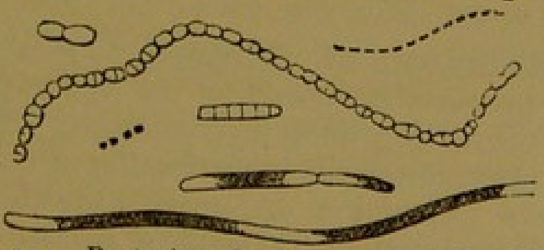

FIG. 14.—*Bacterium Lactis* × 1140 (after Lister).

When viewed with a lower power in a field of yeast, it 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.

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 acid and also salicylic 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 either 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 albuminoids 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.

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. 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.

**251. Diastasic action of Bacteria.**—This latter action is a consequence of the property possessed by the *bacteria* of attacking albuminoid 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 so 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 albuminoid 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 albuminoids 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 appearances 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 affected 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 peptonizing 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 albuminous 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 albuminoids, but exert no diastasic action. These albuminoid 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 albuminoids. 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.

Even at the risk of tautology, it must again be stated that lactic fermentation cannot proceed without the intervention of the organism known as the lactic ferment, and that the yeast organism *per se* never produces the least trace of lactic acid.

**252. Viscous Fermentation.**—Viscous fermentation is that variety which causes "ropy" beer. By means of an organism, consisting of globular cells of from 1·2 to 1·4 mkms. in diameter, adhering together in long chains, glucose is converted into a peculiar sugar, or somewhat allied body, termed mannite, $C_6H_{14}O_6$, and a gum similar to dextrin. On placing the viscous ferment into a saccharine liquid containing nitrogenous matter and the requisite mineral salts, viscous fermentation begins, and the liquid speedily becomes thick and sirupy.

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 probably due to the same cause.

**253. 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—

$$\underset{\text{Lactic Acid.}}{2HC_3H_5O_3} = \underset{\text{Butyric Acid.}}{HC_4H_7O_2} + \underset{\text{Carbon Dioxide.}}{2CO_2} + \underset{\text{Hydrogen.}}{2H_2}$$

As before mentioned, the ferment producing this change is either *B. subtilis* or *B. amylobacter*. 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, it is possible that the butyric ferment may be capable of acting directly on the sugar itself.

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 so a hopped wort is much less liable to lactic fermentation than one unhopped. For a similar reason, bakers add hops to their patent yeast worts.

**254. Putrefactive Fermentation.**—Putrefaction is that change by which most organic bodies containing nitrogen in an albuminoid form are first resolved into substances having a most putrid odour, and ultimately into inorganic products of oxidation. *Bacterium termo* has already been mentioned as the principal organism 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 albuminoid 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.

**255. 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. Schützenberger demurs to this opinion of Pasteur's, but says nothing as to the experimental evidence on which Pasteur's belief is based. Writes Schützenberger—"If fermentation is the result of such a need of oxygen, that the ferment takes it up from organic compounds, exciting their decomposition by a rupture of equilibrium, we cannot understand how oxygen can act as a poison to the ferment." But, although fermentation may be the result of a nutritive act in which decomposition is effected for the sake of oxygen, it does not necessarily follow that free oxygen can support the life of this particular ferment. While plants can obtain their necessary carbon, hydrogen, and nitrogen, from inorganic compounds, animals, as previously stated, can only assimilate these elements from organic bodies. It may well be that the *vibrio* of putrefaction also finds itself unable to assimilate free oxygen, and can only nourish itself by the putrefactive decomposition of albuminoid and similar bodies. In fact, the conditions of life of this species are so different that some observers, among whom Roscoe may be cited, view the *vibrio* of putrefaction as an animal rather than as a plant.

**256. Conditions inimical to Putrefaction.**—First and foremost among these is the keeping out of the germs of putrefactive ferments from the substance. Meat and albuminoid 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.

**257. 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.

**258. 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.

**259. 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.

### Experimental Work.

**260.** 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 five 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.

**261.** The author has now for some time past been engaged on a series of experimental researches which have had as their object the clearing up of points on fermentation as related to bread making, and also the furnishing of trustworthy data as to the effect on yeast of variations in the conditions to which it is subjected during panary fermentation. He takes this opportunity of laying his results before the public for the first time. Those readers who have carefully studied the preceding chapters, and who have also kept themselves *au courant* with scientific articles and discussions on the subject in the trade journals, will immediately see the object of many of the experiments : the reason for others will appear later.

**262. 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, uses 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 by this process, 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 must now be commenced in the following manner : 4·5 grams of the above mixture must be stirred gently, and dissolved in 50 c.c. of drinking water. In this liquid 1 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.

During the summer of 1884 the author made some experiments by this method, using the form of apparatus described above. The following table gives the results obtained; the weights being in grams. At the close of the experiment in each case the acidity was determined and calculated as lactic acid:—

| Sample. | Actual Quantities Used. | | | | | Quantities calculated to unit weight of Yeast. | | | | | Ratio of Acid to Carbon Dioxide. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sugar Mixture. | Yeast. | Carbon Dioxide Gas evolved. | | Lactic Acid. | Sugar Mixture. | Carbon dioxide gas evolved. | | | Lactic Acid. | |
| | | | Weight. | Volume c.c. per gram. | | | Weight. | Volume. | | | |
| | | | | | | | | c.c. per gram. | Cub. in. per ounce. | | |
| Brewers' Yeast, London, No. 1 ... ... | 5·00 | 2·081 | 0·881 | 440 | 0·096 | 2·40 | 0·423 | 211 | 365 | 0·046 | 0·11 |
| " London, No. 2 ... ... | 5·00 | 2·137 | 0·488 | 244 | 0·093 | 2·34 | 0·228 | 114 | 197 | 0·043 | 0·19 |
| " Brighton ... ... ... | 5·00 | 2·756 | 1·237 | 618 | 0·098 | 1·81 | 0·448 | 224 | 387 | 0·036 | 0·08 |
| Pressed Yeast, No. 1 "Cream" Brand ... | 8·12 | 1·000 | 0·753 | 376 | 0·041 | 8·12 | 0·753 | 376 | 650 | 0·041 | 0·06 |
| " " Duplicate ... ... | 8·12 | 1·000 | 0·767 | 383 | 0·041 | 8·12 | 0·767 | 383 | 662 | 0·041 | 0·05 |
| " No. 2 Another Brand ... | 8·12 | 1·000 | 0·660 | 330 | 0·070 | 8·12 | 0·660 | 330 | 571 | 0·070 | 0·11 |
| " " Duplicate ... ... | 8·12 | 1·000 | 0·658 | 329 | 0·070 | 8·12 | 0·658 | 329 | 569 | 0·070 | 0·11 |
| " No. 3 Same Brand on different day ... ... | 8·12 | 1·000 | 0·575 | 287 | 0·058 | 8·12 | 0·575 | 287 | 496 | 0·058 | 0·10 |
| " " Duplicate ... ... | 8·12 | 1·000 | 0·581 | 290 | 0·058 | 8·12 | 0·581 | 290 | 502 | 0·058 | 0·10 |
| "Bakers' Patent" Yeast ... ... | 8·12 | 25·000 | 0·296 | 148 | 0·054 | 0·32 | 0·012 | 5·92 | 10·2 | 0·002 | 0·17 |
| " Duplicate ... ... | 8·12 | 25·000 | 0·291 | 145 | 0·054 | 0·32 | 0·012 | 5·80 | 10·0 | 0·002 | 0·17 |

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 amounted to some 80 or 90 grams, while the weight of carbon dioxide evolved varied 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.

**263. 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. As a result of numerous experiments, the writer now employs the form of apparatus figured below:

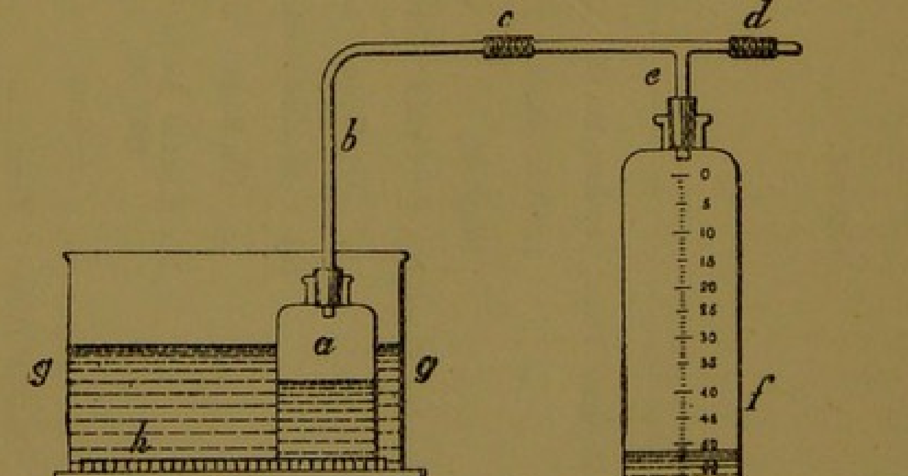

FIG. 15.—YEAST TESTING APPARATUS.

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. 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. 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 are made under precisely similar conditions.

The corrections for absorption are not made in the following readings, 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.

**264. 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, ½ oz.; Sugar Mixture, ½ oz.; Water, 6 oz. at 30° C.
No. 2. Duplicate of No. 1.
No. 3. French Compressed Yeast, ¼ oz.; Sugar Mixture, ½ 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 the 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 into 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.

**265. Constancy of Strength of same Yeast.**—In many of the following experiments yeast of the same brand was used, though on different days; it is a matter, therefore, of some importance to know the extent of variation found on yeast of the one brand at different times. One brand of yeast (Vandermin's "Cream") gave the following results:—

No. 1.—April 27th, 1885,
No. 2.—May 7th, 1885,
No. 3.—June 30th, 1885,
} Cream 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.

**266. 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.

**267. 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, $\frac{1}{2}$ oz. (14·2 grams); compressed yeast, $\frac{1}{8}$ oz. (3·5 grams); water, 6 oz. (170 grams) at 30° C.

No. 2. Yeast mixture, $\frac{1}{2}$ oz.; compressed yeast, $\frac{1}{8}$ oz.; water, 6 oz. at 30° C.

No. 3. Pure sugar, $\frac{1}{2}$ oz.; pepsin, 1·5 grams; compressed yeast, $\frac{1}{8}$ oz.; water, 6 oz. at 30° C.

No. 4. Yeast mixture, $\frac{1}{2}$ oz.; pepsin, 1·5 grams; compressed yeast, $\frac{1}{8}$ oz.; water, 6 oz. at 30° C.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 0·8 | | 0·8 | | 0·3 | | 1·1 |
| ½ hour ... | 0·8 | | 0·8 | | 0·3 | | 1·1 | |
| | | 3·1 | | 6·7 | | 2·0 | | 9·3 |
| 1 ,, ... | 3·9 | | 7·5 | | 2·3 | | 10·4 | |
| | | 4·3 | | 11·2 | | 7·4 | | 14·6 |
| 1½ hours ... | 8·2 | | 18·7 | | 9·7 | | 25·0 | |
| | | 3·8 | | 9·1 | | 6·8 | | 13·0 |
| 2 ,, ... | 12·0 | | 27·8 | | 16·6 | | 38·0 | |
| | | 4·3 | | 10·8 | | 8·1 | | 14·2 |
| 2½ ,, .. | 16·3 | | 38·6 | | 24·7 | | 52·2 | |
| | | 4·3 | | 12·4 | | 11·6 | | 18·8 |
| 3 ,, ... | 20·6 | | 51·0 | | 35·3 | | 71·0 | |
| | | 4·3 | | 11·0 | | 9·3 | | 16·0 |
| 3½ ,, ... | 24·9 | | 62·0 | | 44·6 | | 87·0 | |
| | | 4·1 | | 12·1 | | 9·9 | | 18·2 |
| 4 ,, ... | 29·0 | | 74·1 | | 55·5 | | 105·2 | |
| | | 3·7 | | 9·9 | | 14·3 | | 16·6 |
| 4½ ,, ... | 32·7 | | 84·0 | | 69·8 | | 121·8 | |
| | | 3·9 | | 11·0 | | 5·0 | | 17·4 |
| 5 ,, ... | 36·6 | | 95·0 | | 74·8 | | 139·2 | |
| | | 3·9 | | 9·0 | | 9·2 | | 14·4 |
| 5½ ,, ... | 40·5 | | 104·0 | | 84·0 | | 153·6 | |
| 6 ,, ... | ... | | ... | | ... | | ... | |
| | | 10·8 | | 28·0 | | 28·0 | | 27·9 |
| 6½ ,, ... | ... | | ... | | ... | | ... | |
| 7 ,, ... | 51·3 | | 132·0 | | 112·0 | | 181·5 | |
| | | 3·2 | | 7·2 | | 10·0 | | 2·0 |
| 7½ ,, ... | 54·5 | | 139·2 | | 122·0 | | 183·5 | |
| | | 3·4 | | 6·6 | | 9·0 | | 1·0 |
| 8 ,, ... | 57·9 | | 145·8 | | 131·0 | | 184·5 | |
| | | 1·6 | | 4·6 | | 6·5 | | 0·0 |
| 8½ ,, ... | 59·5 | | 150·4 | | 137·5 | | 184·5 | |
| | | 3·5 | | 4·5 | | 7·3 | | |
| 9 ,, ... | 63.0 | | 154·9 | | 144·8 | | ... | |

On the next day, a second series of experiments were made, which were exactly the same as the first in all particulars, except that a quarter instead of an eighth of an ounce of yeast was employed in each case. The results follow as before :—

Date, 27th April, 1885.

No. 1. Pure sugar, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.

No. 2. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.

No. 3. Pure sugar, ½ oz.; pepsin, 1·5 grams; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.

No. 4. Yeast mixture, ½ oz.; pepsin, 1·5 grams; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | |
| 0 | 0·0 | | 0·0 | | 0·0 | | 0.0 | |
| | | 4·3 | | 5·4 | | 0·4 | | 9·3 |
| ½ hour | 4·3 | | 5·4 | | 0·4 | | 9·3 | |
| | | 8·7 | | 16·3 | | 6·4 | | 22·3 |
| 1 ,, | 13.0 | | 21·7 | | 6·8 | | 31·6 | |
| | | 11·0 | | 19·6 | | 11·4 | | 24·4 |
| 1½ hours | 24·0 | | 41·3 | | 18·2 | | 56·0 | |
| | | 10·2 | | 21·7 | | 13·0 | | 26·0 |
| 2 ,, | 34·2 | | 63·0 | | 31·2 | | 82·0 | |
| | | 9·9 | | 15·0 | | 14·5 | | 24·9 |
| 2½ ,, | 44.1 | | 78·0 | | 45·7 | | 106·9 | |
| | | 9·9 | | 18·0 | | 16·1 | | 27·6 |
| 3 ,, | 54·0 | | 96·0 | | 61·8 | | 134·5 | |
| | | 10·0 | | 19·0 | | 16·5 | | 22·5 |
| 3½ ,, | 64·0 | | 115·0 | | 78·3 | | 157·0 | |
| | | 9·0 | | 15·3 | | 15·5 | | 17·4 |
| 4 ,, | 73·0 | | 130·3 | | 94·8 | | 174·4 | |
| | | 9·4 | | 13·8 | | 17·2 | | 11·9 |
| 4½ ,, | 82·4 | | 144·1 | | 112·0 | | 186·3 | |
| | | 9·1 | | 10·4 | | 16·1 | | 5·3 |
| 5 ,, | 91·5 | | 154·5 | | 128·1 | | 191·6 | |
| | | 7·5 | | 9·5 | | 14·6 | | 1·9 |
| 5½ ,, | 99·0 | | 163·0 | | 142·7 | | 193·5 | |
| | | 9·1 | | 7·2 | | 14·5 | | 0·0 |
| 6 ,, | 108·1 | | 170·2 | | 157·2 | | 193·5 | |
| | | 8·4 | | 4·8 | | 12·1 | | |
| 6½ ,, | 116·5 | | 175·0 | | 169·3 | | ...... | |
| | | 8·5 | | 2·7 | | 10·2 | | |
| 7 ,, | 124·0 | | 177·7 | | 179·5 | | ...... | |
| | | 7·1 | | 1·3 | | 10·0 | | |
| 7½ ,, | 131·1 | | 179·0 | | 189·5 | | ...... | |
| | | 6·8 | | 0·3 | | 7·5 | | |
| 8 ,, | 137·9 | | 179·3 | | 197·0 | | ...... | |
| | | 5·7 | | 0·0 | | 6·6 | | |
| 8½ ,, | 143·6 | | 179·3 | | 203·6 | | ...... | |
| | | 5·5 | | | | 4·2 | | |
| 9 ,, | 149·1 | | ...... | | 207·8 | | ...... | |
| | | 5·6 | | | | 2·0 | | |
| 9½ ,, | 154·7 | | ...... | | 209·8 | | ...... | |
| | | 5·0 | | | | 0·8 | | |
| 10 ,, | 159·7 | | ...... | | 210·6 | | ...... | |
| | | 2·7 | | | | 0·9 | | |
| 10½ ,, | 162·4 | | ...... | | 211·5 | | ...... | |

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.
$\frac{1}{2}$ " " 8 " = 14·2 "
$\frac{1}{4}$ " " 4 " = 7·1 "
$\frac{1}{8}$ " " 2 " = 3·5 "

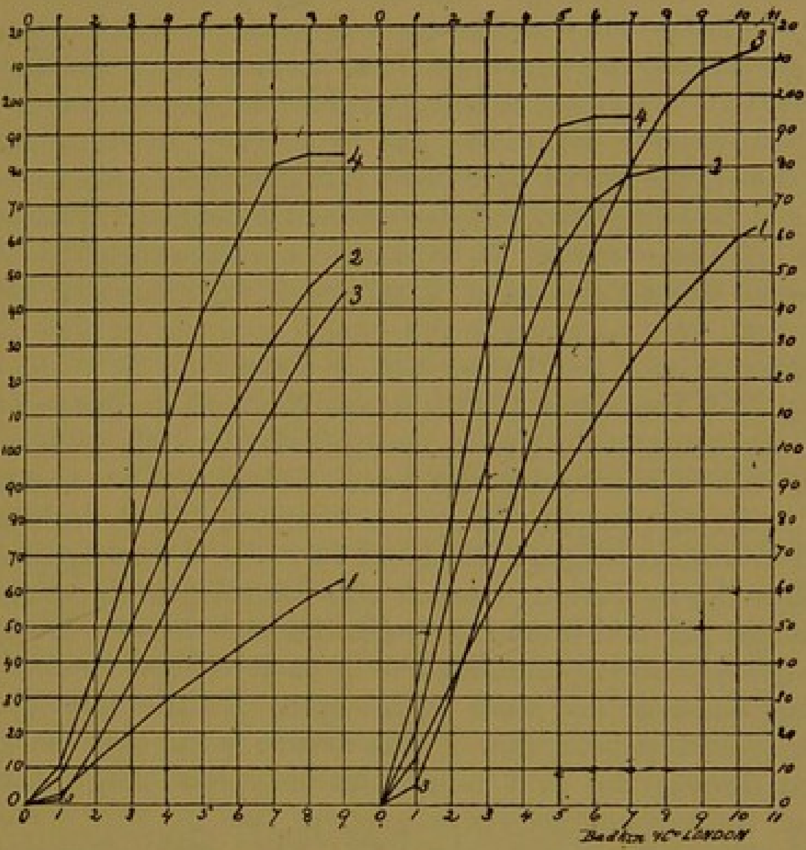

FIG. 16.

In order to render these tabulated results more clear they have been set out diagrammatically. The numbers along the bottom of the diagram, Figure 16, represent the hours at which the readings were taken: those arranged vertically up the sides show the number of cubic inches of gas. The first or left hand series of results are those obtained with $\frac{1}{8}$ oz. of yeast. Take No. 1 of this series as an illustration of how these lines are set out; at the end of one hour, 3·9 cubic inches of gas had been evolved; therefore on the vertical line, with 1 at its base, a mark was made at a distance of 3·9 up the line, reckoning the distance between each two horizontal lines as 10. At the end of the second hour, 12·0 cubic inches had been evolved, and so, on line 2 a mark is made at the 12 cubic inch mark; at three hours the gas registered 20·6 cubic inches, and accordingly a mark is made on line 3 at 20·6 cubic inches. These marks are continued for every reading taken. They are then joined together with the production of such a line as that marked 1 in the diagram. If these readings were taken at very short intervals, say of five minutes, and such a diagram constructed with a vertical line for every five minutes, the line produced by connecting up each reading would give a fairly smooth curve. Remember, that a curve may be said to be made up of an infinite number of infinitely short straight lines placed end to end (a circle is sometimes called an infinite polygon.) The actual lines in the diagram approach to such curves, and are commonly spoken of as "curves," although made up of short straight lines. The present and similar diagrams may be said to represent the curves showing the relation between the quantity of gas a yeast evolves and the time it takes in so doing. The more rapid the evolution of gas, the more nearly does the curved line approach the vertical, while when no gas is being evolved, the curve becomes horizontal. During the time that the speed at which gas is being evolved increases, hour by hour, the curve bends upwards; while the gas is coming off with absolute uniformity of speed, the curve becomes a straight line; when the speed at which the gas is being evolved decreases, the curve bends downwards. The object of these curves is to enable a comparison to be made at sight between the results of a number of experiments. When it is desired to read very accurately the exact quantity of gas given off at any particular time, the tables should be consulted.

Studying first the results with one-eighth of an ounce of yeast, in No. 1 with pure sugar the gas is evolved slowly, but with considerable constancy: this is shown by the curve being almost a straight line. Compared with the sugar, the yeast mixture, No. 2, induces a much more rapid evolution of gas: but little is evolved during the first hour, but after that the evolution proceeds at a tolerably uniform rate of about 10 cubic inches per half-hour: towards the end the speed begins to fall off. Throughout the experiment, the quantity of gas evolved is at each reading more than double that with sugar. In the next place, a mixture of sugar and pepsin, No. 3, was tried: with this the quantity of gas evolved during the first hour was very low, 2·3, but during the second hour the production increases over that of pure sugar, and consequently curve 3 crosses over curve 1. No. 3 then proceeds uniformly, but with an average of about 20 cubic inches behind No. 2: toward the end it begins to fall off, but only slightly; in two or three hours' time No. 3 would probably have crossed No. 2. The whole of these three were still actively evolving gas at the taking of the last reading. In No. 4, pepsin was added to yeast mixture; in this the evolution of gas was most rapid of all; from the start right on it keeps well in advance of the others: at first with each reading the speed increases, but at the end it falls off, and at last entirely ceases, having caused in eight hours the evolution of 184·5 cubic inches of gas, the correction for absorption being neglected.

Practically the same effects are observed with the quarter-ounce tests as were obtained in the eighth of an ounce experiments. The evolution of gas was in each case very uniform, at first a slight increase and afterward a regular falling off. No. 1 is again the lowest, but shows that at the last reading gas was still rapidly coming off. Nos. 2 and 4 again occupy very nearly the same relative position to each other, but in this experiment No. 2 is exhausted at the end of the eighth hour, while No. 4 ceases to evolve gas after six hours. No. 3 again starts slowly, and only in the third hour overtakes No. 1, but at the end of seven hours it has also overtaken and passed No. 2, giving at the end of ten and a half hours a reading of 211·5 cubic inches. The effect of the greater quantity of yeast was in each case to hasten fermentation: this will again be referred to when dealing specially with the question of quantity.

In order to test whether the pepsin itself gave off gas, 1·5 grams of it were taken and mixed with water and yeast, as in the preceding experiments: no gas, however, was evolved. A further experiment was made in a similar fashion with white of egg, but no gas was produced. As a third test, 15 grams of white of egg were mixed with 6 oz. of 2·5 per cent. salt solution at 25° C., and then one quarter ounce of yeast added. At the end of ten hours, 1·3 cubic inches of gas were evolved, which quantity had increased in twenty-two hours to 1·5 cubic inches: this is practically equivalent to the non-production 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 ten 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.

**268. 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, 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, and illustrated in the left hand series of the accompanying diagram, Fig. 17. It should be noticed that in this diagram the vertical scale is different to that in the last; the space between each two lines is equal to two instead of ten cubic inches.

Date, 8th May, 1885.

No. 1. 40 per cent. filtered flour infusion, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 2. Unboiled malt wort, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 3. Boiled wort, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 4. Yeast mixture and water, Sp. G. 1007·2, 6 oz. at 30° C.; compressed yeast, ¼ oz.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | Temperature. |
|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | |
| 0 hour ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 30·2 |
| | | 2·2 | | 6·5 | | 7·5 | | 12·0 | |
| 1 " ... | 2·2 | | 6·5 | | 7·5 | | 12·0 | | 31·0 |
| | | 3·0 | | 7·9 | | 8·4 | | 10·4 | |
| 2 hours ... | 5·2 | | 14·4 | | 15·9 | | 22·4 | | 31·0 |
| | | 1·3 | | 1·9 | | 1·9 | | 1·7 | |
| 3 " ... | 6·5 | | 16·3 | | 17·8 | | 24·1 | | 30·5 |
| | | 0·9 | | 0·7 | | 0·4 | | 0·2 | |
| 4 " ... | 7·4 | | 17·0 | | 18·2 | | 24·3 | | 30·5 |
| | | 0·9 | | 0·1 | | 0·0 | | 0·0 | |
| 5 " ... | 8·3 | | 17·1 | | 18·2 | | 24·3 | | 31·0 |

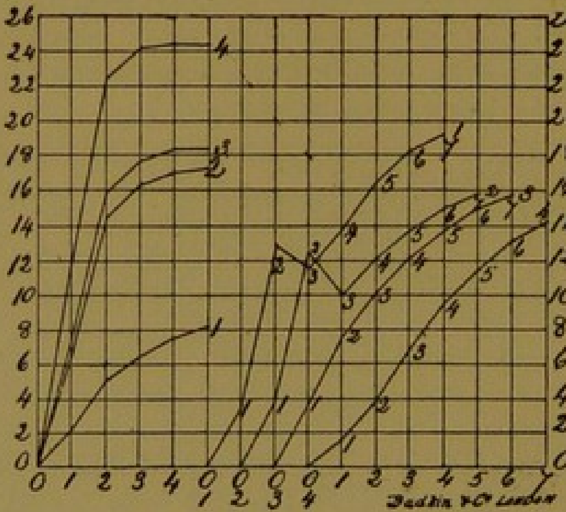

FIG. 17.

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 albuminoids 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 albuminoids 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.

**269. Comparison between Flour, and its various constituents fermented separately.**—From the baker's point 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 similar 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, ¼ oz.

No. 2. 34 grams flour; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 3. Washed insoluble residue from 34 grams of flour; water, 6 oz. at 30° C.; compressed yeast, ¼ 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 ¼ 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 ¼ 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, ¼ oz.

No. 7. 20 per cent. filtered flour infusion, 6 oz. at 30° C.; wheat starch, 5 grams, ungelatinised; compressed yeast, ¼ oz.

Date, 11th May, 1885.

No. 8. Wheat starch, 5 grams, gelatinised, water, 6 oz. at 30° C.; compressed yeast, ¼ oz.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | No. 5. | | No. 6. | | No. 7. | | No. 8. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| 1 hour ... | 0·2 | 0·2 | 3·8 | 3·8 | 0·2 | 0·2 | 10·4 | 10·4 | 0·3 | 0·3 | 18·5 | 18·5 | 2·8 | 2·8 | 0·3 | 0·3 |
| 2 hours ... | 0·6 | 0·4 | 8·2 | 4·4 | 0·6 | 0·4 | 29·5 | 19·1 | 0·5 | 0·2 | 20·8 | 2·3 | 5·1 | 2·3 | 0·4 | 0·1 |
| 3 „ ... | 1·2 | 0·6 | 11·5 | 3·7 | 1·1 | 0·5 | 35·0 | 5·5 | 0·6 | 0·1 | 28·1 | 7·3 | 6·3 | 1·2 | 0·5 | 0·1 |
| 4 „ ... | 1·8 | 0·6 | 14·0 | 2·5 | 1·8 | 0·7 | 37·3 | 2·3 | 0·9 | 0·3 | 31·5 | 3·4 | 7·0 | 0·7 | 0·6 | 0·1 |
| 5 „ ... | 2·2 | 0·4 | 16·0 | 2·0 | 2·7 | 0·9 | 37·5 | 0·2 | 1·1 | 0·2 | 32·8 | 1·3 | 7·6 | 0·6 | 0·7 | 0·1 |
| 6 „ ... | 2·5 | 0·3 | 17·5 | 1·5 | 3·0 | 0·3 | 37·5 | 0·0 | 1·3 | 0·2 | 33·7 | 0·9 | 8·2 | 0·8 | 0·9 | 0·2 |
| 7 „ ... | 2·9 | 0·4 | 18·5 | 1·0 | 3·2 | 0·2 | ...... | | 1·3 | 0·0 | 33·7 | 0·0 | 8·5 | 0·5 | 1·0 | 0·1 |
| 8 „ ... | 3·3 | 0·4 | 19·6 | 1·1 | 3·3 | 0·1 | ...... | | 1·5 | 0·2 | ...... | | 8·5 | 0·0 | 1·2 | 0·2 |
| 9 „ ... | ...... | | ...... | | ...... | | ...... | | 1·5 | 0·0 | ...... | | ...... | | ... | |
| 21 „ ... | ...... | | ...... | | ...... | | ...... | | ...... | | ...... | | ...... | | 7·0 | 5·8 |
| 22 „ ... | ...... | | ...... | | ...... | | ...... | | ...... | | ...... | | ...... | | 7·8 | 0·8 |

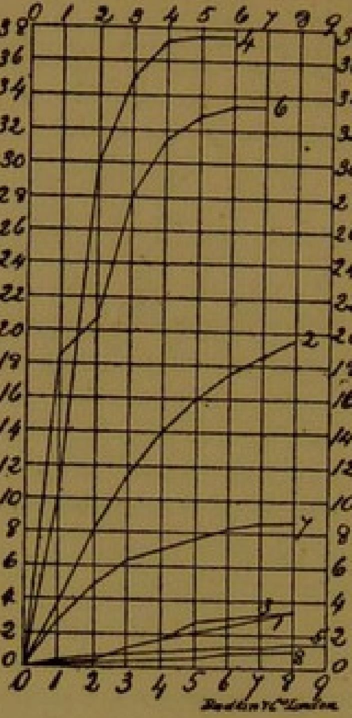

FIG. 18.

No. 1, consisting of 20 per cent. flour infusion gave off very little gas, the quantity amounting to only 3·3 cubic inches in eight 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 eight hours there being 19·6 cubic inches of gas evolved. After the second hour, the evolution fell off slowly but regularly : this is well shown in the curve in the diagram. 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 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. The curve shows the sudden drop in gas production very clearly. 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. 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 VII., paragraph 169). 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 albuminoids 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.

**270. 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 erthyro-dextrins. 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 albuminoids. 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 albuminoids 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 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 albuminoids; 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 albuminoids 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 albuminoids, 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 albuminoids with greater readiness. The only deduction from these determinations is, that **the amount of albuminoids 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 albuminous 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.

| Time. | Gas Evolved in Cubic Inches. | | |
|---|---|---|---|
| | No. 1. | | No. 2. |
| 0 ... ... ... | 0·0 | | 0·0 |
| | | 1·7 | |
| 1 hour ... ... | 1·7 | | 5·0 |
| | | 3·3 | |
| 2 hours ... ... | 5·0 | | ... |
| | | 1·7 | |
| 3 ,, ... ... | 6·7 | | ... |
| | | 1·5 | |
| 4 ,, ... ... | 8·2 | | ... |
| | | 0·8 | |
| 5 ,, ... ... | 9·0 | | .. |
| | | 0·6 | |
| 6 ,, ... ... | 9·6 | | 73·5 |
| | | 0·6 | |
| 7 ,, ... ... | 10·2 | | ... |
| | | 0·8 | |
| 8 ,, ... ... | 11·0 | | ... |
| | | 1·0 | |
| 9 ,, ... ... | 12·0 | | ... |
| | | 3·0 | |
| 22 ,, ... ... | 15·0 | | ... |

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. |
| Albuminoids, 0·517 grams present. | Albuminoids, 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 albuminoids, 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 albuminous 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 albuminous 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 albuminoids, 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 albuminous constituents of dough.** It should be noticed that no assertion is made that no gas whatever is derived from the albuminous constituents of flour; it is possible that in extreme cases, gas is produced from albuminous matters as a result of butyric and putrefactive fermentations; but in ordinary breadmaking, 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 albuminoids, is the result, not of the action of yeast, but of *bacteria*. Further, the statement that albuminous 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.

**271. 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: as a matter of convenience in engraving, the curves are shown at the right hand side of the diagram, Figure 17, paragraph 268.

Date, 27th May, 1885.

No. 1. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.

No. 2. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.; salt, 2·5 grams = 1·4 per cent. salt solution.

No. 3. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.; salt, 5·0 grams = 2·9 per cent. salt solution.

No. 4. Flour, 34 grams; water, 6 oz. at 30° C.; compressed yeast, ¼ oz.; salt, 8·5 grams = 5·0 per cent. salt solution.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | Temperature. |
|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 30.0 |
| | | 3·5 | | 3·7 | | 3·8 | | 1 5 | |
| 1 hour ... | 3·5 | | 3·7 | | 3·8 | | 1·5 | | 31·0 |
| | | 9·5 | | 8·7 | | 3·7 | | 2·4 | |
| 2 hours ... | 13·0 | | 12·4 | | 7·5 | | 3·9 | | 29·5 |
| | | −1·5 | | −2·4 | | 2·6 | | 2·9 | |
| 3 „ ... | 11·5 | | 10·0 | | 10·1 | | 6·8 | | 29·0 |
| | | 2·4 | | 2·1 | | 2·1 | | 2·6 | |
| 4 „ ... | 13·9 | | 12·1 | | 12·2 | | 9·4 | | 29·5 |
| | | 2·6 | | 1·7 | | 1·6 | | 2·3 | |
| 5 „ ... | 16·5 | | 13·8 | | 13·8 | | 11 7 | | 29·7 |
| | | 1·7 | | 1·4 | | 1·3 | | 1·6 | |
| 6 „ ... | 18·2 | | 15·2 | | 15·1 | | 13·3 | | 30·0 |
| | | 1·0 | | 0·6 | | 0·6 | | 0·9 | |
| 7 „ ... | 19·2 | | 15·8 | | 15·7 | | 14·2 | | 29·6 |

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. A remarkable occurrence was noticed in these two experiments: the reading at the end of the third hour was less than that at the end of the second: the evolution of gas seems to have entirely stopped for a time, while some of that which had been evolved was re-absorbed. It is difficult to account for this diminution, especially as it occurred in only two of the tests that were being made at the same time. It is not due in any way to leakage, because with an apparatus arranged as this is, leakage could only cause an abnormal *increase* in the volume of the gas. The irregularity having been observed, it was thought well to mention it as being a point of some interest, and also on the principle that whenever an experiment is quoted, the account should be absolutely impartial. The curves in this particular diagram are set out in a somewhat different manner to those which have preceded: they were so closely identical at several readings that if set off from the same zero it would have been extremely difficult to distinguish one from the others. Accordingly, the zero of each was commenced on a separate line. In this case, the number of each curve is given under the zero, and the hours at which the readings were taken are marked to the right hand side below the curve. With the exception of the break during the third hour of Nos. 1 and 2 the whole of these curves are very regular. Between Nos. 2 and 3 there is very little difference; gas was evolved more rapidly from No. 2 at the outset, but at the end there was a difference of but 0·1 cubic inch. No. 4 solution, containing 5 per cent. of salt, gave off gas more slowly at the first, gaining a little after, but throughout fell behind the others. 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.

**272. 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 breadmaking. 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, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. a 30° C.

Date, 12th May, 1885.

No. 2. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; pure wheat starch, 5 grams.

No. 3. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; wheat starch, 5 grams, gelatinised and allowed to cool.

Date, 14th May, 1885.

No. 4. Yeast mixture, ½ oz.; compressed yeast, ¼ oz.; water, 6 oz. at 30° C.; raw flour, 5 grams.

Date, 13th May, 1885.

No. 5. Yeast mixture, ½ oz.; compressed yeast, ¼ 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.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | No. 5. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| 1 hour ... | 37·5 | 37·5 | 23·1 | 23·1 | 15·2 | 15·2 | 18·4 | 18 4 | 20·3 | 20·3 |
| 2 hours ... | 78·6 | 41·1 | 55·3 | 32·2 | 45·0 | 29·2 | 57·5 | 39·1 | 64·6 | 44·3 |
| 3 " ... | 117·0 | 36·4 | 98·5 | 43·2 | 90·5 | 45·5 | 100·0 | 42·5 | 114·8 | 50·2 |
| 4 " ... | 149·0 | 32·0 | 133·0 | 34·5 | 119·5 | 29·0 | 132·6 | 32·6 | 160·2 | 45·4 |
| 5 " ... | 167·8 | 18·8 | 163·0 | 30·0 | 147·6 | 28·1 | 164·3 | 31·7 | 193·3 | 33·1 |
| 6 " ... | 174·5 | 6·7 | 173·7 | 10·7 | 167·8 | 20·2 | 173·5 | 9·2 | 205·2 | 11·9 |
| 7 " ... | 174·5 | 0·0 | 173·7 | 0·0 | 177·8 | 10·0 | 175·2 | 1·7 | 208·2 | 3·0 |
| 8 " .. | ...... | | ...... | | 182·8 | 5·0 | ...... | | 209·4 | 1·2 |
| 9 " ... | ...... | | ...... | | 183·0 | 0·2 | ...... | | ...... | |
| 10 " ... | ...... | | ...... | | 183·5 | 0·5 | ...... | | ...... | |

| Time. | No. 6. | | No. 7. | | No. 8. | | No. 9. | | No. 10. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| 1 hour ... | 19·0 | 19·0 | 22·0 | 22·0 | 21·5 | 21·5 | 32·6 | 32·6 | 8·1 | 8·1 |
| 2 hours .. | 65·6 | 46·6 | 66·3 | 44·3 | 59·6 | 38·1 | 72·6 | 40·0 | 35·1 | 27·0 |
| 3 " ... | 113·9 | 48·3 | 109·2 | 42·9 | 98·5 | 38·9 | 113·5 | 40·9 | 65·3 | 30·2 |
| 4 " ... | 158·3 | 44·4 | 152·2 | 43·0 | 137·3 | 38·8 | 130·5 | 17·0 | 99·5 | 34·2 |
| 5 " ... | 184·6 | 26·3 | 177·1 | 24·9 | 160·5 | 23·2 | 171·0 | 40·5 | 130·0 | 30·5 |
| 6 " ... | 188·0 | 3·4 | 183·5 | 6·4 | 170·2 | 9·7 | 178·0 | 7·0 | 150·5 | 20·5 |
| 7 " ... | 188·0 | 0·0 | 183·5 | 0·0 | 171·6 | 1·4 | 178·0 | 0·0 | 165·2 | 14·7 |
| 8 " ... | ...... | | ...... | | 171·6 | 0·0 | ...... | | ..... | |

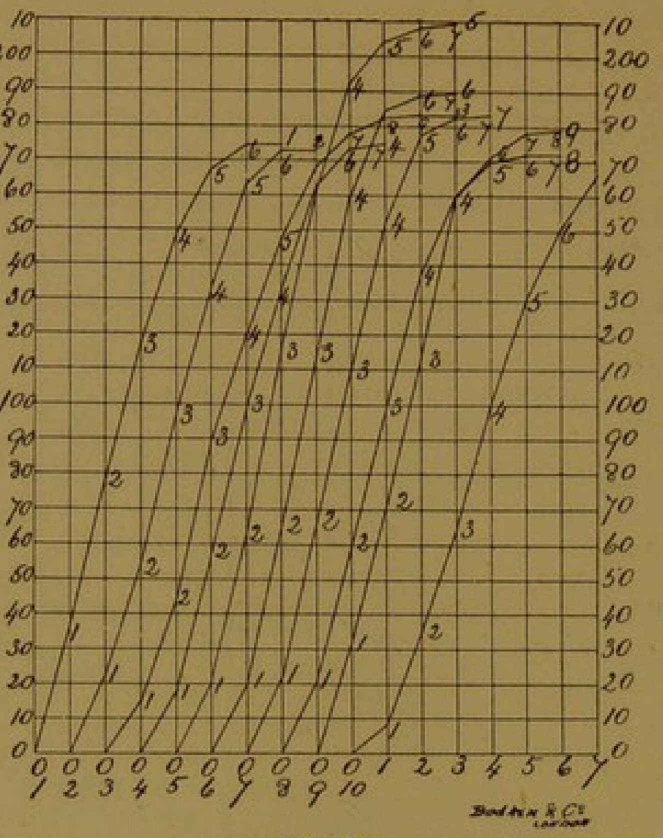

FIG. 19.

In the accompanying diagram, Fig. 19, the curves representing the above results are set out. As in many instances they resemble each other very closely, each curve is drawn from a separate zero, underneath which is placed the number of the experiment. The numbers underneath and to the right of the curves indicate the hours at which the respective readings were taken. No. 1 simply represents the evolution of gas by the yeast mixture and water only, when fermented: the action was very regular, and ceased entirely at the end of six hours. No. 2 is the same mixture, together with the ungelatinised wheat-starch, from the same sample as was described as used in certain previous experiments. 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 269) 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 for the first five hours 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 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 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 : the curve more nearly approaches the vertical, 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 albuminoids 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. Experiment No. 7 was suggested to the author by the gentleman whose papers on Breadmaking in the "British and Foreign Confectioner" above the *nom de plume* of "Tablier Blanc" are so well known to the readers of that Journal. 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 are 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. The bread produced is among the best with which the author is acquainted. Nos. 8, 9, and 10, were similar experiments to those of the preceding series (paragraph 271), 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.**

**273. 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. The corresponding curves are shown in the diagram, Fig. 20. The curve marked 1A, is copied from the diagram illustrating the effect of variations of temperature, Fig. 21, and represents the gas evolved during the fermentation of ½ ounce of sugar, and six ounces of water at 30° C., with a ¼ ounce of yeast. It is here introduced for the sake of comparison.

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.

| TIME. | GAS EVOLVED IN CUBIC INCHES. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 19·0 | | 13·2 | | 15·0 | | 10·0 |
| 1 hour .. | 19·0 | | 13·2 | | 15·0 | | 10·0 | |
| | | 19·2 | | 21·9 | | 26·2 | | 23·8 |
| 2 hours ... | 38·2 | | 35·1 | | 41·2 | | 33·8 | |
| | | 15·7 | | 26·9 | | 25·3 | | 24·3 |
| 3 ,, ... | 53·9 | | 60·8 | | 66·5 | | 58·1 | |
| | | 18·3 | | 20·2 | | 23·5 | | 25·9 |
| 4 ,, .. | 62·2 | | 81·0 | | 90·0 | | 84·0 | |
| | | 10·8 | | 29·0 | | 27·6 | | 30·4 |
| 5 ,, ... | 73·0 | | 110·0 | | 117·6 | | 114·4 | |
| | | 11·3 | | 25·0 | | 20·5 | | 19·2 |
| 6 ,, ... | 84·3 | | 135·0 | | 138·1 | | 133·6 | |
| | | 14·1 | | 22.3 | | 17·0 | | 17·2 |
| 7 ,, ... | 98·4 | | 157·3 | | 155·1 | | 150·8 | |
| | | 11·9 | | 15·2 | | 13·9 | | 14·2 |
| 8 ,, ... | 110·3 | | 172·5 | | 169·2 | | 165·0 | |
| | | 9·0 | | 10·1 | | 12.3 | | 10·1 |
| 9 ,, ... | 119·3 | | 182·6 | | 181·5 | | 175·1 | |
| | ...... | | ... .. | | | 4·3 | | 8·4 |
| 10 ,, ... | ...... | | ...... | | 186·8 | | 183·5 | |

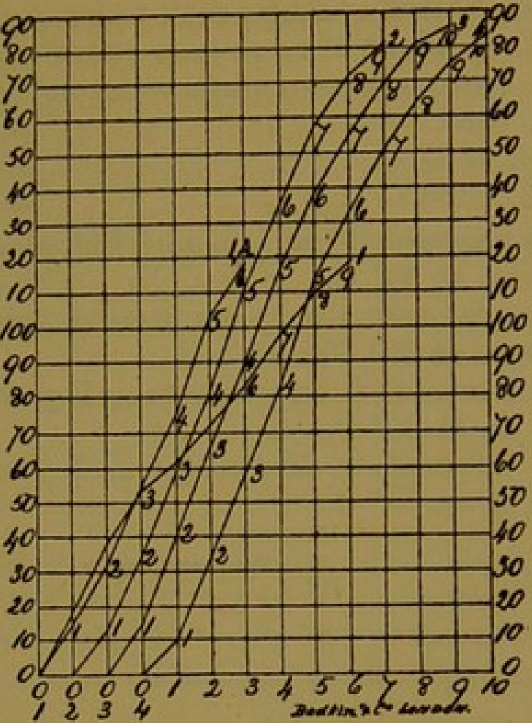

FIG. 20.

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, as in 1A. 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.**

**274. 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 series of 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.) In the following tables each series of tests is distinguished by a letter in order to admit of more easy reference.

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. ,,

A
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.

| A | Gas Evolved in Cubic Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time. | No. 1 at 20° C. | | No. 2 at 25° C. | | No. 3 at 30° C. | | No. 4 at 35° C. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 2·0 | | 10·0 | | 28·7 | | 38·0 |
| 1 hour .. | 2·0 | | 10·0 | | 28·7 | | 38·0 | |
| | | 11·5 | | 19·8 | | 31·9 | | 46·1 |
| 2 hours ... | 13·5 | | 29·8 | | 60·6 | | 84·1 | |
| | | 14·5 | | 23·2 | | 43·6 | | 43·9 |
| 3 ,, ... | 28·0 | | 53·0 | | 104·2 | | 128·0 | |
| | | 16·7 | | 22·0 | | 40·8 | | 31·9 |
| 4 ,, ... | 44·7 | | 75·0 | | 145·0 | | 159·9 | |
| | | 20·3 | | 19·0 | | 30·0 | | 15·1 |
| 5 ,, ... | 65·0 | | 94·0 | | 175·0 | | 175·0 | |
| | | 18·8 | | 19·3 | | 2·8 | | 0·0 |
| 6 ,, ... | 83·8 | | 113·3 | | 177·8 | | 175·0 | |

B
No. 1. Sugar, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 20° C.
No. 2. Sugar, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 25° C.
No. 3. Sugar, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 30° C.
No. 4. Sugar, ½ oz.; compressed yeast, A, ¼ oz.; water, 6 oz. at 35° C.

| B | Gas Evolved in Cubic Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time. | No. 1 at 20° C. | | No. 2 at 25° C. | | No. 3 at 30° C. | | No. 4 at 35° C. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 1·3 | | 7·0 | | 15·0 | | 20·5 |
| 1 hour ... | 1·3 | | 7·0 | | 15·0 | | 20·5 | |
| | | 6·7 | | 12·0 | | 17·5 | | 24·5 |
| 2 hours ... | 7·0 | | 19·0 | | 32·5 | | 45·0 | |
| | | 6·5 | | 13·0 | | 22·6 | | 25·0 |
| 3 ,, ... | 13·5 | | 32·0 | | 55·1 | | 70·0 | |
| | | 7·4 | | 13·0 | | 20·9 | | 23·0 |
| 4 ,, ... | 20·9 | | 45·0 | | 75·0 | | 93·0 | |
| | | 8·1 | | 13·0 | | 29·0 | | 23.2 |
| 5 ,, ... | 29·0 | | 58·1 | | 104·0 | | 116·2 | |
| | | 7·5 | | 14·1 | | 14·0 | | 18·6 |
| 6 ,, .. | 36·5 | | 72·2 | | 118·0 | | 134·8 | |

C
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.

| C | Gas Evolved in Cubic Inches. | | | |
|---|---|---|---|---|
| Time. | No. 1 at 20° C. | No. 2 at 25° C. | No. 3 at 30° C. | No. 4 at 35° C. |
| 0 ... ... | 0·0 | 0·0 | 0·0 | 0·0 |
| | 1·5 | 3·0 | 7·8 | 12·2 |
| 1 hour ... | 1·5 | 3·0 | 7·8 | 12·2 |
| | 4·2 | 5·5 | 6·3 | 5·6 |
| 2 hours ... | 5·7 | 8·5 | 14·1 | 17·8 |
| | 2·8 | 3·7 | 4·4 | 3·4 |
| 3 ,, ... | 8·5 | 12·2 | 18·5 | 21·2 |
| | 2·6 | 2·5 | 2·7 | 2·6 |
| 4 ,, ... | 11·1 | 14·7 | 21·2 | 23·8 |
| | 1·9 | 2·0 | 2·0 | 2·7 |
| 5 ,, ... | 13·0 | 16·7 | 23·2 | 26·5 |
| | 1·6 | 1·5 | 1·2 | 1·8 |
| 6 ,, ... | 14·6 | 18·2 | 24·4 | 28·3 |

D
No. 1. Yeast mixture, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 20° C.
No. 2. Yeast mixture, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 25° C.
No. 3. Yeast mixture, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 30° C.
No. 4. Yeast mixture, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 30° C.

| D | Gas Evolved in Cubic Inches. | | | |
|---|---|---|---|---|
| Time. | No. 1 at 20° C. | No. 2 at 25° C. | No. 3 at 30° C. | No. 4 at 35° C. |
| 0 ... ... | 0·0 | 0·0 | 0·0 | 0·0 |
| | 5·6 | 11·0 | 2·45 | 51·7 |
| 1 hour ... | 5·6 | 11·0 | 24·5 | 51·7 |
| | 17·7 | 26·3 | 39·0 | 51·3 |
| 2 hours ... | 23·3 | 37·3 | 63·5 | 103·0 |
| | 19·0 | 27·9 | 47·2 | 48·7 |
| 3 ,, ... | 42·3 | 65·2 | 110·7 | 151·7 |
| | 18·9 | 26·3 | 36·8 | 27·5 |
| 4 ,, ... | 61·2 | 91·5 | 147·5 | 179·2 |
| | 19·8 | 22·0 | 29·0 | 0·8 |
| 5 ,, ... | 81·0 | 113·5 | 176·5 | 180·0 |
| | 19·4 | 18·9 | 2·8 | 0·0 |
| 6 ,, ... | 100·4 | 132·4 | 179·4 | 180·0 |

E
- No. 1. Sugar, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 20° C.
- No. 2. Sugar, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 25° C.
- No. 3. Sugar, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 30° C.
- No. 4. Sugar, ½ oz.; compressed yeast, B, ¼ oz.; water, 6 oz. at 35° C.

| E | Gas Evolved in Cubic Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time. | No. 1 at 20° C. | | No. 2 at 25° C. | | No. 3 at 30° C. | | No. 4 at 35° C. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 7·3 | | 7·7 | | 17·2 | | 27·0 |
| 1 hour ... | 7·3 | | 7·7 | | 17·2 | | 27·0 | |
| | | 11·7 | | 17·3 | | 24·9 | | 31·6 |
| 2 hours ... | 19·0 | | 25·0 | | 42·1 | | 58·6 | |
| | | 12·2 | | 18·7 | | 29·7 | | 26·4 |
| 3 " .. | 31·2 | | 43·7 | | 71·8 | | 85·0 | |
| | | 11·8 | | 17·5 | | 25·7 | | 30·0 |
| 4 " ... | 43·0 | | 61·2 | | 97·5 | | 115·0 | |
| | | 12·5 | | 17·8 | | 32·0 | | 26·0 |
| 5 " ... | 55·5 | | 79·0 | | 129·5 | | 141·0 | |
| | | 11·5 | | 19·0 | | 6·0 | | 21·0 |
| 6 " ... | 67·0 | | 98·0 | | 145·5 | | 162·0 | |

F
- No. 1. Flour, 34 grams; compressed yeast, B, ¼ oz.; water, 6 oz. at 20° C.
- No. 2. Flour, 34 grams; compressed yeast, B, ¼ oz.; water, 6 oz. at 25° C.
- No. 3. Flour, 34 grams; compressed yeast, B, ¼ oz.; water, 6 oz. at 30° C.
- No. 4. Flour, 34 grams; compressed yeast, B, ¼ oz.; water, 6 oz. at 30° C.

| F | Gas Evolved in Cubic Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time. | No. 1 at 20° C. | | No. 2 at 25° C. | | No. 3 at 30° C. | | No. 4 at 35° C. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 1·6 | | 3·8 | | 11·0 | | 12·3 |
| 1 hour ... | 1·6 | | 3·8 | | 11·0 | | 12·3 | |
| | | 2·4 | | 5·9 | | 6·4 | | 6·7 |
| 2 hours ... | 4·0 | | 9·7 | | 17·4 | | 19·0 | |
| | | 2·5 | | 6·5 | | 4·6 | | 3·2 |
| 3 " ... | 6·5 | | 16·2 | | 22·0 | | 22·2 | |
| | | 2·2 | | 8·1 | | 2·7 | | 3·3 |
| 4 " ... | 8·7 | | 24·3 | | 24·7 | | 25·5 | |
| | | 1·8 | | | | 3·1 | | 2·7 |
| 5 " ... | 10·5 | | ...... | | 27·8 | | 28·2 | |
| | | 1·6 | | | | 1·4 | | 1·7 |
| 6 " ... | 12·1 | | ...... | | 29·2 | | 29·9 | |

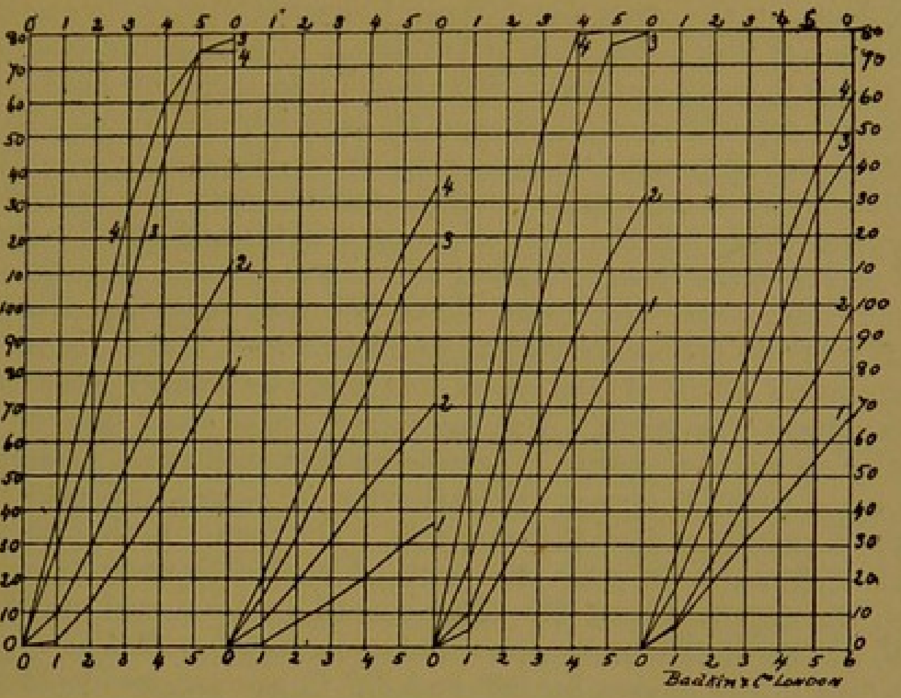

FIG. 21.

Figure 21 gives the curves of the series A, B, D, E, in the order of their sequence. The two Flour series, C and F, are given separately in Figure 22, because of their being drawn to a different vertical scale. Considering first the A 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 than at 30° C. In the B series, where the 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.

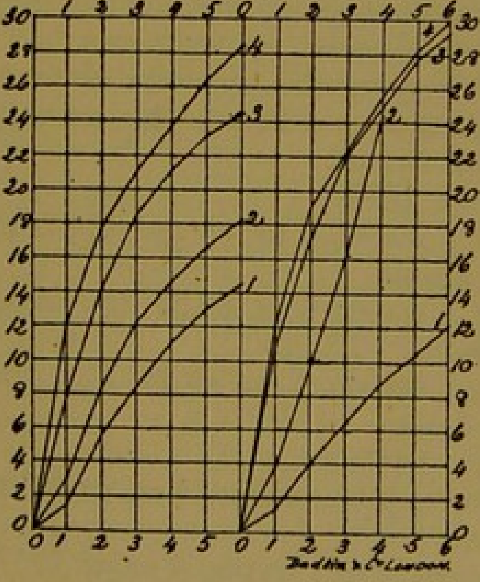

FIG. 22.

With flour, on the other hand, there is a more equal increase between each member of the series, but still there is a greater increase between Nos. 2 and 3 than the others. The remaining series of tests, D, E, F, are an exact repetition of A, B, and C, except in the employment of a different brand of yeast. Again, very much the same distinctions are observable between the members of the same series; this is readily seen by an examination of the sets of curves in D and E. It should be pointed out that the yeast B gives off, in every case, more gas during the same time than did yeast A in the corresponding experiment. This difference is not so striking in the two sets A and D, because, with the stimulating effect of the yeast mixture, the weaker yeast is helped proportionately 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. The result is that there is not so much difference between the sets of curves D and E as there is between the curves A and B. The second yeast caused, in the Flour series F, at the higher temperatures a more rapid evolution of gas than did the first. The curves for 30° and 35° C. are almost identical. For the first four hours the yeast B caused a remarkably rapid evolution of gas: at the end of that time the experiment was spoiled through an accident to the apparatus. At 20° C., yeast B gave off somewhat less gas from the flour mixture than did yeast A: out of the 24 different tests this is the only one in which the second yeast produced less gas. 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.**

**275. Results of using different quantities of Yeast.**—In the first series of experiments described (paragraph 267) two complete sets were made, the one with an eighth of an ounce of yeast, the other with a quarter of an ounce. As might be expected, with the greater quantity, more gas was evolved during the same time, but the effect of using twice as much yeast was not to cause twice as rapid an evolution of gas. The following experiments had as their object the study of the effect of varying the quantity of yeast, on the amount of gas evolved. The yeasts A and B, are the same as have been already referred to under those names.

Date, 14th July, 1885.

No. 1. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'A,' $\frac{1}{8}$ oz. = 2 drams.

No. 2. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'A,' $\frac{3}{16}$ oz. = 3 drams.

No. 3. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'A,' $\frac{1}{4}$ oz. = 4 drams.

Date, 8th July, 1885.

No. 4. Yeast mixture, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'A,' $\frac{1}{8}$ oz.

No. 5. Yeast mixture, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'A,' $\frac{3}{16}$ oz.

No. 6. Yeast mixture, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'A,' $\frac{1}{4}$ oz.

No. 7. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{1}{8}$ oz.

No. 8. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{3}{16}$ oz.

No. 9. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{1}{4}$ oz.

Date, 14th July, 1885.

No. 10. Yeast mixture, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{1}{8}$ oz.

No. 11. Yeast mixture, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{3}{16}$ oz.

No. 12. Yeast mixture, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{1}{4}$ oz.

Date, 15th July, 1885.

No. 13. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B,' $\frac{1}{4}$ oz. = 7·1 grams.

No. 14. Sugar, $\frac{1}{2}$ oz.; water, 6 oz. at 25° C.; compressed yeast, 'B' 6·4 grams = 10 per cent. less than in No. 13.

| Time. | Gas Evolved in Cubic Inches. | | | | | |
|---|---|---|---|---|---|---|
| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | No. 6. |
| 0 ... | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| | 1·2 | 2·0 | 3·1 | 4·8 | 6·1 | 8·5 |
| 1 hour... | 1·2 | 2·0 | 3·1 | 4·8 | 6·1 | 8·5 |
| | 4·3 | 7·0 | 9·9 | 12·7 | 16·9 | 20·8 |
| 2 hours | 5·5 | 9·0 | 13·0 | 17·5 | 23·0 | 29·3 |
| | 6·5 | 9·2 | 11·5 | 14·5 | 19·0 | 23·7 |
| 3 " ... | 12·0 | 18·2 | 24·5 | 32·0 | 42·0 | 53·0 |
| | 6·7 | 9·6 | 11·8 | 17·7 | 21·0 | 26·0 |
| 4 " ... | 18·7 | 27·8 | 36·3 | 49·7 | 63·0 | 79·0 |
| | 6·7 | 9·8 | 12·9 | 15·2 | 18·3 | 22·5 |
| 5 " ... | 25·4 | 37·6 | 49·2 | 64·9 | 81·3 | 101·5 |
| | 7·6 | 10·9 | 13·3 | 21·0 | 23·7 | 39·5 |
| 6 " ... | 33·0 | 48·5 | 62·5 | 85·9 | 105·0 | 141·0 |
| | No. 7. | No. 8. | No. 9. | No. 10. | No. 11. | No. 12. |
| 0 ... | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| | 1·2 | 2·4 | 6·6 | 0·9 | 4·1 | 6·0 |
| 1 hour... | 1·2 | 2·4 | 6·6 | 0·9 | 4·1 | 6·0 |
| | 5·5 | 11·6 | 17·9 | 10·3 | 17·4 | 30·2 |
| 2 hours | 6·7 | 14·0 | 24·5 | 11·2 | 21·5 | 36·2 |
| | 7·6 | 12·0 | 17·0 | 15·3 | 26·5 | 28·0 |
| 3 " ... | 14·3 | 26·0 | 41·5 | 26·5 | 48·0 | 64·2 |
| | 7·2 | 11·7 | 17·5 | 14·1 | 21·2 | |
| 4 " ... | 21·5 | 37·7 | 59·0 | 40·6 | 69·2 | ...... |
| | 7·0 | 11·1 | 16·0 | 18·4 | 22·9 | |
| 5 " ... | 28·5 | 48·8 | 75·0 | 59·0 | 92·1 | ...... |
| | 10·4 | 14·9 | 18·5 | 14·3 | 24·0 | |
| 6 " ... | 38·9 | 63·7 | 93·5 | 73·3 | 116·1 | ...... |
| | No. 13. | No. 14. | Ratios between 13 & 14. | | | |
| 0 ... | 0·0 | 0·0 | | | | |
| | 5·0 | 3·0 | 1·66 | | | |
| 1 hour... | 5·0 | 3·0 | | | | |
| | 16·0 | 11·5 | 1·39 | | | |
| 2 hours | 21·0 | 14·5 | | | | |
| | 22·7 | 19·0 | 1·19 | | | |
| 3 " ... | 43·7 | 33·5 | | | | |
| | 23·3 | 20·3 | 1·15 | | | |
| 4½ " ... | 67·0 | 53·8 | | | | |
| | 18·0 | 16·9 | 1·06 | | | |
| 5½ " ... | 85·0 | 70·7 | | | | |
| | 8·2 | 7·3 | 1·12 | | | |
| 6 " ... | 93·2 | 78·0 | | | | |

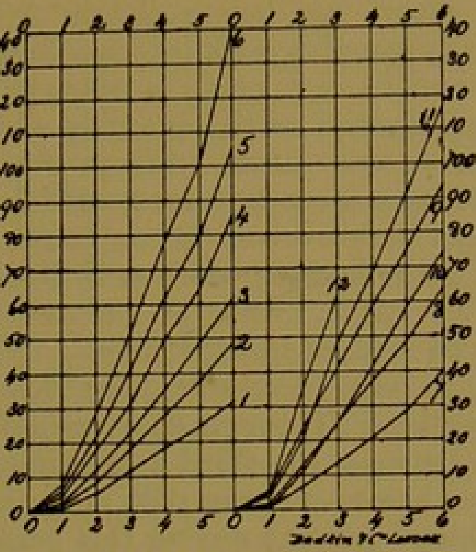

FIG. 23.

The first twelve of these results are illustrated in figure 23, those obtained with yeast A being first given, and then those obtained by the use of yeast B. It may be noticed that the stronger of the two yeasts causes throughout the more copious evolution of gas. Unfortunately, No. 12 test was accidentally spoiled at the end of three hours. In order to facilitate a comparison of these tests with each other, the mean, in each case, between the eighth and quarter of an ounce tests, has been calculated for the total of gas at three and six hours respectively. In addition, the means between the quantities of gas evolved in the same tests during the fourth hour has been similarly calculated; these quantities are those indicated by the numbers placed outside the brackets, between the three and four hour readings. The mean of any two numbers is obtained by adding them together, and dividing the sum by 2. As 3 is the mean between 2 and 4, theoretically one would expect that three drams of yeast would cause an evolution of gas closely corresponding with the mean of the quantities yielded by 2 and 4 drams of yeast respectively. The table below gives these calculated means, side by side with the actual quantities obtained by experiment.—

| Means between 2 and 4 dram experiments. | | Actual quantities evolved in 3 dram experiments. | |
|---|---|---|---|
| Nos. 1 & 3 at 3 hours, | 18·2 | No. 2 at 3 hours, | 18·2 |
| ,, at 6 hours, | 47·7 | ,, at 6 hours, | 48·5 |
| ,, during 4th hour, | 9·2 | ,, during 4th hour, | 9·6 |
| Nos. 4 & 6 at 3 hours, | 42·5 | No. 5 at 3 hours, | 42·0 |
| ,, at 6 hours, | 113·4 | ,, at 6 hours, | 105·0 |
| ,, during 4th hour, | 21·8 | ,, during 4th hour, | 21·0 |
| Nos. 7 & 9 at 3 hours, | 27·9 | No. 8 at 3 hours, | 26·0 |
| ,, at 6 hours, | 66·2 | ,, at 6 hours, | 63·7 |
| ,, during 4th hour, | 12·3 | ,, during 4th hour, | 11·7 |
| Nos. 10 & 12 at 3 hours, | 45·3 | No. 11 at 3 hours, | 48·0 |
| ,, during 3rd hour, | 21·6 | ,, during 3rd hour, | 26·5 |

An examination of these results shows that the quantity of gas evolved is fairly proportional to the amount of yeast employed; as the "means" in almost every case agree closely with the gas actually evolved in the direct experiments with intermediate quantities of yeast. Experiments Nos. 13 and 14 were made in order to determine the effect produced by a slight diminution of the quantity of yeast; in the former, half an ounce, 7·1 grams, was taken, while in No. 14, 6·4 grams were used, this quantity being ninety per cent. of 7·1 grams. In No. 13, 93·2 cubic inches of gas were evolved in six hours; ninety per cent. of this amounts to 83·9 cubic inches; whereas in No. 14, with ninety per cent. of yeast, but 78·8 cubic inches of gas are produced. Another point of interest may be noticed in experiments 13 and 14; the rate of evolution of gas during each successive hour rises and falls in almost exactly the same proportion. Through an oversight, an hour and a half was allowed to elapse between the third and fourth reading, but as this occurred with the both, the results are still comparative. In each case the maximum evolution of gas was during this period of one and a half hours. The constancy of this proportion or ratio is best shown by dividing one of the numbers by the other: if the ratio between them were in every case alike, the resulting quotients would be throughout identical. In the table, the column headed "Ratios" consists of figures opposite the brackets in No. 13, divided by those in No. 14; the last four such ratios agree very nearly, thus showing clearly how closely the proportional rate of evolution agrees in each case. At the end, when the speed of production of gas has fallen off to less than one half during the hour, the ratio remains practically the same. Now, in No. 14, the quantity of sugar still remaining in the solution must be more than in No. 13, and if the rate of evolution fell off only because of there being less sugar, a greater falling off might be expected in No. 13 than in No. 14: while as a matter of fact just the opposite occurs, the proportionate falling off being slightly more in the latter. Besides the diminution of the sugar, another factor is at work in lessening the evolution of gas, and that is the gradual exhaustion of the yeast cell: consequently, fermentation in sugar is particularly valuable where the object is to measure the strength or vital capacity for producing fermentation that any yeast possesses, especially when the fermentation has to depend on the original cells and not on the progeny produced by budding. For these reasons, sugar fermentation is, in the author's view, preferable, when testing a yeast as to its fitness for bakers' use. Summing up the results of these experiments—

**Working at 25° C., with the yeast apparatus, the quantity of gas evolved is fairly proportional to that of yeast employed.**

**When measuring the strength of yeast for bakers, sugar is indicated as the most suitable fermenting medium.**

**276. Further comparisons of Fermentation in Flour and Sugar Solutions.**—Since the greater part of this chapter was written, and almost immediately before going to press, some experiments were made, which seem to be of sufficient importance to warrant their special introduction here. Some samples of French compressed yeast, and also of English brewer's yeast, washed and compressed for continental export, were forwarded to the author for examination. With these yeasts the following series of tests were made—

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.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | No. 5. | | No. 6. | | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 25·0 |
| 1 hour ... | 6·0 | 6·0 | 3·7 | 3·7 | 3·5 | 3·5 | 11·2 | 11·2 | 5·7 | 5·7 | 0·7 | 0·7 | 25·0 |
| 2 hours ... | 18·7 | 12·7 | 10·0 | 6·3 | 13·5 | 10·0 | 35·0 | 23·8 | 21·0 | 15·3 | 1·1 | 0·4 | 25·0 |
| 3 " ... | 36·5 | 17·8 | 18·0 | 8·0 | 21·2 | 7·7 | 60·0 | 25·0 | 39·0 | 18·0 | 1·2 | 0·1 | 25·2 |
| 4 " ... | 53·0 | 16·5 | 25·2 | 7·2 | 25·5 | 4·9 | 79·0 | 19·0 | 52·7 | 13·7 | 1·5 | 0·3 | 25·0 |
| 5 " ... | 72·7 | 19·7 | 33·1 | 7·9 | 29·0 | 3·3 | 97·5 | 18·5 | 67·2 | 14·5 | 1·7 | 0·2 | 25·0 |
| 6 " ... | 91·2 | 18·5 | 40·8 | 7·7 | 32·3 | 3·3 | 115·2 | 17·7 | 80·0 | 12·8 | 1·9 | 0·2 | 25·0 |
| | No. 7. | | No. 8. | | No. 9. | | No. 10. | | No. 11. | | | | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | | | 25·0 |
| 1 hour ... | 4·0 | 4·0 | 0·0 | 0·0 | 0·0 | 0·0 | 3·7 | 3·7 | 0·3 | 0·3 | | | 25·7 |
| 2 hours ... | 21·7 | 17·7 | 0·0 | 0·0 | 0·2 | 0·2 | 17·5 | 13·8 | 1·5 | 1·2 | | | 25·5 |
| 3 " ... | 43·5 | 21·8 | 0·2 | 0·2 | 0·5 | 0·3 | 36·0 | 18·5 | 0·7 | 0·8 | | | 25·0 |
| 4 " ... | 55·0 | 11·5 | 0·3 | 0·1 | 0·7 | 0·2 | 47·0 | 11·0 | 1·0 | 0·3 | | | 25·0 |
| 5 " ... | 65·0 | 10·0 | 0·5 | 0·2 | 1·0 | 0·3 | 57·0 | 10·0 | 1·0 | 0·0 | | | 25·0 |
| 6 " ... | 80·3 | 15·3 | 0·5 | 0·0 | 1·0 | 0·0 | 72·0 | 15·0 | 1·0 | 0·0 | | | 25·0 |

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. So far as a conclusion can be drawn from these few experiments, brewers' yeasts may cause copious evolution of gas from yeast mixture and sugar solution, but are unable to produce gas, under this system of testing, from dilute mixtures of flour and water. Further, little or no fermentation occurs even when sugar is added to the flour and water mixture. Under the microscope, both brewers' yeasts were healthy in appearance; the cell walls in the compressed sample appeared somewhat thin, but there was no striking divergence from the normal. These results obtained on brewers' yeasts are so anomalous, that it was thought due to the readers of this work to insert them. At the earliest possible moment, the author will proceed to examine these remarkable results more exhaustively, and hopes shortly to be able to make public the results of such investigation. It should be mentioned that in comparison of yeasts of the same type with each other, as for instance the various brands of French compressed yeasts, the results of fermentations in flour practically agree with those of fermentation in yeast mixture and sugar solutions.

### EXPERIMENTAL WORK.

**277.** 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 also prepare diagrams of curves representing graphically the quantities of gas he finds to be evolved. For this latter purpose he may procure an exercise book, ruled both ways of the page, with lines about a quarter of an inch apart. The hours and volumes in cubic inches should then be set off exactly as in the diagrams given in the preceding pages. Omitting the experiments on the measurement of the carbon dioxide gas evolved by weighing the apparatus, the student 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 264th 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.

**278. 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 paragraph 471, chapter XX. 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.

**279. 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 24.

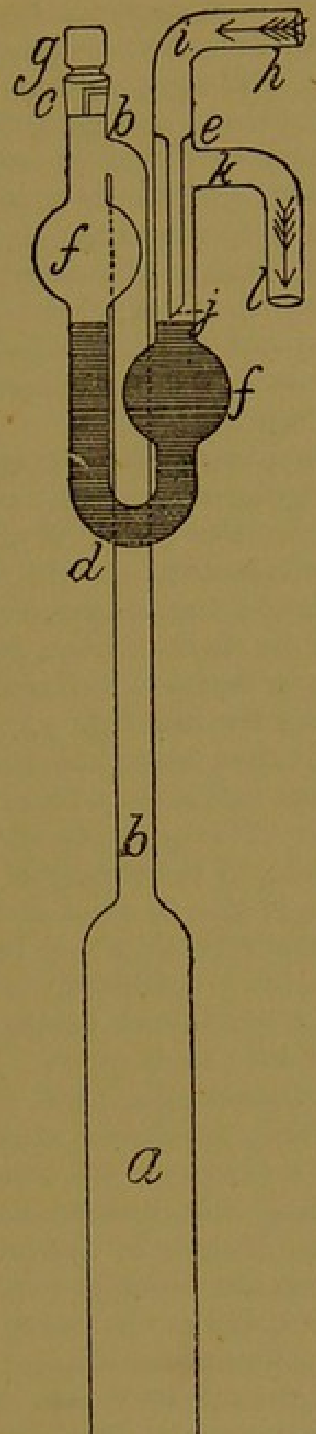

FIG. 24.—AUTOMATIC TEMPERATURE REGULATOR.

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 two 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.

By means of a screw-clamp 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 to 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 ¼ 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.

280. **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 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 the 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.

**281. 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) is 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.

**282. 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.

**283. 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.

**284.** For baking purposes three commercial varieties of yeast are employed, namely, Brewers', Continental 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.

**285.** 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 than 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 so the yeast produced is 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 æerated during its flow down the side of the cask. For baking purposes, the thorough æration of yeast is essential.

**286. 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 magnifying power of about 1000 diameters. Thoms, whose microscopic researches on bakers' yeasts are so well known to bakers, employs an immersion lens, giving him a magnification of about 2500 diameters; but it is doubtful whether any except microscopists of long experience could work with such high 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 that, 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, examine the sample very carefully for free sporules floating in the liquid: these are small round globules, requiring careful examination for their detection. They are produced by the absorption of the walls of the cell, and the consequent setting free of its contents. Should the yeast contain any considerable number of these, it must be taken as evidence that the cell walls are either naturally excessively delicate and thin, or that it has been kept long enough for the cells to have commenced breaking down. As in breadmaking, 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 with full maturity, removed from the state in which the cell walls break down, and set free the immature sporules, which must require some time before they can have vigorous fermenting power. The contents of the cells should show slight granulations: their entire absence may arise from the yeast being too fresh, and only just skimmed, or from the cells being sufficiently old for the interior protoplasm to have broken down into a watery mass. In the former instance the contents will be watery throughout; in the latter, immature sporules may be seen floating within the cell: these, on careful examination, may be distinctly seen to possess the Brownian movement: if so, the yeast is far gone, and will be found weak and exhausted for bread making. 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. For an admirable series of illustrations of the appearance of yeast under the microscope the reader is referred to Faulkner and Robb's translation of Pasteur's "Studies on Fermentation."

In order to facilitate comparison, yeast, various disease ferments, starch, and other impurities associated with yeast are shown together in the following figure:—

FIG. 25.—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.

Sketches will follow of different yeasts examined by the writer, but these, as has been already mentioned, are simply fac-similes of such studies as should be made by the student during the course of his work, and entered in his note-book. This form of illustration has been adopted in order to thus serve as a guide to the student.

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.

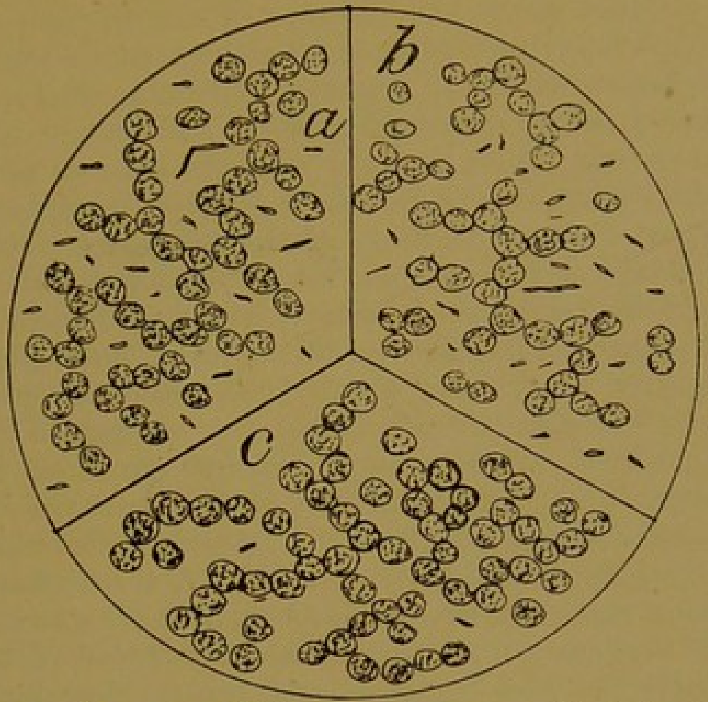

FIG. 26.—BREWERS' YEAST. Different specimens magnified about 440 diameters.

The sketches for the above engraving were made in the summer, and represent samples of brewer's 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 sketches 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.

### MANUFACTURE OF COMPRESSED YEASTS.

**287.** 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, the Netherlands, 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.

Mr. Bischof, London, the importer of Encore yeast, has kindly furnished the author with an account of the processes employed in the manufacture of that yeast. The Encore stands with others in the highest class of imported yeasts; therefore, a description embodying the mode of its production may be taken as a type of the methods employed generally by the best distillers in yeast manufacture. It is obvious that any extended description of the production of compressed yeasts is a distillers' rather than a bakers' question, therefore the following account gives the principles rather than the details of the various processes employed. It should further be mentioned that in addition to the outline supplied by Mr. Bischof, the author has incorporated information and experience gained from other sources. Distillers employ, in the preparation of their mash, a mixture of malt and raw grains: the latter consist principally of barley, rice, degermed maize, and rye. The latter of these, in the mixture, produces a wort well fitted for a healthy growth of yeast. To a great extent the particular raw grain selected depends on their relative cheapness from time to time; but where the distiller wishes to find a market for his yeast, as well as his spirit, it is essential that only the best and soundest variety of grain be selected. The raw grain mixture is first mashed at a temperature commencing at from 50° to 60° C. (122° to 140° F.), and gradually increased to from 65° to 70° C. At the end of two or three hours the malt is added to an extent of from one seventh to one quarter of the whole of tne grain used; the mashing is then continued until all the starch has been converted into maltose. One point of difference between ordinary distillers' and brewers' mashes is that the latter find the presence of lactic ferments in small quantity to be an advantage, as the subsequent fermentation is consequently more energetic and complete, resulting in a larger yield of alcohol. Distillers therefore frequently allow their malt to lie until lactic ferments have developed in considerable numbers on the grain. This does not, however, apply to those distillers who make the production of yeast their principal object, as they do all they can to absolutely prevent lactic fermentation. Distillers who simply wish to produce spirits do not trouble to skim off their yeast, but place mash and yeast together in the stills. The saccharified mash is next cooled by refrigerators, and fermented by the addition of mother yeast. As the fermenting operation is performed for the purpose not only of producing alcohol but also the growth of yeast, it should be conducted so as to induce a healthy development of yeast. For this purpose the wort should be well ærated, being "roused" from time to time: the fermenting tuns should be sufficiently shallow to expose a large surface to air. At the time when the fermentation is most energetic, **the yeast is skimmed off the surface**, and conveyed by wooden shoots to steam sieves, by which the husks are eliminated, the strained liquid passing on to the settling cisterns. When settled, the surface liquid is drained off and sent for distilling purposes, and the yeasty sediment mixed with starch, and put into the filter presses, which squeeze out all the liquid, leaving a dough-like paste, which when sufficiently dry, is packed in bags and packets, and is ready for distribution to wherever it may be needed.

Yeast, from its peculiar slimy nature, cannot be pressed well—hence the addition of starch, which permits the removal of more of the liquid from the yeast. Absolutely pure yeasts do not keep so well as the same yeasts with an addition of from 5 to 10 per cent of starch. In high-class yeasts the quantity added is about 5 or 6 per cent. Starch is undoubtedly at times added to yeast in large excess; it then becomes an adulterant: this fraud is, however, readily detected by treating the sample of yeast with iodine. For this purpose, break up a little of the yeast with water in a test tube, add some tincture of iodine, and shake up; the starch on standing will more or less separate out as a dark blue layer at the bottom of the tube. One of the best tests for starch adulteration 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. 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 it should melt readily 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. The following sketch was made from a sample of compressed yeast. 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 ,, |

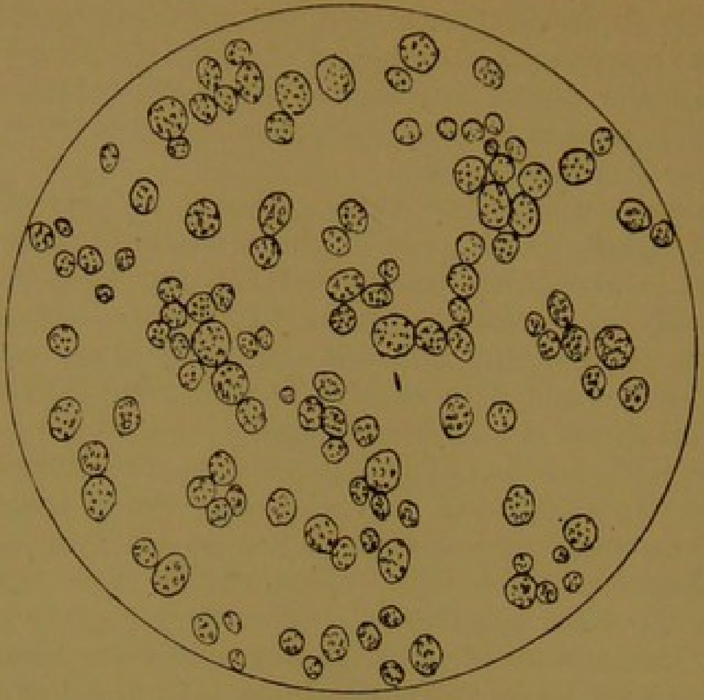

FIG. 27.—CONTINENTAL PRESSED YEAST, magnified about 440 diameters.

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.

### "Patent," or Bakers' Home-Made Yeasts.

**288.** 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 continental 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 enormous 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 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.

**289. 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 28 represents its appearance after three days.

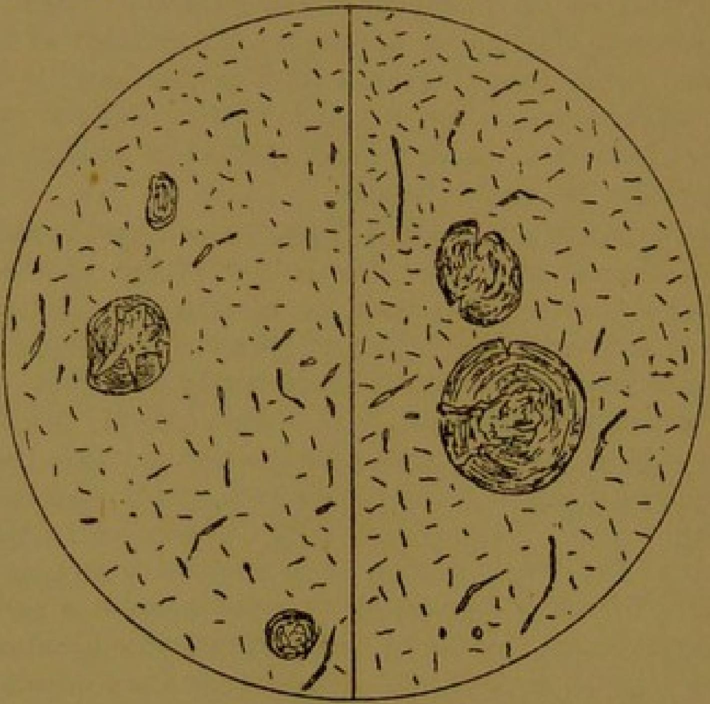

FIG. 28.—MALT WORT ALLOWED TO FERMENT SPONTANEOUSLY.

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.

The most careful examination of field after field revealed not a single 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.

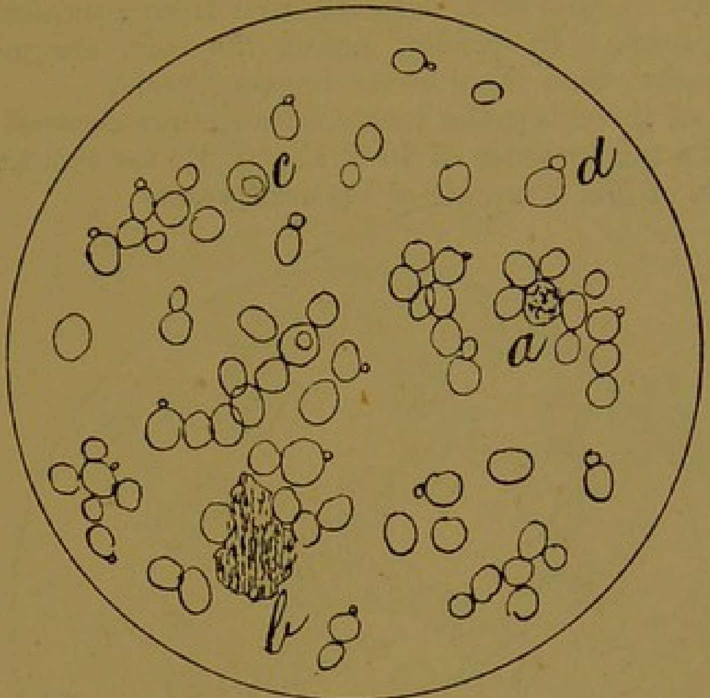

FIG. 29.—BREWERS' YEAST, 24 hours after being sown in Malt Wort. Magnified about 440 diameters.

This figure 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.

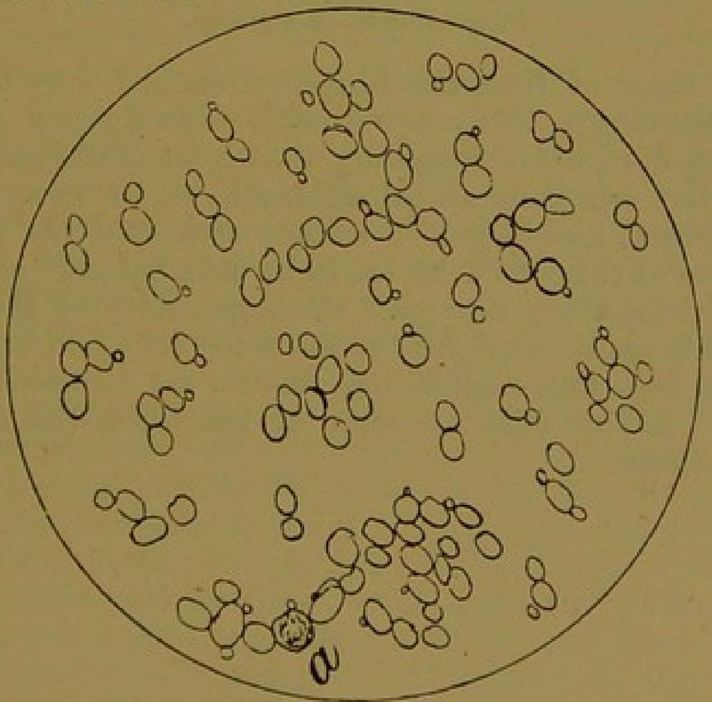

FIG. 30.—COMPRESSED YEAST, 24 hours after being in Malt Wort. Magnified about 440 diameters.

The appearance of this figure is very similar to that of the preceding one. An example of an old cell is to be seen at *a*, 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.

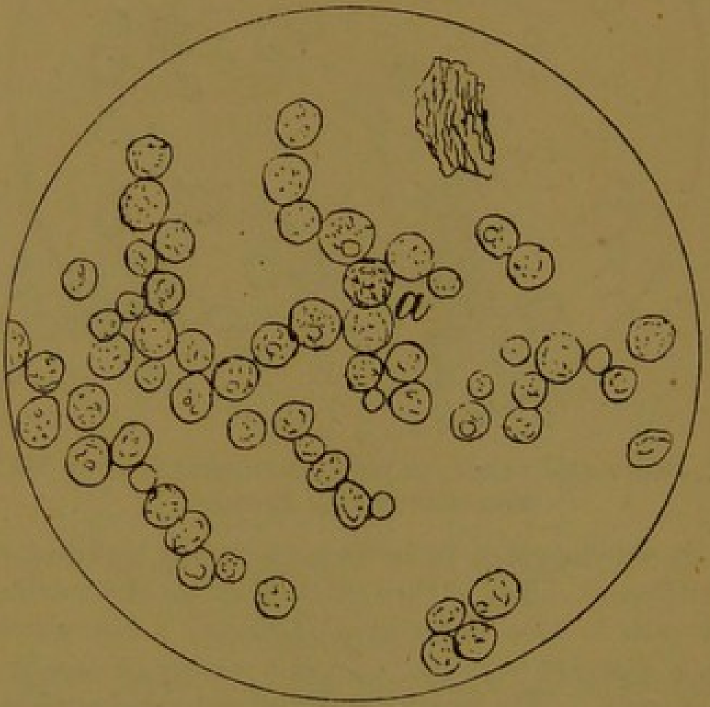

FIG. 31.—BREWERS' YEAST, three days after being sown in Malt Wort. Magnified about 440 diameters.

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.

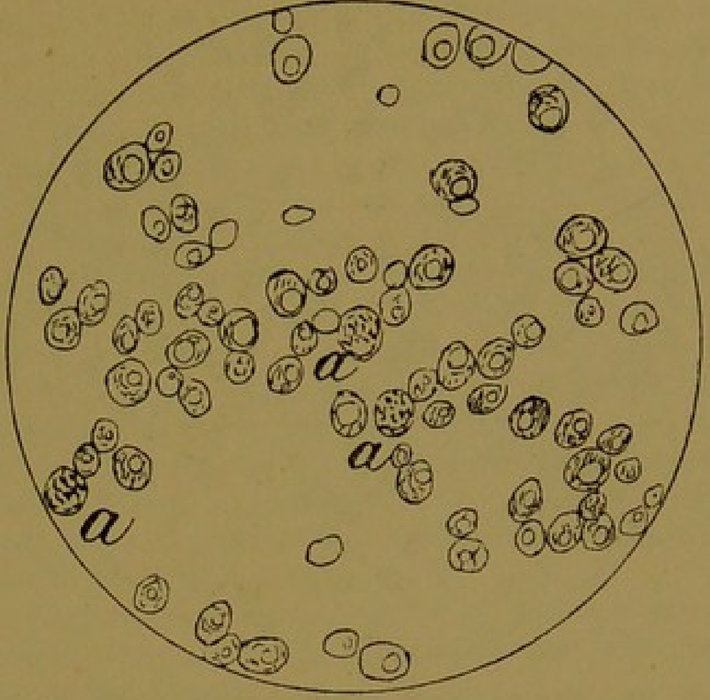

FIG. 32.—COMPRESSED YEAST, three days after being sown in Malt Wort.
Magnified about 440 diameters.

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 vini;* a growth which has been described in chapter IX. The cells of *mycoderma* are in appearance somewhat like elongated yeast cells, and are shown in figure 33.

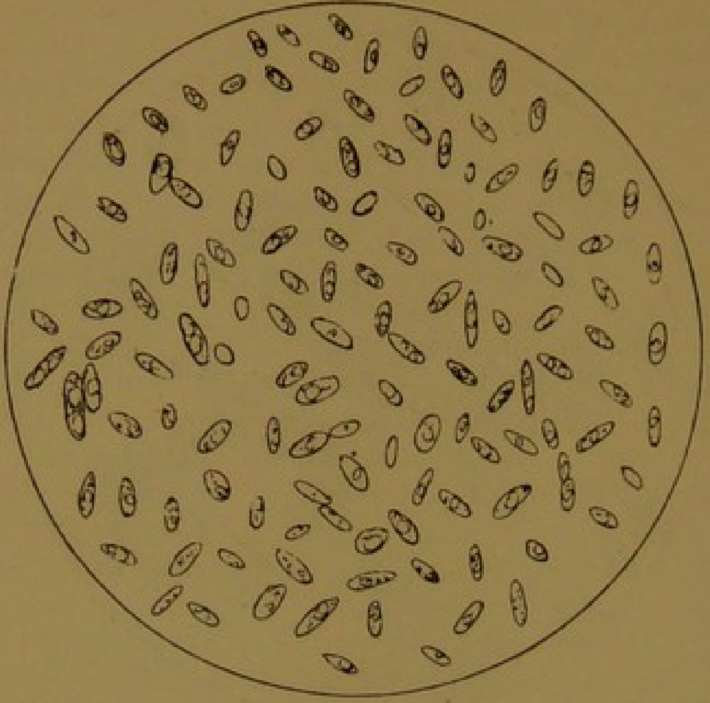

FIG. 33.—FILM OF MYCODERMA, taken from surface of sample of Compressed Yeast. Magnified about 440 diameters.

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.

**290. Patent Yeast Recipes.**—The following two recipes for the preparation of patent yeast are quoted from the "Millers' Gazette."

**291. Virgin Malt Yeast, Haig's "Patent."**—1 lb. hops, and 7 imperial gallons of water are mashed for twenty minutes, then boiled for ten or fiteen minutes, and strained, cooled down to 170° F., and 12lb. malt stirred into the infusion; this, after mashing for fifteen minutes, has the malt grains separated or pressed out, and the liquor allowed to cool down to and kept at the temperature at which fermentation—spontaneous—(not below 76° or over 80°)—will be carried on.

This is the Virgin Yeast.

Fermentation will or should begin in from eighteen to twenty hours, and continue after that sixteen to twenty-four. When at its full height, take from the top half-a-gallon and place it in a close jar, in which place also 1 oz. or less bicarbonate of soda, and then cork air-tight and keep in a cool place.

This is a store for next brewing.

**292. Banbury Patent Yeast.**—9 gallons water, ½ lb. hops, ½ lb. bruised ginger. Let these simmer three hours, then strain off, and when cooled to 160-170° F., stir in 7 lb. malt. Mash for three hours, strain and well squeeze the malt grains. When the mash-liquor has cooled to 70-76°, start fermentation with one gallon of "patent" yeast from previous brewing, and add 8 lb. flour. Next day put into a cask and bung close.

This yeast is used with ferment, one quart (2½ lb.) to the sack, nine hours from time of starting ferment to setting sponge.

The recipes are both stated to give good results; but the author has no personal acquaintance with the working of either. There are radical defects in the mode of procedure in each recipe.

**293. Patent Yeast, Feaist's Formula.**—Mr. Feaist, of Hastings, is well known as one of the largest bakers in the south of England;

and so far as the writer knows he stands almost alone among the large bakers as using only patent yeast, to the exclusion of all other varieties. The following is a description of his method of preparing patent yeast, 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. The wort is then set; fermentation sets in, and the yeast is 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. Mr. Feaist devotes great attention to his yeast, and his efforts result in the production of a first-class article.

**294. Suggestions on Yeast Brewing; what to do, and what to avoid.**—Mr. Feaist's quantities 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. 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, 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. Dealing with this topic, "Tablier Blanc," in the "British and Foreign Confectioner," forcibly writes,—"Weak worts are very liable to turn sour. I have seen 20 gallons of water, and 120 used, each with the same quantity of malt and hops; that is six times as much water in one case as in the other, and the result was that one gallon of the strong was found to be better than six of the weak. I will now close these remarks on barm-brewing with a maxim which is worth remembering, and should be borne in mind and acted on whilst making it. It is this—Water is not barm, therefore use as little of it as you can."

**295. 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."

**296. Microscopic Sketches of Patent Yeast.**—In the following figure are given microscopic sketches made of patent yeasts collected in the South of England.

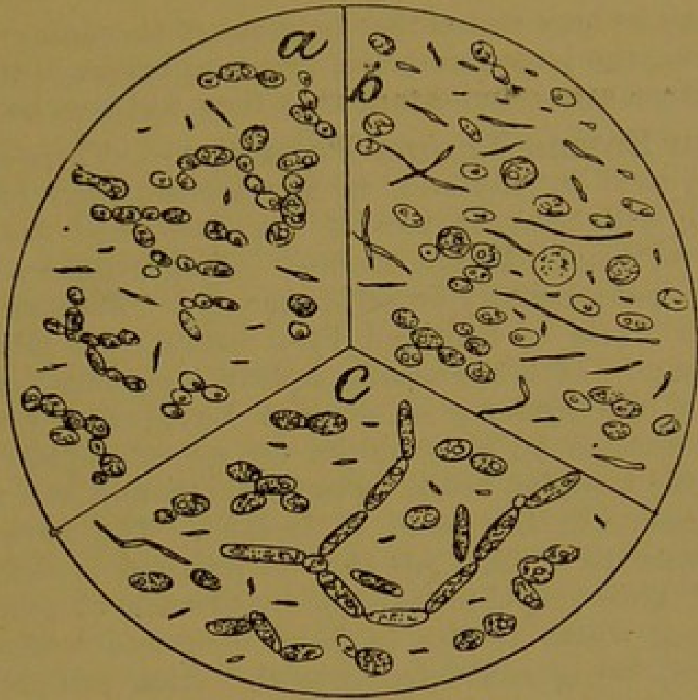

FIG. 34.—BAKERS' PATENT YEAST, different specimens magnified about 440 diameters.

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 termed yeast or *bacteria;* certainly these 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 baker *a* does a larger trade than does baker *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.

**297.** There have recently appeared two authoritative statements on Scotch flour barms; the one in "The American Miller," by Thoms; the other in "The British and Foreign Confectioner," by a "Glasgow Baker," of whom it may be here stated that he is one of the most eminent and experienced among the large number of practical bakers in that city. Both these descriptions are so important that they will best be given in full.

**298. Flour Barms, Thoms' Formulæ.**—"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 twenty 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 easy 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.

**299. "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.)

**300. "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.

**301. "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 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.

302. "**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 for 18 to 24 hours in a cool place, so that the old cells, which have then passed the active budding stage, may in peace and quietness resolve their protoplasm into spores or young cells. This is best promoted at a temperature between 40° F. and 60° F. That is the meaning of the advice to remove barm, after active fermentation, to a cool place. Barm at this stage should be kept in shallow tubs, or coolers, where a large surface is exposed to free oxygen. Free oxygen is indispensable to healthy cell life at this spore-forming stage."

303. **Flour Barms, "Glasgow Baker's" Formula.**—"I purpose showing in this article that Scotch bakers can and do make healthy barm, and keep it so, without the slightest scientific knowledge, being solely guided by sight and taste. The grounds for the statement I shall fully advance after giving the recipe.

304. "**Ingredients.**—15 lbs. malt crushed, 4 lbs. English hops, 3 qrs. home winter wheat flour, 1 qr. hard spring wheat flour (either Baltic or American).

305. "**Mode.**—Boil hops with 3 gallons water for 15 minutes, with this liquor mash the malt; temperature, 165° F. (74° C.); allow it to

be in a tub for 4 hours, then wring or squeeze the malt by hand, keeping in mind that the last drops are the most valuable. Strain through a sieve of 6 holes to the inch, add 2 gallons hot water. The liquor should now be about 130° F. (53° C.), which is the proper heat for the batter. This is made by adding flour, and doughing up the liquor to the consistency of a dough for morning rolls, as made in Scotland, or Vienna rolls in England. Your tub, containing the batter, should be 24 inches wide, by 27 deep. It must now be drawn close to boiler for you to draw your water, which should be 220°. [As 212° F. is the boiling point of water, it is difficult to understand how "Glasgow Baker's" water, when drawn into the tub, should be at a temperature of 220° F.] For stirring, use a stick of hard wood, 1½ in. in diameter, 4½ ft. long. Two men should be standing by, as stirring must be performed at such a speed that the strongest man cannot continue stirring more than 3 gallons without a rest. The operation should be continuous, each man taking the stick alternately as the other rests. The most trying stirring is when the third 3 gallons have been added, because here the scald must take place. If you are to have a perfect scald 50 to 60 seconds will suffice. The stirring speed should be 120 to 130 strokes per minute. You will now know whether your water has been perfectly boiling, as the scald will be so thick after 45 seconds stirring that the strongest man will have difficulty in driving the stirring-pole through it. The mixture has now lost the appearance of raw flour and water, and assumed a rich yellow hue, and has the sweet taste of cooked flour. The critical stage has now been passed. Continuing the stirring at 70 to 80 strokes to the minute, you add, in two equal portions, 6 gallons more water, stirring about 70 seconds for each of the 3 gallons. Your scald is now made, and should be put in a cellar with a fair ventilation, and at a temperature of not less than 60° in winter, and the nearer this temperature is kept to in summer the less difficulty will arise in keeping the barm sweet and regular. After standing 4 hours, several rents will appear across the surface, and little patches of white froth will rise from these rents. These will continue to grow larger for the next 18 hours. The scald may be stored from 24 to 36 hours old, provided the heat is not over 80°, for weather such as has been experienced in November, 1884. The mode of storing barm is as follows: put this quantity of scald into a tub double the size of that used for scalding, add 3 gallons of healthy Parisian barm, and 14 lbs. fresh flour, stirring well, cleaning sides of tub thoroughly. It will be up its full height in the tub in about 10 hours, and in from 18 to 24 hours time it will have dropped in the tub about 6 in. It should at this stage be divided into coolers—tubs 24 in. wide, 13 in. deep. Twelve hours after this it may be used for English or fancy bread, but for Scotch square batched bread it requires 48 hours in the coolers to mellow it sufficiently. New barm gives too much bulk, and cannot be skinned or piled, as the Scotch bakers term the texture of the loaf. Barm for storing should not be more than four days old—that is from the date of storing.

"I have in the foregoing treated of the methods of producing healthy barm, and I now offer a few hints as to the signs by which practical men know whether barm is or is not healthy. When the barm comes up well in the tub, with thousands of little bells coming up to the surface, and breaking as they come, driving the large dull and floury bells to the sides of the tub, where they disappear slowly. When barm is ripe for cooling, clear bells, or, as bakers term them, "black bells," appear on the clear surface. They appear at first sight "black" on a white surface; but, on looking into them, you see they are simply a transparent bubble without trace of flour. Barm makers have got to know, from a long course of observation, that these are the sure signs of perfect healthy barm, and they state they have never seen bad bread made from barm of this description. The term "Lifey" is applied to healthy barm; the term "Dead" is applied to barm when all the active healthy little bubbles or cells cease to come up and explode on the surface. By the very face of it, when in this state, a practical man on looking at it will shake his head, and say, "It is gone; I will not use it." He will then taste it, and if the taste bears him out, he will make up his mind to put it down the sink. This is the knowledge the practical man has, and his discoveries, it will be observed, are made through sight and taste only.

"It will naturally be asked "Why don't you show us that your practical man can keep his barm healthy, and how he does it?" This is how it is done. When he sees the bubbles rising feebly, he at once says there is a want of "life" or "forces," and will infuse fresh life by storing half from a young barm 36 hours old, and half the 48 or 72 hours sickly barm. This will, under ordinary circumstances, bring it right, but if the appearance is still dull he will keep adding every time he stores a new scald, a larger proportion of the young barm, till he is satisfied he has brought it round. The only exception to such is when barm gets fired, through a thunderstorm, in which case, as a rule, it is completely killed, and cannot produce sweet bread. It often happens, however, in a cellar with, say, 10 tubs of barm, that only half or so are affected by the electric fluid, the remaining ones keeping quite "healthy." In such a case the baker can start fresh lots from the uninjured tubs, but if all are fired, then he must go and get a store of "healthy" barm from some neighbour who has been less unfortunate than himself; but here again he must use his judgment as to whether his friend's barm is "healthy," and I have never known a practical man deceived in such. Many of the men who make the barm in the largest bread factories in Scotland, have no scientific knowledge of barm. They never read a book on the subject, nor have they ever heard the matter contained therein spoken of. Many of the barm makers in Scotland started as careful lads, entrusted with the scalding of the tubs with boiling water, which is most essential, in order to kill the particles of old fermentation; and I have known such lads who could neither read nor write become highly successful barm makers.

"This article is not written to show that science is useless to bakers, but is a simple statement of facts, showing the stage of perfection at which practical men had arrived before scientists took the subject in hand. I have known such bakers who did not require to change their store for two years at a time, and have had successful runs of sweet barm for years."

**306.** It is somewhat amusing to read the statement of the purpose for which this article was written—namely, to show how Scotch bakers make healthy barm, without scientific knowledge. There is an old story of a man who in advanced years discovered, with much surprise, that he had been talking prose all his life without knowing it. Scotch bakers have reduced barm and bread-making to a science, "without knowing it." Defining science as knowledge, systematically arranged—such knowledge to be true science must be founded on careful and patient observation. Notice how thoroughly scientific the "Glasgow Baker's" method is. He works with exactness; at every stage of his process he brings to bear the result of life-long observation; as a consequence, he is able to tell directly whether the growth of his barm is good or bad: all this is the application of genuine scientific methods. But the "Glasgow Baker's" science is, although true science, defective and imperfect science. The methods of how to work have been conquered; but the reasons why have been ignored. Science insists, not merely that methods shall be systematic, accurate, and good, but also insists on knowing why they are so. The man who knows the why and wherefore of a step has some chance of improving on the methods he has been in the habit of using; the man who only knows it is so, "because it is so," simply flounders hopelessly, at once getting out of his depth, if he ventures in the unknown waters of attempted improvements. For their own sakes it is time that practical men gave up that idea of science being a sort of fetish, having no connection with practical men's work or ways. Science has its practical side, and is in that respect identical with the ways and methods of practical men: the fact that it also demands an examination into the why and wherefore of things should simply be an additional commendation to men of practice, for nine-tenths of the discoveries and improvements made in arts and manufactures have resulted from careful inquiry into the connection between cause and effect.

**307. Suggested Modifications of Flour Barm Recipes.**—The both of these recipes are the work of practical men who are capable of making, and do make, some of the best bread in the world: the methods used are therefore justified by their being successful. There is however one point in which, in the author's opinion, the methods might be modified with advantage. It will be noticed that in both cases the malt is first mashed with water, so as to convert its starch into maltose and dextrin. In the next place this wort is mixed with flour, so as to make a batter, which in its turn is scalded (that is, the starch of the flour is gelatinised), by the addition of hot water. Now, in this case the hot water is added to the batter containing the malt wort; the inevitable consequence of the addition of boiling water to this must be to destroy some of the diastase of the malt, and consequently to lessen the action which it afterward exerts on the gelatinised starch of the flour. Notice how particularly it is directed that the mixture shall be stirred sharply: this must be done so rapidly, that it is recommended that two men be ready, the one to relieve the other. The rapid stirring, by quickly cooling the added water, by its intermixture with the remainder, lessens the danger of altogether destroying the diastase. As an alternative method, it is suggested that the flour should be mixed with warm water and then scalded in a separate vessel; then when the scalded flour had been cooled to a temperature of from 65° to 70° C., the malt wort might be added. Diastasis would then proceed all the more vigorously, as the malt wort would not have been in any way injured by the addition to it of boiling water. The risk of spoiling the whole of the barm, during scalding, would in this way be almost, if not entirely, avoided.

**308. 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.

**309. Strength of Various Yeasts.**—There follow particulars of the strength of various samples of yeasts, when tested 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 were taken for each test, and six ounces of the patent yeasts, water then being dispensed with. 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.

**310. First Series.**

No. 1. Compressed Yeast, A, 27th April, 1885.
No. 2. Brewers' Yeast, A, from London yeast merchant, 1st May, 1885.
No. 3. Compressed Yeast, B. 5th May, 1885.
No. 4. Dublin Patent Barm, 6th May, 1885.
No. 5. Ditto, another sample, 6th May, 1885.
No. 6. Brewers' Yeast, A, 7th May, 1885.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | No. 5. | | No. 5. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 21·7 | | 2·3 | | 19·2 | | 4·7 | | 0·8 | | 4·3 |
| 1 hour... | 21·7 | | 2·3 | | 19·2 | | 4·7 | | 0·8 | | 4·3 | |
| | | 41·3 | | | | 42·8 | | 15·6 | | 3·7 | | 12·2 |
| 2 hours | 63·0 | | | 33·2 | 62·0 | | 20·3 | | 4·5 | | 16·5 | |
| | | 33·0 | | | | 41·5 | | 15·7 | | 7·0 | | 18·5 |
| 3 ,, ... | 96·0 | | 35·5 | | 103·5 | | 36·0 | | 11·5 | | 35·0 | |
| | | 34·3 | | 18·7 | | 40·1 | | 16·9 | | 9·5 | | 18·0 |
| 4 ,, ... | 130·3 | | 54·2 | | 143·6 | | 52·9 | | 21·0 | | 53·0 | |
| | | 24·2 | | 11·7 | | 24·4 | | 17·1 | | 10·5 | | 22·0 |
| 5 ,, ... | 154·5 | | 65·9 | | 168·0 | | 70·0 | | 31·5 | | 75·0 | |
| | | 15·7 | | | | 9·8 | | 13·6 | | 12·3 | | 23·5 |
| 6 ,, ... | 170·2 | | ... | | 177·8 | | 83·6 | | 43·2 | | 98·5 | |

No. 7. Compressed Yeast, A, 7th May, 1885.
No. 8. Brewers' Yeast, A, 14th May, 1885.
No. 9. Dublin Patent Barm, another sample, 14th May, 1885.
No. 10. ,, 4th sample, ,,
No. 11. Dutch Pressed Yeast, from Dublin, 21st May, 1885.
No. 12. French ,, ,, ,,

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 7. | | No. 8. | | No. 9. | | No. 10. | | No. 11. | | No. 12. | |
| 0 ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 24·5 | | 4·2 | | 11·2 | | 1·8 | | 47·5 | | 35·0 |
| 1 hour | 24·5 | | 4·2 | | 11·6 | | 1·8 | | 47·5 | | 35·0 | |
| | | 36·4 | | 15·1 | | 23·9 | | 4·7 | | 45·5 | | 51·3 |
| 2 hours | 60·9 | | 19·3 | | 35·5 | | 6·5 | | 93·0 | | 86·3 | |
| | | 33·1 | | 17·7 | | 34·2 | | 8·3 | | 51·9 | | 45·7 |
| 3 ,, | 104·0 | | 37·0 | | 69·7 | | 14·8 | | 144·9 | | 132·0 | |
| | | 32·0 | | 17·0 | | 30·8 | | 8·6 | | 25·1 | | 30·3 |
| 4 ,, | 136·0 | | 54·0 | | 100·5 | | 23·4 | | 170·0 | | 162·3 | |
| | | 22.5 | | 18·6 | | 44·3 | | 9·8 | | 1·8 | | 16·2 |
| 5 ,, | 158·5 | | 72·6 | | 144·8 | | 33·2 | | 171·8 | | 178·5 | |
| | | 17·5 | | 19·4 | | 33·2 | | 11·3 | | 0·0 | | 0·1 |
| 6 ,, | 175·0 | | 92·0 | | 178·0 | | 44·5 | | 171·8 | | 178·6 | |

No. 13. Brewers' Yeast, A, 29th May, 1885.
No. 14. Patent Barm, from near Dublin, 29th May, 1885.
No. 15. Brewers' Yeast, A, 11th June, 1885.
No. 16. Brewers' Yeast, A, 25th June, 1885.
No. 17. Compressed Yeast, A, 25th June, 1885.

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. 13. | | No. 14. | | No. 15. | | No. 16. | | No. 17. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 2·4 | | 2·0 | | 3·4 | | 1·6 | | 37·8 |
| 1 hour ... | 2·4 | | 2·0 | | 3·4 | | 1·6 | | 37·8 | |
| | | 11·5 | | 7·0 | | 13·9 | | 8·4 | | 47·2 |
| 2 hours ... | 13·9 | | 9·0 | | 17·3 | | 10·0 | | 85·0 | |
| | | 15·1 | | 10·3 | | 16·7 | | 15·5 | | 39·3 |
| 3 ,, ... | 29·0 | | 19·3 | | 34·0 | | 25·5 | | 124·3 | |
| | | 15·5 | | 12·0 | | 16·0 | | 17·0 | | 36·3 |
| 4 ,, ... | 44·5 | | 31·3 | | 50·0 | | 42·5 | | 160·6 | |
| | | 17·3 | | 12·7 | | 19·5 | | 16·0 | | 6·9 |
| 5 ,, ... | 61·8 | | 44·0 | | 69·5 | | 58·5 | | 167·5 | |
| | | 18·5 | | 14·3 | | 16·0 | | 16·3 | | 0·0 |
| 6 ,, ... | 80·3 | | 58·3 | | 85.5 | | 74·8 | | 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 ¼ 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.

### 311. Second Series.

No. 1. Compressed Yeast, A, 2nd July, 1885.
No. 2. Compressed Yeast, B, ,,
No. 3. Compressed Yeast, B, 8th July, 1885.
No. 4. Compressed Yeast, A, 14th July, 1885.
No. 5. Compressed Yeast, B, 15th July, 1885.
No. 6. Compressed Yeast, A, ,,

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 1. | | No. 2. | | No. 3. | | No. 4. | | No. 5. | | No. 6. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 7·0 | | 7·7 | | 6·6 | | 3·1 | | 5·0 | | 5·0 |
| 1 hour ... | 7·0 | | 7·7 | | 6·6 | | 3·1 | | 5·0 | | 5·0 | |
| | | 12·0 | | 17·3 | | 17·9 | | 9·9 | | 16·6 | | 12·0 |
| 2 hours... | 19·0 | | 25·0 | | 24·5 | | 13·0 | | 21·0 | | 17·0 | |
| | | 13·0 | | 18·7 | | 17·0 | | 11·5 | | 22·7 | | 18·8 |
| 3 ,, ... | 32·0 | | 43·7 | | 41·5 | | 24·5 | | 43·7 | | 35·8 | |
| | | 13·0 | | 17·5 | | 17·5 | | 11·8 | | 47·5 | | 45·9 |
| 4 ,, ... | 45·0 | | 61·2 | | 59·0 | | 36·3 | | | | | |
| | | 13·0 | | 17·8 | | 16·0 | | 12·9 | | | | |
| 5 ,, ... | 58·1 | | 79·0 | | 75·0 | | 49·2 | | | | | |
| | | 14·1 | | 19·0 | | 18·5 | | 13·3 | | | | |
| 6 ,, ... | 72·2 | | 98·0 | | 93·5 | | 62·5 | | 93·2 | | 81·7 | |

No. 7. Patent Yeast, Brighton, 15th July, 1885.
No. 8. Compressed Yeast, B, 24th July, 1885.
No. 9. Compressed Yeast, A, „
No. 10. Brewers' Yeast, B, „
No. 11. Brewers' Yeast, C, „
No. 12. Scotch Flour Barm, „

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 7. | | No. 8. | | No. 9. | | No. 10. | | No. 11. | | No. 12. | |
| 0... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 0·1 | | 12·5 | | 8·0 | | 9·8 | | 6·4 | | 3·0 |
| 1 hour | 0·1 | | 12·5 | | 8·0 | | 9·8 | | 6·4 | | 3·0 | |
| | | 1·6 | | 18·7 | | 14·0 | | 14·7 | | 14·1 | | 7·2 |
| 2 hours | 1·7 | | 31·2 | | 22·0 | | 24·5 | | 20·5 | | 10·2 | |
| | | 4·5 | | 19·0 | | 16·0 | | 15·7 | | 15·0 | | 9·5 |
| 3 „ ... | 6·2 | | 50·2 | | 38·0 | | 40·2 | | 35·5 | | 19·7 | |
| | | 13·4 | | 16·3 | | 15·5 | | 14·1 | | 12·2 | | 8·8 |
| 4 „ ... | | | 66·5 | | 53·5 | | 54·3 | | 47·7 | | 28·5 | |
| | | | | 14·7 | | 15·2 | | 12·7 | | 11·1 | | 8·5 |
| 5 „ ... | | | 81·2 | | 68·7 | | 67·0 | | 58·8 | | 37·0 | |
| | | | | 14·3 | | 13·8 | | 12·5 | | 10·5 | | 8·4 |
| 6 „ ... | 19·6 | | 95·5 | | 82·5 | | 79·5 | | 69·3 | | 45·4 | |
| | | | | 14·0 | | 12·8 | | 11·6 | | 9·7 | | 8·5 |
| 7 „ ... | ... | | 109·5 | | 95·3 | | 91·1 | | 79·0 | | 53·9 | |
| | | | | 12·3 | | 14·1 | | 13·3 | | 9·0 | | 8·0 |
| 8 „ ... | ... | | 121·8 | | 109·4 | | 104·4 | | 88·0 | | 61·9 | |
| | | | | 9·6 | | 11·8 | | 10·6 | | 9·0 | | 7·1 |
| 9 „ ... | ... | | 131·4 | | 121·2 | | 115·0 | | 97·0 | | 69·0 | |

No. 13. Patent Yeast, Brighton, 24th July, 1885.
No. 14. Compressed Yeast, B, 29th September, 1885.
No. 15. Compressed Yeast, C, „
No. 16. Compressed Yeast, A, „
No. 17. Compressed Yeast, B, 7th October, 1885.
No. 18. Compressed Yeast, A, „

| Time. | Gas Evolved in Cubic Inches. | | | | | |
|---|---|---|---|---|---|---|
| | No. 13. | No. 14. | No. 15. | No. 16. | No. 17. | No. 18. |
| 0 ... ... | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| | 1·3 | 6·0 | 5·0 | 3·4 | 4·5 | 2·3 |
| 1 hour ... | 1·3 | 6·0 | 5·0 | 3·4 | 4·5 | 2·3 |
| | 3·4 | 15·1 | 14·3 | 9·8 | 15·2 | 6·7 |
| 2 hours | 4·7 | 21·1 | 19·3 | 13·2 | 19·7 | 9·0 |
| | 5·3 | 15·9 | 16·0 | 12·8 | 15·3 | 9·3 |
| 3 ,, ... | 10·0 | 37·0 | 35·3 | 26·0 | 35·0 | 18·3 |
| | 5·7 | 13·2 | 13·4 | 10·7 | 15·0 | 10·0 |
| 4 ,, ... | 15·7 | 50·2 | 48·7 | 36·7 | 50·0 | 28·3 |
| | 5·8 | 15·3 | 14·8 | 12·3 | 13·4 | 10·7 |
| 5 ,, ... | 21·5 | 65·5 | 63·5 | 49·0 | 63·4 | 38·3 |
| | 5·8 | 12·7 | 12·0 | 11·0 | 9·4 | 10·4 |
| 6 ,, ... | 27·3 | 78·2 | 75·5 | 60·0 | 72·8 | 48·4 |
| | 5·3 | | | | 7·7 | 8·9 |
| 7 ,, ... | 32·6 | ... | ... | ... | 80·5 | 57·3 |
| | 5·2 | | | | | |
| 8 ,, .. | 37·8 | ... | ... | ... | ... | 16·7 |
| | 5·2 | | | | | |
| 9 ,, ... | 43·0 | ... | ... | ... | ... | 74·0 |

No. 19. Compressed Yeast, D, 7th October, 1885.
No. 20. Compressed Yeast, B, 8th October, 1885.
No. 21. Compressed Yeast, B, soaked in water at 25° C. one hour before testing, 8th October, 1885.
No. 22. Compressed Yeast, B, 12th October, 1885.
No. 23. Compressed Yeast, B, 14th October, 1885.
No. 24. Compressed Yeast, A, ,, ,,

| Time. | Gas Evolved in Cubic Inches. | | | | | |
|---|---|---|---|---|---|---|
| | No. 19. | No. 20. | No. 21. | No. 22. | No. 23. | No. 24. |
| 0 ... | 0.0 | 0·0 | 0·0 | 0·0 | 0·0 | 0·0 |
| | 2·0 | 4·2 | 4·6 | 5·5 | 5·0 | 2·3 |
| 1 hour | 2·0 | 4·2 | 4·6 | 5·5 | 5·0 | 2·3 |
| | 6·8 | 11·8 | 12·7 | 16·0 | 15·0 | 6·7 |
| 2 hours | 8·8 | 15·0 | 17·3 | 21·5 | 20·0 | 9·0 |
| | 9·9 | 13·0 | 14·2 | 14·5 | 14·0 | 9·0 |
| 3 ,, | 18·7 | 28·0 | 31·5 | 36·0 | 34·0 | 18·0 |
| | 11·3 | 12·5 | 13·7 | 15·2 | 16·0 | 10·0 |
| 4 ,, | 30·0 | 40·5 | 45·2 | 51·2 | 60·0 | 28·0 |
| | 10·4 | 13·0 | 14·0 | 15·8 | 17·0 | 11·5 |
| 5 ,, | 40·4 | 53·5 | 59·2 | 67·0 | 67·0 | 39·5 |
| | 12·4 | 11·5 | 12·8 | 14·0 | 12·3 | 9·5 |
| 6 ,, | 52·8 | 65·0 | 72·0 | 81·0 | 79·3 | 49·0 |
| | 9·9 | 12·5 | 13·5 | | | |
| 7 ,, | 62·7 | 77·5 | 85·5 | | | |
| | | 13·2 | 14·0 | | | |
| 8 ,, | 18·8 | 90·7 | 99·5 | | | |
| | | 12·5 | 14·0 | | | |
| 9 ,, | 81·5 | 103·2 | 113·5 | | | |
| | | 11·4 | 10·8 | | | |
| 10 ,, | | 114·6 | 124·3 | | | |

No. 25. Compressed Yeast, E, 14th October, 1885.
No. 26. Compressed Yeast, F, " "
No. 27. Compressed Yeast, A, 19th October, 1885.
No. 28. Compressed Yeast, B, " "
No. 29. Compressed Yeast, A, 20th October, 1885.
No. 30. Compressed Yeast, B, " "

| Time. | Gas Evolved in Cubic Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. 25. | | No. 26. | | No. 27. | | No. 28. | | No. 29. | | No. 30. | |
| 0 ... ... | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | | 0·0 | |
| | | 2·2 | | 1·8 | | 3·7 | | 8·2 | | 2·0 | | 5·2 |
| 1 hour ... | 2·2 | | 1·8 | | 3·7 | | 8·2 | | 2·0 | | 5·2 | |
| | | 7·5 | | 5·2 | | 7·6 | | 13·3 | | 4·2 | | 14·3 |
| 2 hours ... | 9·7 | | 7·0 | | 11·3 | | 21·5 | | 6·2 | | 19·5 | |
| | | 2·5 | | 6·0 | | 9·9 | | 13·8 | | 7·8 | | 16·0 |
| 3 " ... | 12·2 | | 13·0 | | 21·2 | | 35·3 | | 14·0 | | 35·5 | |
| | | 13·3 | | 7·0 | | | | | | 8·5 | | 14·5 |
| 4 " ... | 25·5 | | 20·0 | | | | | | 22·5 | | 51·0 | |
| | | 9·0 | | 8·0 | | | | | | 9·0 | | 14·5 |
| 5 " ... | 34·5 | | 28·0 | | | | | | 31·5 | | 65·5 | |
| | | 7·5 | | 6·0 | | | | | | 7·5 | | 13·2 |
| 6 " ... | 42·0 | | 34·0 | | | | | | 39·0 | | 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.

When the readings are not given for any particular yeast to the full extent of the column, it does not mean that the yeast ceased to evolve gas at the time of the last reading given, but that the taking of readings was not continued further.

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.

## MOULDS AND FUNGOID GROWTHS.

**312.** The nature of these has been already referred to in chapter IX., and the mould of beer, *mycoderma vini*, described and its nature 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.

**313. Mycoderma Aceti.**—This organism effects 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:—

$$\underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Aldehyde.}}{2C_2H_4O} + \underset{\text{Water.}}{2H_2O}$$

$$\underset{\text{Aldehyde.}}{2C_2H_4O} + \underset{\text{Oxygen.}}{O_2} = \underset{\text{Acetic Acid.}}{2HC_2H_3O_2}$$

The acetification of wine or beer, under normal circumstances, is undoubtedly due to the action of this *mycoderm*, for no acetic acid is formed on exposing dilute alcohol to air alone; but considerable doubt exists as to the exact function of the organism, which "apparently exercises an influence similar to that of finely divided platinum, and quite different from that of yeast and other microscopic organisms, which excite fermentation" (Miller's Elements of Chemistry.)

*Mycoderma 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 minute cells varying from 1 to 5 mkms. in diameter. The exact botanical position of these organisms is very indefinite, but the balance of evidence is in favour of classing them among the *bacteria*.

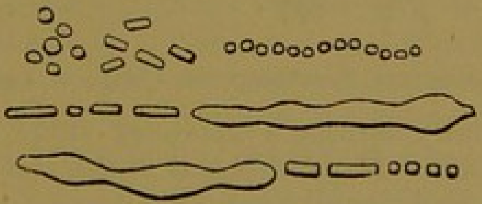

FIG. 35.—*Bacterium Aceti* (after Kopf).

Most antiseptics, and especially sulphur dioxide, are inimical to acetous fermentation. *Mycoderma aceti* is often termed "mother of vinegar." Patent yeasts, on developing a film of either *mycoderma vini* or *aceti*, are often said to have become "mothery."

**314. 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.

**315. 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.

**316. 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.

**317. 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. 36.—MICROCOCCUS PRODIGIOSUS, Cohn, × 1200 (from nature).

The author had recently a sample of bread sent him for examination which contained small red spots, at first sight very like those produced by this organism. Microscopic examination revealed that they were produced by the accidental enclosure within the bread of filaments of red wool: these had in some way got into the dough, and had been baked with the bread.

**318. 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.

**319 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. There nature may briefly be considered at this stage of our work.

**320. 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.

**321. Smut.**—This disease is also known as "dust brand," "chimney sweeper," and by other names all referring to the black appearance 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:

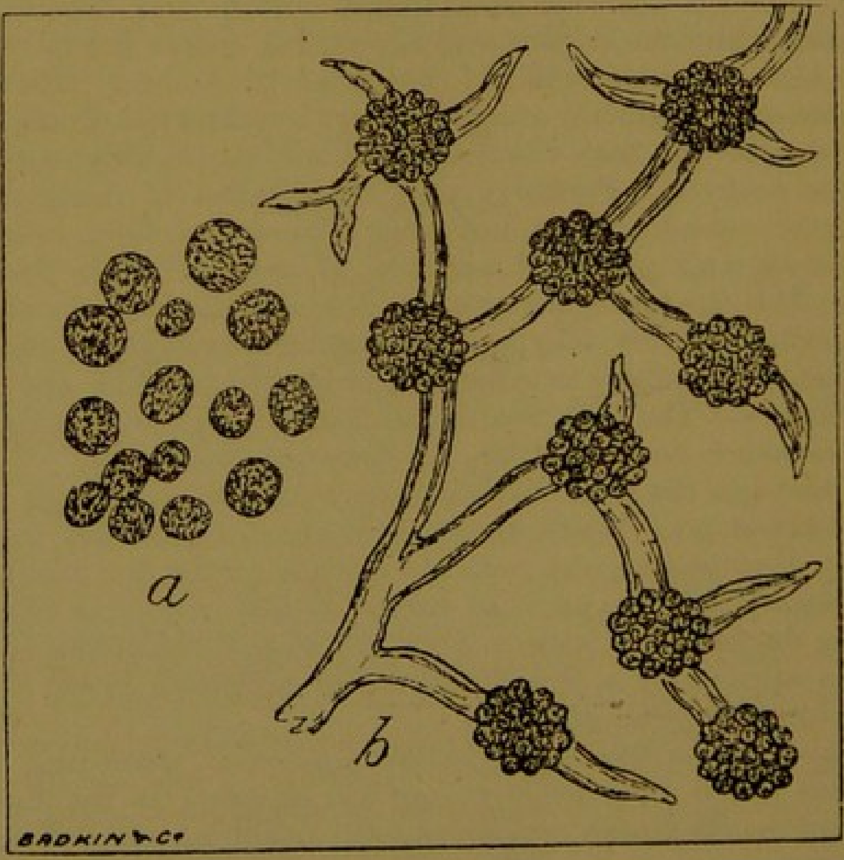

FIG. 37.
*a*, Smut, *b*, Bunt × 400 diameters.

**322. Brefeld on Identity of Smut and Yeast.**—Grove, in his exceedingly useful work on "Bacteria and Yeast Fungi," quotes at length some recently advanced views of Oscar Brefeld, the German naturalist. Grove at the outset discounts Brefeld's opinions by recording that his (Brefeld's) previous researches have often been conducted in an extremely careless manner. Brefeld points out that the successive generations of smut conidia resemble *saccharomyces*, and claims that they are identical with them. He found on cultivating smut spores in suitable media that they continued to bud until the whole of the nutriment was exhausted; on these buds being again sown in a fresh quantity of the medium, budding again commenced. This process was repeated some thirty times in a period of about a year—throughout, the budding conidia resembled yeast in form and dimensions. But little is said as to whether these budding spores of *ustilagineæ* possess the power of exciting alcoholic fermentation.

Not only Brefeld's opinions, but also those of other modern observers, seem gradually to be inclining to the view that yeast is not absolutely a separate and distinct organism; but that it consists of the conidia, or spores, of higher fungi in a budding condition. But until a satisfactory theory is enunciated, in which the connexion between yeast and other species is clearly demonstrated, it is for the present far better to treat the *saccharomycetes* as a separate and distinct order of fungi.

Nevertheless, this view of Brefeld's is of considerable interest to the student of panary fermentation. In the fermentation of must, the yeast spores are carried on the skin of the grape, being associated with the fruit during the time of its growth. In event of Brefeld's hypothesis being correct, then the yeast of bread fermentation would have its ancestor in an organism also accompanying the grain during the growth and development. In leaven, and also flour barms, fermentation sets in not only without any apparent contact with yeast, but also frequently under conditions in which it is extremely difficult to see from whence yeast organisms could have found their way into the fermenting medium. The early history of leaven is lost in obscurity, and no means exist of ascertaining whether bread was originally leavened from a yeast of alcoholic fermentation. But, if the conidia of *Ustilago* be identical with yeast, the latter being simply the same organism, functioning under different conditions, then the origin of the *saccharomyces* of so-called spontaneous bread fermentation is traced at anyrate to a parasitic fungus normally associated with the wheat grain. To the bread-making student Brefeld's theory is an alluring one; but it must be remembered that as yet the evidence in its favour is far from sufficient to establish its right to general acceptance.

**323. 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 about 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. 37 : 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.

**324. 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.

# CHAPTER XIV.

## PHYSICAL STRUCTURE OF THE WHEAT GRAIN.

**325.** 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 fitted for 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.

**326. Longitudinal Section of Whole Grain.**—In the first place, examine the longitudinal section of the grain of wheat with the 3in. 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.

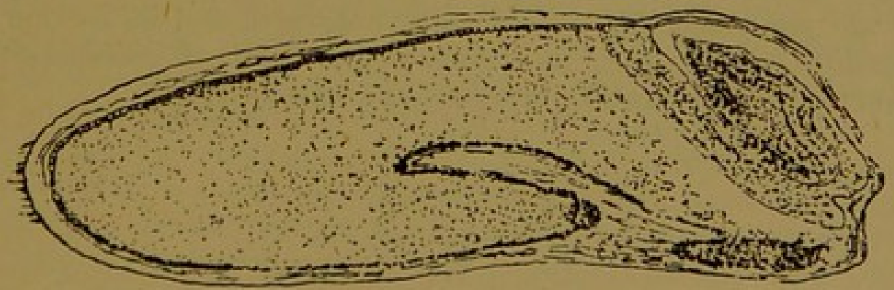

FIG. 38.—LONGITUDINAL SECTION OF GRAIN OF WHEAT, magnified eleven diameters.

This particular section is not made exactly through the crease, but while starting pretty well from the middle of one end, has inclined toward the side while being cut. The germ is seen at the right hand 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 this low power, the square cells of the bran, lining the interior, and known as cerealin 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. In cutting the section, the outer skins of the bran have become separated from the inner, and so increase the apparent thickness of the skin. The more minute examination of the grain is best made by the aid of the higher powers.

**327. Transverse Section of Wheat Grain.**—Examine next a transverse section of a grain of wheat; the section, below figured, Figure 39, was cut from a grain of Kubanka wheat, and passes through the germ.

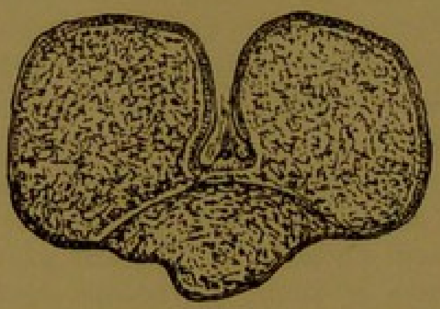

FIG. 39.—TRANSVERSE SECTION OF GRAIN OF WHEAT, magnified 13 diameters.

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 cerealin 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. The outer skins of the bran are here seen more plainly; the square 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.

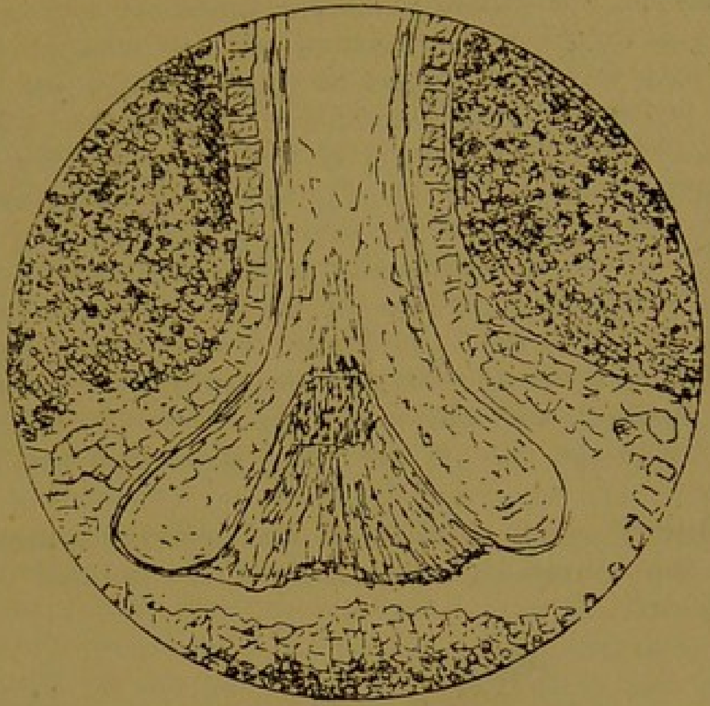

FIG. 40.—VIEW OF CREASE IN GRAIN OF WHEAT, as shown in a transverse section, magnified 110 diameters.

**328. 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 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 their 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 imbedded 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.

**329. The Germ.**—The appearance and general characteristics of the germ itself should now be carefully studied; for this purpose use the one-inch objective.

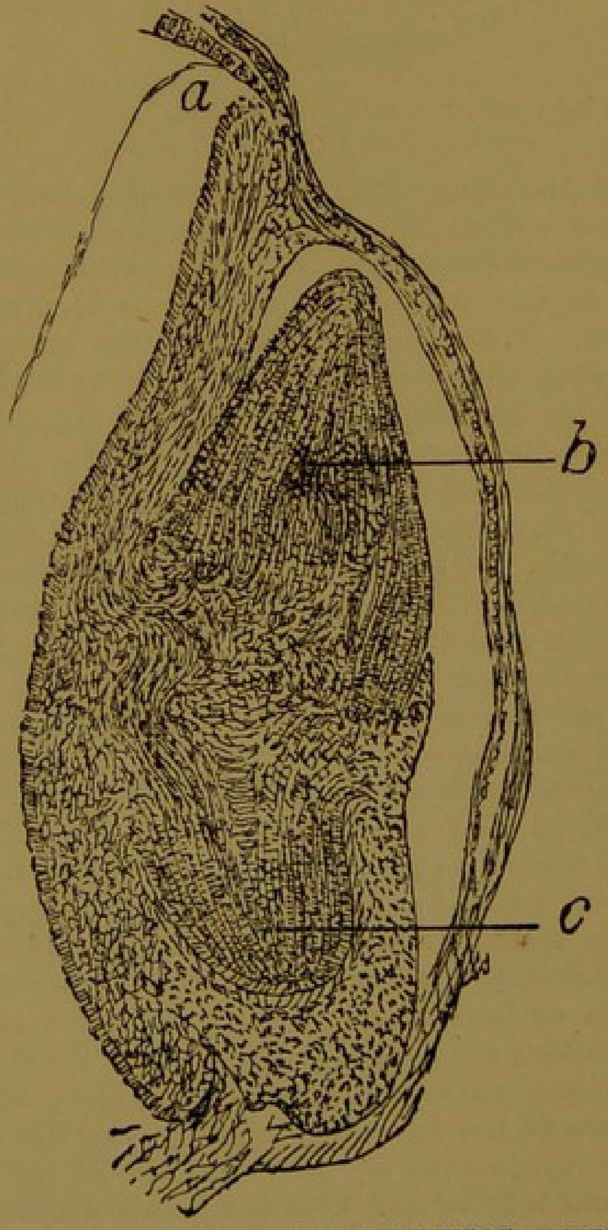

FIG. 41.—LONGITUDINAL SECTION OF GERM OF WHEAT, magnified 32 diameters.

The figure shown is an enlarged one, drawn from the same section as that given in figure 38. Notice, in the first place, that in the act of mounting the section, the skin has become detached from the germ, and also that the germ itself has split slightly near the top. At *a* the cerealin cells of the bran terminate, and only the "testa," or envelope of the true seed, encloses the embryo. The part of the germ marked *b* is that which forms the "plumula," or part of the young plant which penetrates to the surface during growth, and then constitutes the growing stem and leaves of the plant. From *c* the radicle, or rootlet, commences its growth, and forces its way downward into the earth.

On that side nearest the endosperm the germ is enveloped in a thick skin, or epidermis, consisting of a series of elongated cells arranged with their longest diameters towards the endosperm. This peculiar structure is termed the "scutellum," and is the absorptive contrivance by which the germ derives sustenance from the endosperm.

When wheat germinates, the plumula of the germ first bursts through its 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 plumula proceeds outside the grain. As the growth proceeds, the scutellum acts by absorption, and drains the portion of the endosperm lying nearest it of such material as can readily be absorbed by the growing plant. As practically the whole of the nutriment required has thus to be obtained, the starch lying nearest to the scutellum is attacked at a comparatively early period, even though there may be abundance of other formative material of a kind which renders it more easy to assimilate in the more remote parts of the endosperm. The first evidence of any such action of germination upon the starch granules is generally afforded by the appearance of a number of small pits on the surface of the granule, these by-and-bye enlarge into fissures, and the starch granulose is rapidly dissolved. After a time there remains nothing of the granule but the outer skeleton of the starch cellulose, and this too, later on, disappears. An important point that may be mentioned in passing is that this pitting of the starch granule has never been obtained artificially. Experiments have been made with the aqueous extract of malt, and in other ways, but at ordinary temperatures no result has followed. Consequently, this phenomenon must be looked on as one that is essentially connected with the living functions of the vegetable cell. The obvious lesson to be drawn from this by the miller is that sprouted wheat ("growy" wheat) is a dangerous article to use. The embryo is able, during the act of germination, to destroy the outer cellulose of the starch cells, but the ordinary diastasic influences of the soluble albuminoids of wheat (after the germ has been removed) are not capable of action on the previously uninjured starch granules at ordinary temperatures.

**330. 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.

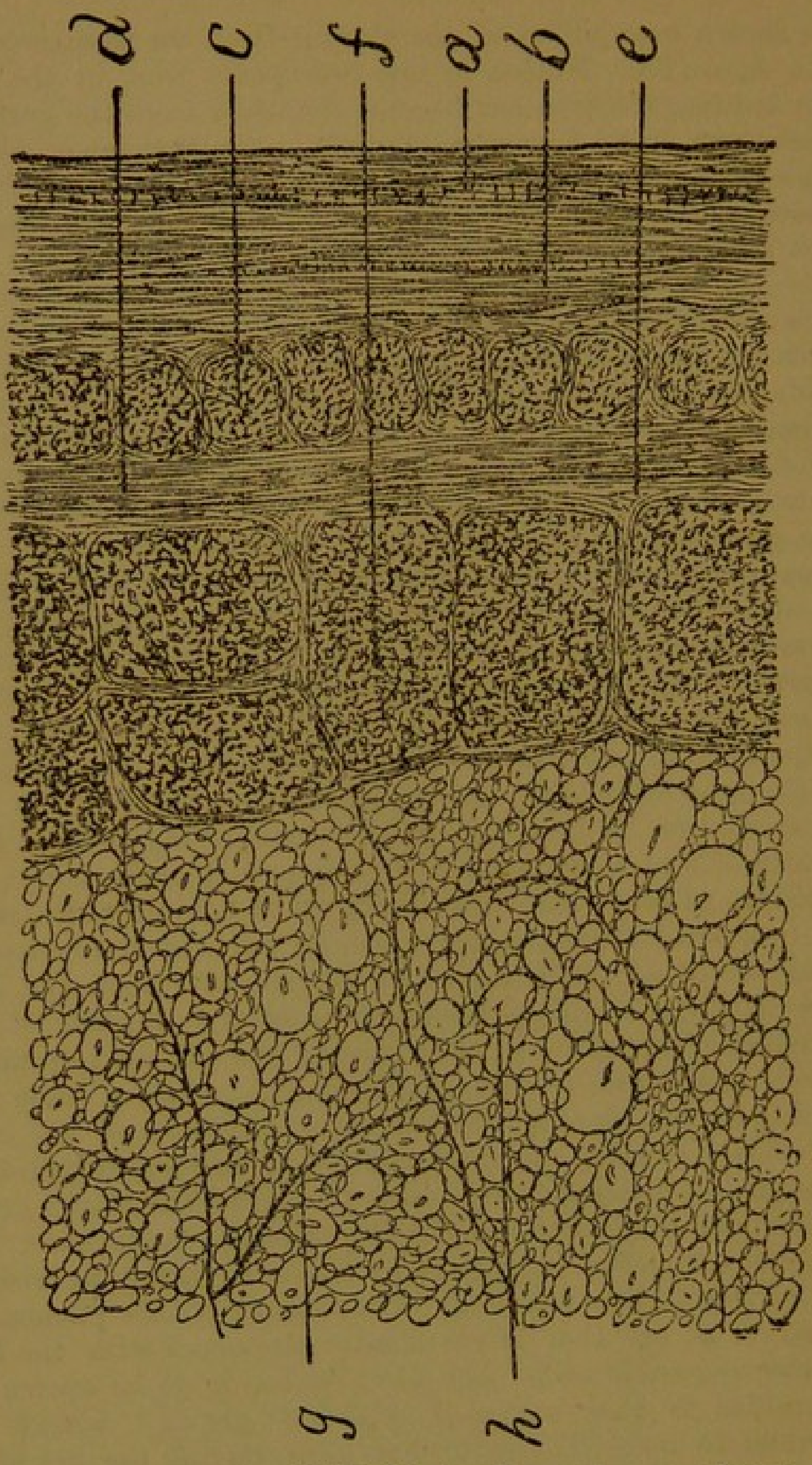

FIG. 42.—LONGITUDINAL SECTION THROUGH BRAN AND PORTION OF ENDOSPERM OF GRAIN OF WHEAT, magnified 440 diameters.

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 the figure :—

*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 cerealin cells. This membrane and the testa together form two per cent. of the grain.

*f*—is the layer of "cerealin" cells, so called from the albuminoid 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 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 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.

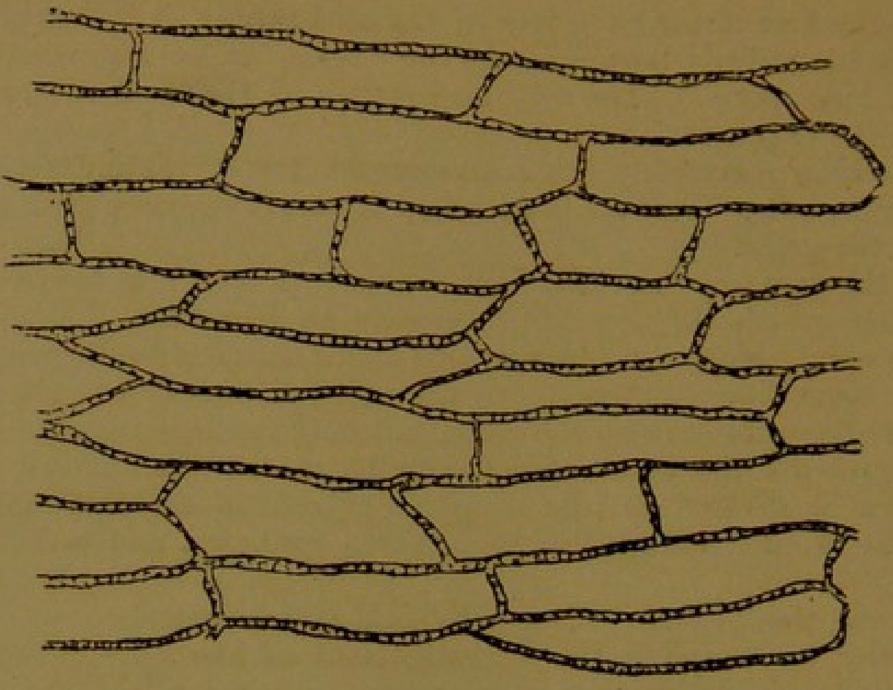

FIG. 43.—OUTER LAYER OF THE BRAN OF WHEAT, magnified 250 diameters.

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 43. 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 44 is a drawing of such hairs.

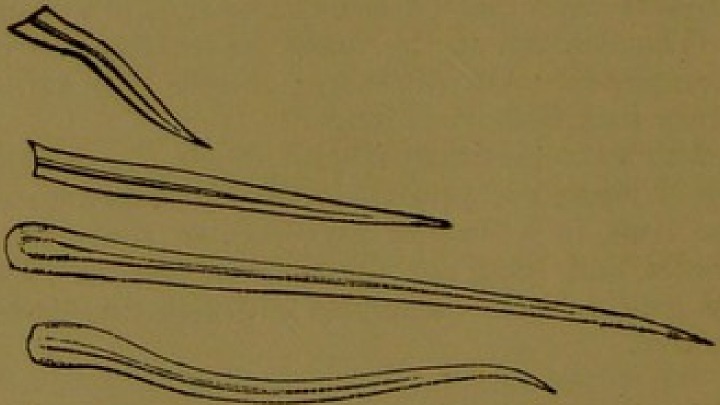

FIG. 44.—BEARD OF GRAIN OF WHEAT.

Next observe the appearance of the second layer of skin that has been detached; this is shown in figure 45.

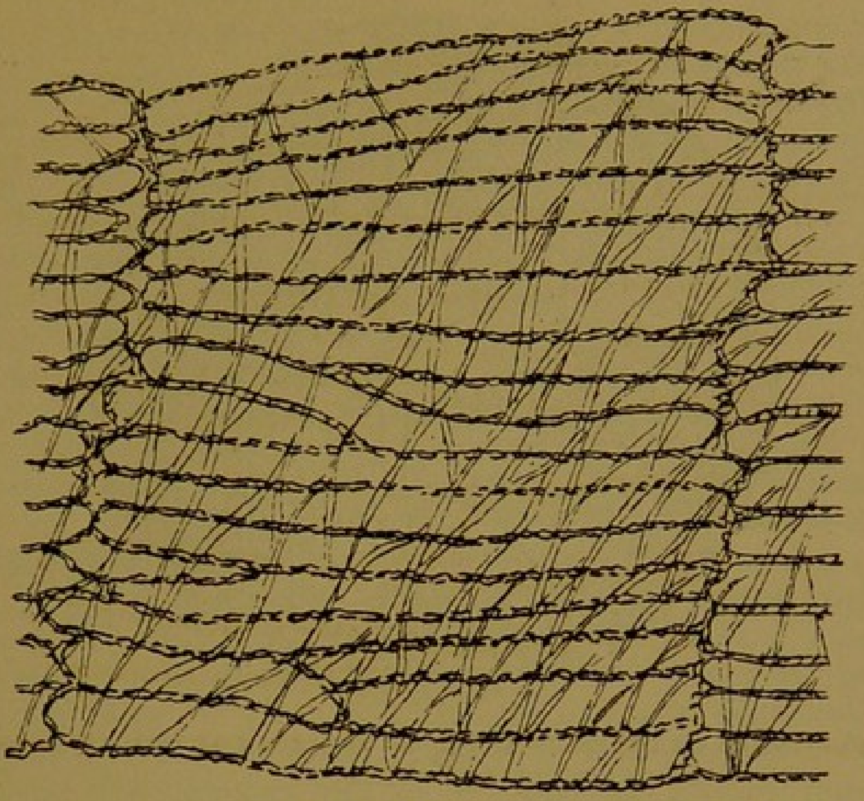

FIG. 45.—MIDDLE LAYER OF THE BRAN OF WHEAT, magnified 250 diameters.

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 42, 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 42, with a similar section cut transversely instead of longitudinally. Such a section is given later in the series. The colour-containing cells underlie those to which reference has just been made.

In the next place examine the inner, or cerealin cell, layer of the bran.

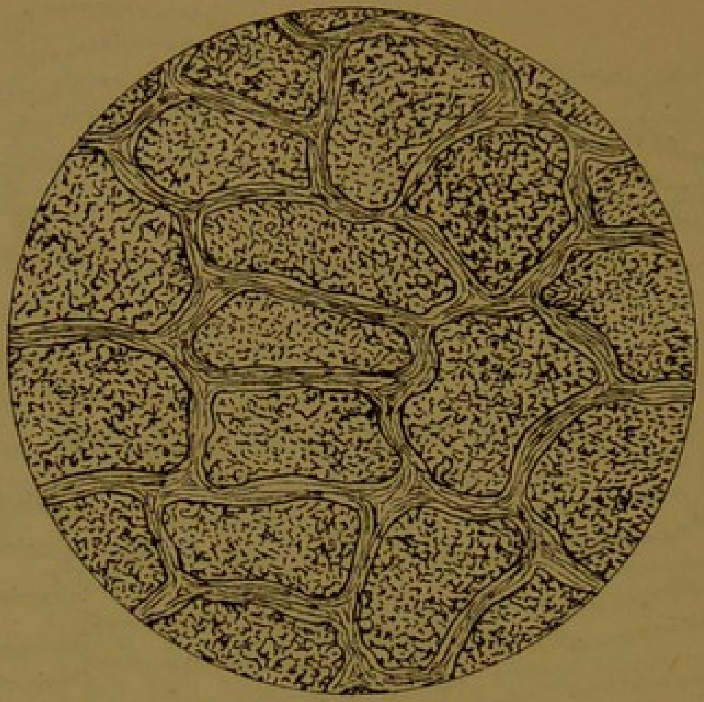

FIG. 46.—INNER OR CEREALIN LAYER OF THE BRAN OF WHEAT, magnified 440 diameters.

The cerealin cells of the bran are often referred to as being cubical; that this, however, is not the fact is well shown in figure 46. 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 42.

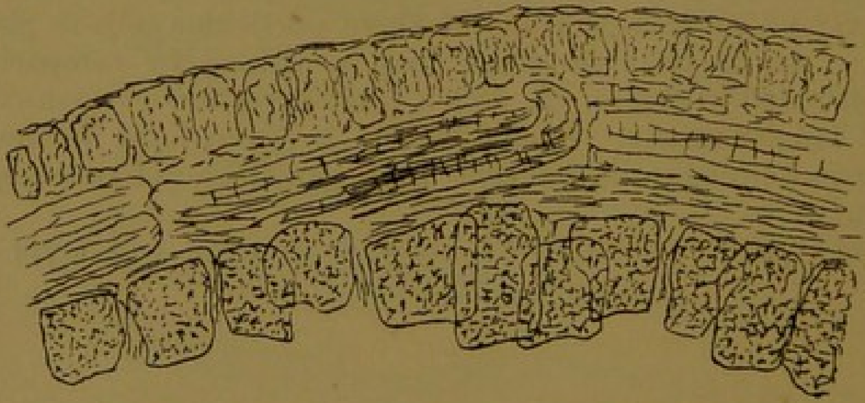

FIG. 47.—TRANSVERSE SECTION THROUGH BRAN OF WHEAT, magnified 250 diameters.

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 cerealin 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.

**331. 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.

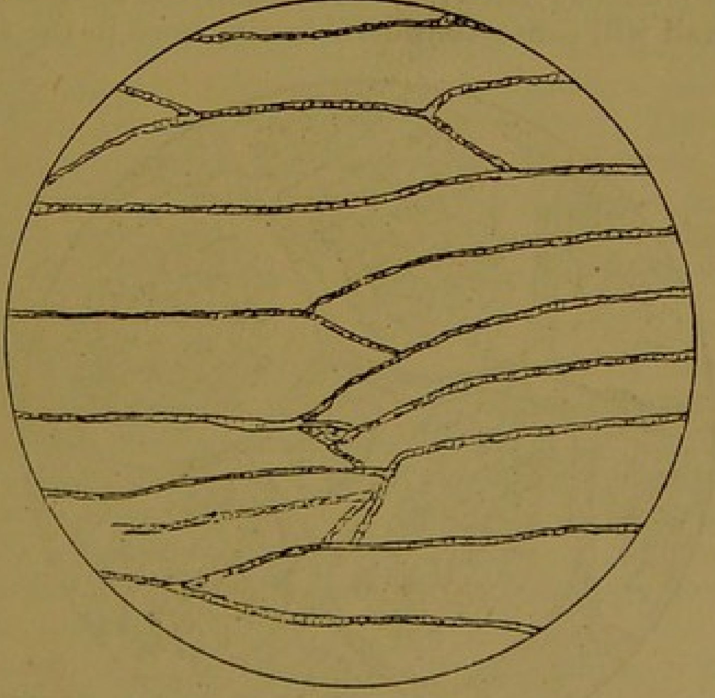

FIG. 48.—CELLULOSE OF OUTER SKIN OF BRAN, magnified 250 diameters.

This is rendered almost transparent, and presents no striking differences in structure from the orignal skin.

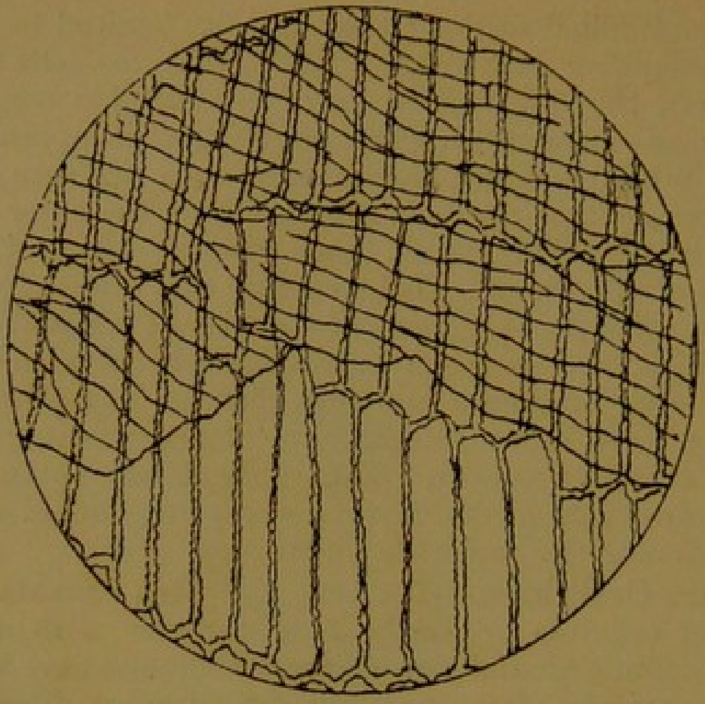

FIG. 49.—CELLULOSE OF MIDDLE SKIN OF BRAN, magnified 250 diameters.

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 cerealin layer or inner skin of the bran contains so large a quantity of albuminous matter, it will readily be imagined that treatment with alkali will cause considerable difference in the appearance of this layer.

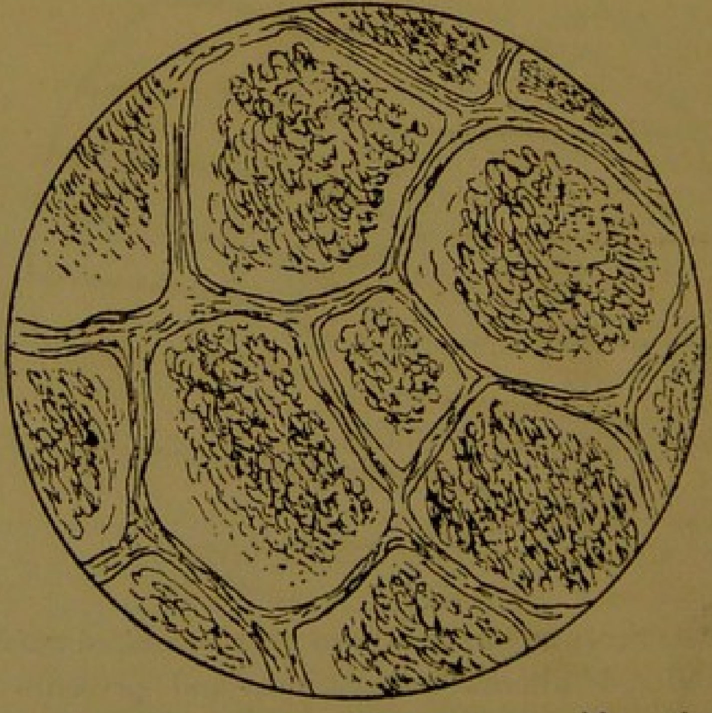

FIG. 50.—CELLULOSE OF CEREALIN LAYER OF BRAN, with portion of Cerealin remaining, magnified 440 diameters.

In figure 50 such a specimen is shown; it will be noticed that a portion only of the cerealin remains, the majority having been removed by the action of the caustic soda.

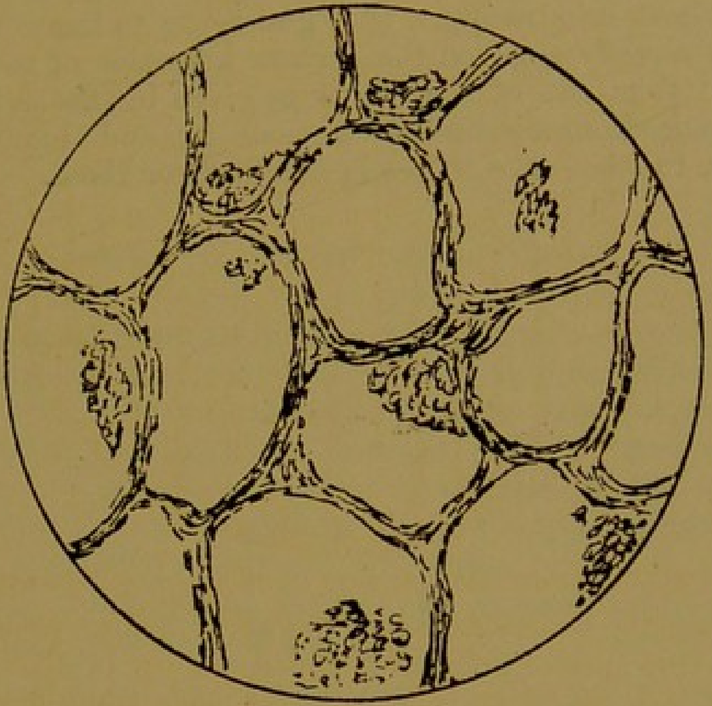

FIG. 51.—CELLULOSE OF CEREALIN LAYER OF BRAN, with only the slightest trace of Cerealin still remaining in some of the cells, magnified 440 diameters.

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 high proportion of colouring matter. The proportion of cellulose in the inner layer is still less, but the amount of cerealin is high. It has been already stated that this body is injurious to the flour, inasmuch as it exerts considerable action on broken starch granules. There are therfore cogent reasons for the non-admission of any part of the bran into the flour.

**332. 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.

Again, the author would add, do not be satisfied with reading descriptions of these things. An attempt has been made to specify the salient points of each slide, but a careful examination of one only will teach more, and yield more to think on, than will a whole chapter devoted to wheat microscopy. It is gratifying to know that study of this kind has already engaged the serious attention of members of the milling craft; thus, out of the drawings given in this series, a number have been made from microscopic sections cut and mounted by a well-known miller, to whom the writer is indebted for them.

# CHAPTER XV.

## CHEMICAL COMPOSITION OF WHEAT.

**333. Principal Constituents of Cereals.**—Proximate analysis of the cereal grains shows that they contain as their principal constituents—fat, starch, cellulose, dextrin, one or more sugars; soluble albuminous bodies, consisting of albumin, legumin and cerealin; insoluble albuminous bodies, consisting of myosin, glutin, mucedin, and fibrin, 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 |

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 service.

**334. 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.

**335. Starch.**—This makes up the principal part of the grain, and in the analyses above given, amounts to 63·71 and 65·86 in the two 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.

**336. 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.

**337. 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 albuminoids. 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 270, 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.

**338. Soluble Albuminoids.**—In technical wheat analysis no attempt is made to separate the albumin from the legumin. In the following analyses these bodies are estimated by what is known as the albuminoid ammonia process, in a portion of the aqueous extract of the flour, of which, 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. Both flours and wheats are therefore to be preferred in which the soluble albuminoids are relatively low. In the case of wheat it is somewhat difficult to form a judgment, because the bran and germ contain considerable quantities of soluble albuminoids; 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, leaves the grain damp, and also leaves the albuminoids 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, averts 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 connexion with this, attention is directed to the paragraph on artificially drying wheats and flours, in the next chapter.

**339. 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 albuminoids, 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.

**340. Insoluble Albuminoids, Gluten.**—The insoluble albuminoids 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 albuminoids in a wheat a close relation exists. With an increase of total albuminoids, both the soluble and insoluble varieties will simultaneously rise in amount. In interpreting analytical results, high soluble albuminoids should not be considered alone—they are the natural concomitants of high total albuminoids and gluten. But where the soluble albuminoids 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.

**341. 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.

**342. 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.

**343. Analyses of English and Foreign Wheats.**—The analyses embodied in the following tables are selected from those of wheats analysed by the author for insertion in his "Confidential Report on Wheat and Flour Supply," particulars of which publication are given in an advertisement at the commencement of book :—

## ENGLISH AND SCOTCH WHEATS.

| No. | Name and Description. | Weight per Bushel. | Moisture. | Soluble Extract. | Soluble Albuminoids. | 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, 1½ 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 66lbs. per bushel. |

## ENGLISH AND SCOTCH WHEATS—*Continued.*

| No. | Name and Description. | Weight per Bushel. | Moisture. | Soluble Extract. | Soluble Albuminoids. | 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 on good heavy land in Essex, 1883; fairly farmed; delivered by farmer at 66·5lbs. 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 albuminoids 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 contains 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 albuminoids. 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 Albuminoids. | 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 albuminoids 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 occuring 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 Albumnoids. | 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<br>29·20 | 9·62<br>10·44 | 2·7<br>2·9 | ...<br>... | 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. |
| 76 | Persian | 60·21 | 11·22 | 5·60 | 1·32 | 16·00<br>22·70 | 6·20<br>8·30 | 2·4<br>2·7 | ...<br>... | |
| 77 | No. 1. Club Calcutta | ... | 11·42 | ... | ... | 16·80<br>21·80 | 5·90<br>7·65 | 2·8<br>2·8 | ...<br>... | |
| 78 | No. 2. Club Calcutta | ... | 11·43 | ... | ... | 16·30<br>21·20 | 6·20<br>7·15 | 2·7<br>2·9 | ...<br>... | |
| 79 | No. 1. American Hard Fyfe Wheat | 65·00 | 11·17 | 4·85 | 1·40 | 32·00<br>24·00 | 11·40<br>9·86 | 2·8<br>2·5 | ...<br>... | |
| 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, and is that which was recently supplied through the Editors of "The Miller" and the "British and Foreign Confectioner" to the leading millers and bakers of the country. The comparatively high moisture, soluble extract, and albuminoids, 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.

**344. Average Composition of American Wheats.**—The following table gives 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 albuminoids are given, being derived from the percentage of nitrogen found :—

## AVERAGE COMPOSITION OF AMERICAN WHEATS.

| No. of Analyses. | District where grown. | Weight of 100 grains. | Water. | Ash. | Oil. | Carbohydrates. | Cellulose. | Albuminoids. | Nitrogen. | Heaviest 100 grains. | Lightest 100 grains. | Highest albuminoids. | Lowest albuminoids. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *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 | 1·76 | 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....... ................... | 3·204 | 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 |

# CHAPTER XVI.

## CHEMICAL COMPOSITION OF FLOUR AND OTHER MILLING PRODUCTS.

**345.** 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. The baking and milling experts are, through long experience, capable of judging these qualities of a flour with wonderful accuracy; but the methods used in so doing have been in most cases of the crudest description. Further, however accurate may have been the results obtained, there has been no precise method of registering them for future reference, nor for instituting 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.

**346. 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. There is, however, this difficulty: while one sample may be considered good, another bad, and a third indifferent, there is no actual standard of comparison with which each may be compared, and so its colour expressed in definite terms. For scientific purposes it has been long felt that some standard scale of colour was necessary, so that flours might be compared with it, and then the results expressed numerically, thus fulfilling the above-mentioned condition. Such a scale would require to be made of colours that do not bleach or undergo change on keeping; the tint should as closely as possible resemble that of flour, and the character of the coloured surface should resemble that of flour after being wetted and dried. The author believes that, as the result of many months' work and experiment, he has succeeded in producing a scale that satisfies these requirements. He wishes it to be distinctly understood that all credit for devising the method of testing is due to Pékar. He is simply responsible for the production of the scale for purposes of comparison.

Flours differ, not only in depth of tint, but also in actual colour. For most purposes of comparison they may, however, be divided into two varieties, the prevailing tones of which are respectively grey and yellow. The greater number of flours fall into the grey class, while a few of the very finest patents, represented notably by the best Hungarian brands, have a rich yellow tint.

The colours selected for the scale are—first, a greyish yellow; and second, a purer yellow tint. A scale of each colour is constructed: they are termed the Grey and Yellow Scales respectively. 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 number 2 is exactly twice as dark as number 1, while number 8 is four times as dark as number 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, number 1 yellow is about equal to 1½ grey; number 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 number 1 to number 10 yellow.

In preparing the scales, special precautions are taken to ensure that the tint obtained are of mathematically accurate intensity. Each sheet, after being tinted, is carefully examined, and any which appear in the slightest degree irregular are rejected. Those finally approved are then cut into pieces of the requisite size, and mounted in a suitable case.

In testing the flours for the subsequent analyses a number were taken at the same time, placed on a plate of zinc, and pressed so as to give the flour a smooth surface. The samples were then dipped in a sloping direction into water, allowed to remain some ten or twelve seconds, withdrawn, placed aside, and allowed to dry at the ordinary temperature. In reading the colour it was first determined whether the flour corresponded more closely to the Grey or Yellow Scale; then, by careful observation, the numbered tint was selected which agreed with the flour in depth of colour. If the sample fell between any two tints, the colour was indicated by a fraction, as for instance, 2·5 or 3·4. Having gone through the whole of the samples being tested, and having expressed their colours in numbers, a second examination of the series was made. Those flours which approximated in colour were tested against one another—thus, suppose two had been marked 7·0 G.; it was then determined whether they agreed with each other, if so they were passed, but if not they were again compared with the scale and numbered respectively, 7·0 and 7·1, or whatever other numbers were deemed to most accurately represent the colour. In this way, by a system of comparison and counterchecking, the absolute value of the colour was arrived at as closely as possible.

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 where 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.

In connexion with this matter of colour a question arises as to how far the colour of a flour, as determined by this test of Pékar's, agrees with that of the baked loaf. Millers who have given the subject careful attention, state that at times test loaves baked from the flours under examination have their colours in just the reverse order to those of the original flours when compared by Pékar's method; this is stated to occur more particularly with patent flours. This must of necessity be taken into account when determining flour colours by this process. In connexion with the baking test, as a means of judging the colour of a sample of flour, it must be remembered that from the same flour not only will two bakers very often get bread of different degrees of colour, but also that one and the same baker may perceptibly improve the colour of his loaf by modifications in his methods of panification. Now, under these circumstances, it is evident that a baking test cannot be viewed as an absolute one, so far as colour is concerned. As will be hereafter explained, a falling off in colour during fermentation is due to certain chemical changes, resulting from the action of yeast and diastasis—hence, if two flours have by Pékar's test the same colour, and the one produces a lighter loaf than the other, then No. 2 flour is less capable of withstanding the fermentative changes than is the other. It is possible that by shortening the length of time which this second flour is fermented that its colour *may* be brought on an equal to that of the first. If the two flours be tested for Strength and Stability in the manner to be subsequently described, it will in all probability be found that the second possesses the latter quality in less degree.

Notwithstanding that discrepancies of this sort may at times occur between Pékar's test and the results of baking experiments, the author lays great value on this test of Pékar's, because it gives the absolute colour of the flour only, uncomplicated with effects due to fermentation. The baker, and indirectly the miller, are very much at the mercy of the journeyman baker. On some day a heavy dark coloured batch of bread is produced; the journeyman at once says the flour is wrong, or the yeast is bad, never a suggestion that the fault may be due to mistakes or accidents in fermentation. The baker often finds himself in doubt as to what is really the cause of the inferior quality of the bread; let him, for one thing, make this Pékar's test on the flour of the particular batch, against that he has been previously using. If the last lot of flour is decidedly lower in colour he may fairly ascribe the fault to a change in the flour with which he is supplied. On the other hand, if the two are indistinguishable, the probabilities are greatly in favour of the fault resting with the fermentation and general working of the dough. He may now go a step further, and test for Strength and Stability; if they are the same in the two flours he may be morally certain that the fault is not in the flour, but in the yeast or the manipulation during fermentation. But should the flour which produced the darker coloured loaf be the less stable, then very possibly the falling off in colour is due to the flour. The importance of these tests is not so much the simple valuation of the particular flour which may be under examination, as the light which they throw on whether it is the flour or the quality of yeast and mode of fermentation which is responsible for the inferior loaf. One of the baker's greatest difficulties when anything goes wrong with his bread is to know what it is; until he ascertains that, any attempts at improvement are so many leaps in the dark.

In the case of patent flours, which do not produce breads of the corresponding colours, the author would again suggest the making of stability tests as well: he is strongly of opinion that the instances will be very few in which the falling off in bread-colour, as distinguished from flour-colour, is not accompanied by loss of stability. He would suggest in such cases that a shorter period of fermentation should be employed, with the belief that an improved bread-colour would result. Such a flour would also arrive at maturity in dough in a shorter time so far as other changes are concerned.

The statement is at times made by bakers, that the bread from a particular flour is improved in colour by a longer time in fermentation. The author has never personally investigated this point, but is of opinion that no actual bleaching of dough can thus occur. It is quite possible that instead of a chalky whiteness a flour may, by longer fermentation, develop a rich yellow bloom.

**347. Strength.**—The Strength 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 strength of the flour falls below the average, there is every probability that the wheat is through some cause unsound. Hence, strength determinations are valuable in several respects. Although not always applied in precisely the same sense, for our present purpose, **Strength 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. "Strength" is also sometimes used as the measure of the capacity of a flour for producing a well-risen loaf. Although this means something different from the former definition, yet the two qualities generally go pretty well together. In order to avoid misunderstanding, it must be understood that when the term Strength is here used it is in reference to the water absorbing capacity of the flour.

Undoubtedly one of the best methods of determining the strength 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 has devised and patented apparatus, which has as its object the determination of Strength, and giving a numerical expression of the result. The starting point was to decide on some mode of expressing strength: 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.

Harris, a well-known London authority on baking, states that, on making a series of baking and also doughing tests on flour, the former tests up to the baking stage agree with the tests made by Thoms' doughing method; but that great discrepancies are shown after baking, principally because it naturally follows that the higher the percentage of water absorbed, the greater will be the loss by evaporation in baking.

These tests he regards as showing that calculations based simply upon how much water any given flour will absorb, may be entirely upset when the bread made from such flour is submitted to the test of weighing after leaving the oven.

Thoms' table provides for loss in working, but is throughout calculated on the basis of 70 oz. of dough being weighed into the oven for each 4lb. loaf; no allowance is therefore made for different amounts of loss in the oven. As Harris remarks, the loss, by evaporation in baking, naturally increases with the percentage of water present in the dough.

But although Harris' baking tests do not agree in actual weight of bread with that estimated from Thoms' table, they yet show that the flours which yielded highest and lowest results by Thoms' doughing test, also yielded highest and lowest results in bread; thus establishing the trustworthiness of the principle of the doughing test, although not altogether confirming Thoms' estimate of actual bread yield.

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.

**348. Strength 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 patented apparatus; 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.

**349. The Viscometer.**—Having made the dough, the next thing is to estimate 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 patented 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.

The viscometer consist 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.

It is obvious, that the first consideration with regard to such a mode of testing is, whether or not it really gives an indication of the yield of bread of which each particular flour is capable. The opinion of millers and bakers generally is, that doughing a flour shows, as no other method can, the strength of a sample of flour. Experiment has demonstrated, however, that the stiffness of a sample of dough depends on a number of conditions. It is first of all affected by the amount of kneading to which the dough is subjected; further, as the length of time, since the flour and water have been mixed, increases, the stiffness of the dough varies. During this time two sets of changes are going on; first, the water added is being absorbed by the starch and gluten particles of the flour: this causes an increase of stiffness, until this absorption has ceased. Then, in the next place, the gluten begins to soften, and so the dough becomes slacker. Bakers partly judge of the quality of a flour by the rate at which it falls off during fermentation: it being well known that some flours produce doughs which become slack more quickly than others. If it were practicable, a good test would be to run the dough through the viscometer after it had fermented for some hours: but as the dough has then become spongy, trustworthy results could not be obtained. A convenient measure of the rate of this degradation is furnished by letting the dough, made from flour and water only, stand for twelve or twenty-four hours and then testing its strength. The standing in this way has much the same effect as has fermentation; consequently the doughing test after standing affords valuable information as to the stability of the flour during fermentation. By means, therefore, of tests made after the lapse of some hours, the relative permanency in dough, of different varieties of flour, may be shown. Such testings also indicate whether a flour should be used in the sponge or dough stage, or whether it is best fitted for long or short processes of fermentation; thus a flour which was fairly strong when first doughed, but which fell off in strength comparatively quickly, should evidently be either used in the dough stage or fermented by some rapid method. The temperature and atmospheric conditions have also some effect on the stiffness of doughs; this effect though not of wide range is very perceptible. It is noticed that sometimes a series of flours give rather stiffer doughs at one time than another, while the relative members of the series occupy precisely the same positions, one towards the other. These variations are not, however, of great extent.

**350. Outline of Method Employed in Viscometric Strength Determinations.**—The author adopts as his standard stiffness for doughs, a dough of such stiffness as allows the piston of the viscometer to fall, from mark to mark, in sixty seconds. This dough is about the stiffness of that commonly employed for tin bread; such at least is the opinion of several bakers who have seen the instrument. Many bakers are in the habit of employing stiffer doughs, while others use dough in a slacker condition. The following is an outline of the exact process that was employed in doughing and testing flours for strength, as given in the subsequent analyses:—One-and-a-half ounces of flour are weighed in a counterpoised dish, transferred to a basin, and a number of quarts of water added from the specially graduated burette. The flour and water are mixed together with a glass rod; the dough and any particles of flour are then removed by means of a spatula, and placed in one of Pfleiderer's hand doughing machines for testing purposes. The machine is fitted with a revolution indicator, and fifty revolutions are given to the dough; this is then taken out and placed in a small clean tumbler, having its upper edge ground flat; a ground glass plate is taken, a drop of water placed on its under side, and then used as a covered for the tumbler. At the end of one hour the dough is taken out, very carefully put in the cylinder of the viscometer, and then tested by running the piston through, the time being taken in seconds. If preferred, the flour and water may be mixed in the machine direct, thus saving time. Pfleiderer now specially furnishes for the purpose a machine with absolutely water-tight bearings; one of these has been employed by the author in his more recent tests.

The use of Pfleiderer's machine is not a necessity, but is of service as providing a means of doughing with absolutely the same amount of kneading in each test. Hand doughing may be employed instead, provided it be very carefully and thoroughly done.

When the character of the flour is known approximately beforehand, a quantity of water is taken that, so near as can be judged, shall make a dough which runs through in sixty seconds. Having thus made one test, if necessary, two more are started two quarts apart, with such quantities as shall cause the one dough to be too stiff and the other too slack. These are then tested exactly as before, and thereby the strength found. Supposing that 68 quarts run through in 37 seconds, and 70 quarts in 78 seconds, then the following calculation gives the quantity equivalent to 60 seconds:—

$\frac{78 - 37}{4} = 11$ = number of seconds difference produced by additions of a pint.

37 + (11 × 2) = 59 seconds; therefore 69 quarts would run through in 59 seconds, and that quantity is taken as the strength. The principle of this will be seen by a little thought—the strength is not given nearer than quarts and pints—the difference between the higher and lower figures gives the effect produced by two quarts; each successive pint it may be assumed will produce approximately a quarter of this effect, therefore if the time equivalent to pint after pint be added, and the nearest figure to 60 be taken, then the quantity of water represented by this amount will be the quarts per sack according to the definitions of standard strength before given.

**351. Results of Viscometric Strength Determinations.**—The subjoined table gives the strength of various flours, not only at an hour, but after standing various other times in dough; the results of various experiments are given; those in the heavier figures are the calculated quarts per sack for 60 seconds. Analyses of these flours are given in a subsequent table; the numbers in both cases correspond.

DETAILED RESULTS OF EXPERIMENTS, WITH THE VISCOMETER, ON THE STRENGTH OF FLOURS.

| No. | Names and Description of Flours. |
|---|---|
| 1 | Straight Grade, from No. 2 Calcutta Wheat. |
| 2 | ,, ,, Odessa Wheat. |
| 3 | ,, ,, Saxonska Wheat. |
| 4 | ,, ,, Australian Wheat. |
| 5 | Town Whites. |
| 6 | Town Households. |
| 7 | Taylor's Town Households. |

| 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. |
| I | 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 |
| | ...... | ...... | ...... | ...... | ...... | ..... | ...... | ...... |
| 2 | 68 | 93 | ...... | ...... | 62 | 100 | 58 | 10 |
| | 70 | 63 | ...... | ...... | **64** | **60** | 60 | 8 |
| | **70** | **60** | ...... | ...... | 64 | 54 | 62 | 6 |
| | 72 | 42 | ...... | ...... | 66 | 49 | 64 | 4 |
| | ...... | ...... | ...... | ...... | 68 | 30 | ...... | ...... |
| | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 3 | 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 | ...... | ...... |
| | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 4 | 68 | 71 | 66 | 103 | 64 | 125 | 58 | 115 |
| | **69** | **60** | **68** | **60** | 66 | 80 | 60 | 90 |
| | 70 | 39 | 68 | 55 | 68 | 66 | 62 | 64 |
| | ...... | ...... | ...... | ...... | **68·5** | **60** | **63** | **60** |
| | .. ... | ...... | ...... | ...... | ..... | ...... | 64 | 56 |
| | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 5 | 66 | 132 | ...... | ...... | 64 | 121 | 56 | 164 |
| | 68 | 96 | ...... | ...... | 66 | 64 | 58 | 110 |
| | 70 | 66 | ...... | ...... | **67** | **60** | 60 | 94 |
| | **72·25** | **60** | ...... | ...... | 68 | 52 | **61·5** | **60** |
| | 71 | 41 | ...... | ...... | ...... | ...... | 62 | 51 |
| | ...... | ...... | .. ... | ...... | ...... | ...... | ...... | ...... |
| 6 | 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 |
| | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 7 | 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 |

| No. | Names and Descriptions of Flours. |
|---|---|
| 8 | Porter's Patent Flour, from American Hard Fyfe Wheat. |
| 9 | Porter's Bakers' Flour, " " " |
| 10 | Hungarian Flour, A A A A A. |
| 11 | English Wheat Flour. |

TIME ALLOWED TO REMAIN IN DOUGH—ONE HOUR.

| No. | Quarts per Sack. | Seconds. | No. | Quarts per Sack. | Seconds. |
|---|---|---|---|---|---|
| 8 | 66 | 215 | 9 | 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 |
| 10 | 74 | 255 | 11 | 58 | 183 |
| | 76 | 170 | | 60 | 120 |
| | **78** | **60** | | 62 | 82 |
| | 80 | 38 | | **63** | **60** |
| | 82 | 25 | | 64 | 27 |
| | 84 | 18 | | 66 | 19 |
| | 86 | 10 | | ...... | ...... |

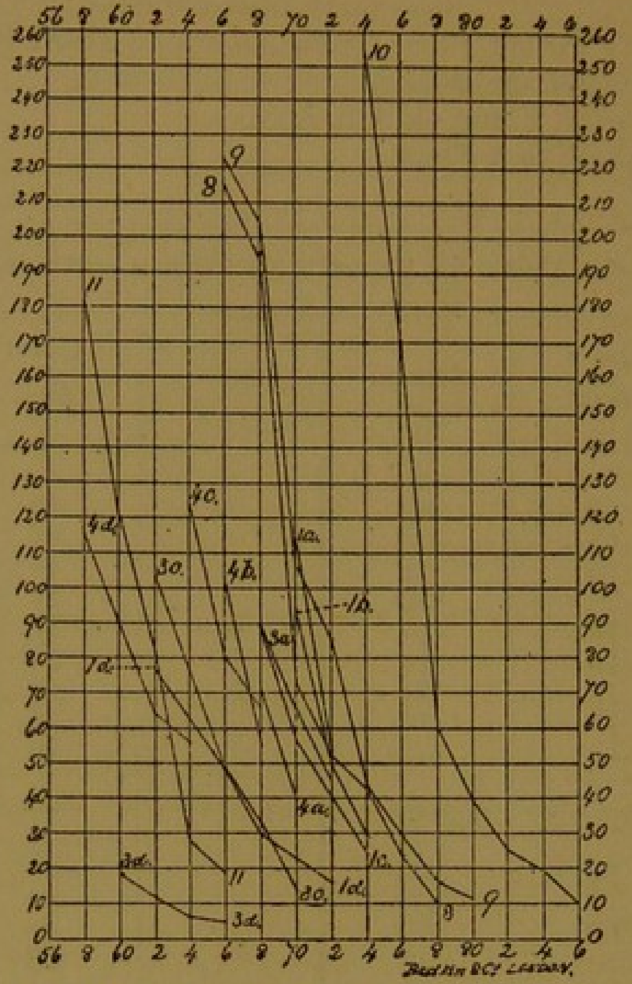

FIG. 52.—DIAGRAM OF STRENGTH RESULTS.

In this diagram, the results of the Strength tests have been set off as a series of curves. On the horizontal lines the numbers representing quarts of water have been set off, and the number of seconds of time taken in each viscometer test on the vertical lines. The different series of tests on the same flour are distinguished by the letters *a*, *b*, *c*, *d*, being applied respectively to the immediate, half-hour, three hours, and twenty-four hours tests. No. 1 *a* is just a little ahead of No. 1 *b*, while 1 *d* has fallen off 7·5 quarts from the immediate test. No. 3 is a sample of Saxonska, and has fallen 5 quarts in three hours, while the Calcutta only fell off 2 quarts in the same time; in twenty-four hours the loss in strength is far more than 10 quarts. Considering next the Australian, No. 4, its strength, on immediate test, is lower by 1·5 quarts than is that of the Saxonska; but after standing three hours their relative strengths are such that the Australian is by 3 quarts the stronger of the two, while in twenty-four hours the total falling off is only 6 quarts. An extended series of tests has been made on Nos. 8-11 in order to show the character of the curves produced in each case.

It will be noticed that the lines in the diagram vary somewhat in the amount of their obliquity; thus 1 *d* approaches more nearly to the horizontal than does 3 *c*. This is also frequently noticed in two flours doughed under the same conditions; the conclusion is that the stiffness of certain flours is more affected by the addition of the same quantity of water than is that of others. As an illustration, compare the curves of Nos. 10 and 11; the latter is an English wheat flour, and has at 60 seconds a strength of 63 quarts; an additional 3 quarts of water reduces the viscometer time to 18 seconds. With the Hungarian flour, No. 10, the strength at 60 seconds is 78 quarts; an additional 3 quarts only reduces the viscometer time to 34 seconds; while to reduce the stiffness of this dough to the same as that of the English wheat flour, with an additional 3 quarts of water, requires that an additional 6 quarts of water must be added. Viscometer tests show, therefore, not only the number of quarts of water required by any flour to produce a dough of a standard stiffness, but also the sensitiveness of a flour to the addition of extra water. Some flours will bear more water being added without very greatly lowering their stiffness; others, by the addition of the same extra quantity of water, are reduced almost to a batter. As a rule, the weaker flours are also more sensitive to the addition of extra water.

**352. 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. He has also had the advantage of having as a colleague in this work his late assistant Mr. W. Frank Grace, F.C.S.

The subjoined table gives the moisture, soluble extract, soluble albuminoids, wet and dry gluten, fat, cellulose, ash, and phosphoric acid of each sample, and also the colour of the flours. The colours were examined before the Standard Scale had attained its final form, so that possibly, were the estimations again to be made, there might be some slight differences; such deviations would, however, be only very trifling. The results contained in the table are set out graphically in the two-page diagram, Fig. 53, inserted on pages 264-5.

Every care has been taken in ensuring accuracy of the results; where seeming doubtful, duplicate experiments have been performed; these have in some cases led to the making of certain corrections, but usually the results have been confirmatory of those first obtained.

The wheat mixture in use was composed of three parts Winter American, one part Spring American, and two parts of California; it weighed 64 lbs. per bushel.

## COMPOSITION OF ROLLER MILLING PRODUCTS.

| Description. | Moisture. | Soluble Extract. | Soluble Albuminoids. | 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<br>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 | recove | rable. | 3·98 | 1·32 | 2·226 | — | 10·98 |
| ,, ,, Seventh ,, (Bran dusted) ... ... ... | 11·39 | 9·80 | 2·33 | None | recove | rable. | 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 Albuminoids. | 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 | 0·031 | 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 | 7·58 | 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 Stuffed 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 |

**353. Explanation of Diagram.**—This diagram, Fig. 53, pages 264 and 265, was arranged and set out by Mr. Zimmer, milling engineer, whose services are retained by Mr. J. Harrison Carter. The author supplied him with the data contained in the foregoing table, and to Mr. Zimmer belongs the credit of setting out in so clear and admirable a manner the tabulated 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 analysis, 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 albuminoids, 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 represents the difference between the total of directly estimated constituents and 100, the difference being made up by starch, indeterminate albuminoids, &c.

In each square the constituents are arranged in the following order:—

Water.
Soluble 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.

**354. 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 albuminoids, ash, phoshoric 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.

**355. 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.

**356. 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.

**357. 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 albuminoids 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 $\begin{cases} 3{\cdot}06 \\ 3{\cdot}10 \end{cases}$ (duplicates) to 0·252 and 0·34. The colour is 4·59, 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.

**358. 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.

**359. Coarse Sharps, or Thirds.**—These also contain gluten, but only a very small amount, 2·64. The soluble extract and albuminoids are very high, so also are the fat and cellulose.

**360. Rolled Sharps.**—These are not included in the diagram. The soluble extract and albuminoids are even higher than in the preceding; ash, phosphoric acid, and fat, are also high.

361. **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 albuminoids: 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 albuminoids 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.

362. **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 cellulose of the endosperm of the grain. On consulting figure 40 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.

363. **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 albuminoids 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.

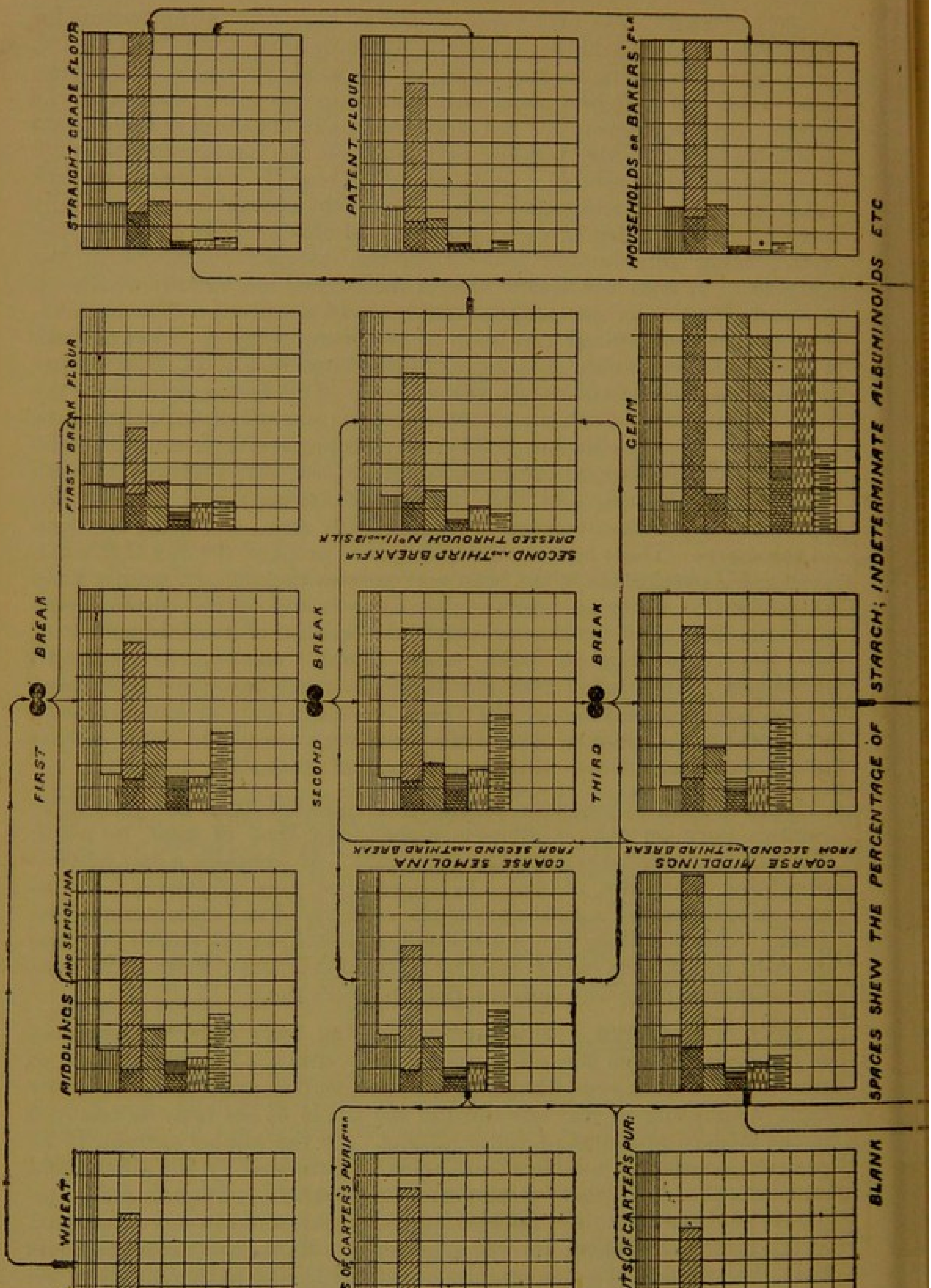

FIG. 53.—COMPOSITION OF ROLLER MILLING PRODUCTS.

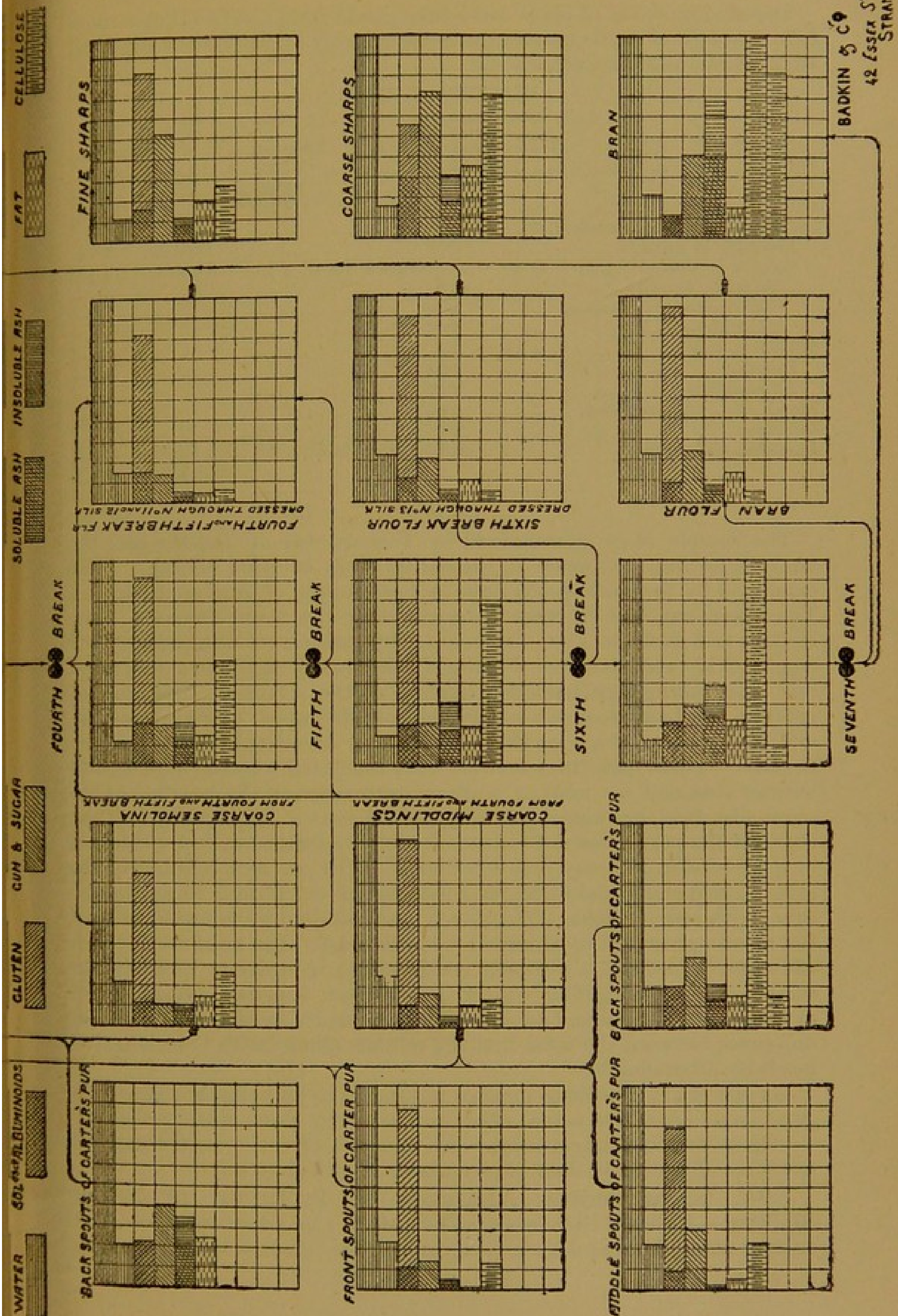

FIG. 53.—COMPOSITION OF ROLLER MILLING PRODUCTS.

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 | | | | |
| Albuminoids, | | 3·65 | | | | |
| Soluble in water, | 4·44 | | | | | |
| Dextrin, | | 1·44 | | | | |
| Albuminoids, | | 3·00 | | | | |
| Starch, &c., undetermined, | | 9·95 | | 40·76 | | 33·78 |
| Cellulose, | | 1·75 | | 5·96 | | |
| Insoluble albuminoids, | | 26·60 | Total albds., | 22·68 | Sol. albds., | 15·51 |
| | | | | | Insol. albds., | 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 albuminoids were determined by a nitrogen combustion; in order to estimate the soluble albuminoids, 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 albuminoids is reckoned as insoluble albuminoids.

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.

**364. 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 & 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 are of such great value as to warrant their quotation, together with the remarks thereon, in full.

ANALYSES OF THE PRODUCTS OF ROLLER MILLING, BY RICHARDSON.

| NAMES. | Water. | Ash. | Oil. | Carbohydrates. | Fibre. | Albuminoids. | Nitrogen. | Phosphoric Acid. | Ratio Nitrogen to Phosphoric Acid. | Gluten. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Moist. | Dry. |
| **O. A. Pillsbury & Co., Minneapolis, Minn.** | % | % | % | % | % | % | % | % | % | % | % |
| Wheat as it enters the mill .. .. | 9·66 | 1·91 | 2·61 | 69·94 | 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. | Carbohydrates. | Fibre. | Albuminoids. | Nitrogen. | Phosphoric Acid. | Ratio Nitrogen to Phosphoric 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. | Carbohydrates. | Fibre. | Albuminoids. | Nitrogen. | Phosphoric Acid. | Ratio Nitrogen to Phosphoric 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 |
| Third | 12·50 | ·85 | 2·79 | 70·20 | ·53 | 13·13 | 2·10 | ·45 | 4·67 | 37·78 | 12·68 |
| Second | 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 | 89·25 | 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. | Carbohydrates. | Fibre. | Albuminoids. | 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 | .. | .. | .. | .. |

**365. "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 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 albuminoids 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 albuminoids; 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 albuminoids, 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 albuminoids. 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 albuminoids 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 albuminoids 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 wants 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 albuminoids, 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, albuminoids, 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 albuminoids 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 higher middlings are the richest, and if the analyses of the flours are 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 discover 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 albuminoids, 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 albuminoid 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."

**366. 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, strength, and colour. The wheat mixture consisted of—

2 Parts Australian.
2 ,, Californian.

1 Part White Kurrachee.
2 „ Canadian White.
2 „ Chicago Spring.
2 „ Saxonska.
1 „ Hard Duluth.
1 „ Polish Red.
4 „ Oregon.
1 „ English.
—
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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. 54. | DESCRIPTION. | Moisture. | Crude Gluten. | | | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|
| | | | Wet. | Dry. | Ratio. | | |
| | Wheat .. .. .. | 13·50 | 25·0 | 9·15 | 2·7 | .. | .. |
| 1 | I. Break Flour .. .. | 13·18 | 21·0 | 8·57 | 2·4 | 20 G. | 60 |
| 2 | II. III. IV. } Breaks Flour .. .. | 13·40 | 27·0 | 9·80 | 2·7 | 2 G. | 61 |
| 3 | V. Break Flour .. .. | 12·80 | 43·0 | 14·6 | 2·9 | 16 G.Y. | 77 |
| 4 | I. Reduction .. .. | 13·24 | 22·0 | 7·7 | 2·8 | 3 G. | 60 |
| 5 | II. Reduction .. .. | 12·45 | 25·0 | 9·2 | 2·6 | 7 Y. | 71 |
| 6 | III. IV. } Reduction .. .. | 13·52 | 26·0 | 9·3 | 2·7 | 2 Y. | 66 |
| 7 | IV. V. } Reduction .. .. | 13·04 | 29·0 | 10·1 | 2·8 | 10 Y. | 70 |
| 8 | VI. Reduction .. .. | 13·40 | 27·0 | 9·5 | 2·8 | 9 Y. | 71 |
| 9 | VII. Reduction .. .. | 12·30 | 32·0 | 10·5 | 3·0 | 12 Y. | 75 |
| 10 | Straight Grade Flour . | 12·94 | 25·0 | 9·5 | 2·6 | 6 G. | 67 |
| 11 | Patent Flour .. .. .. | 12·94 | 22·0 | 8·1 | 2·7 | 5 Y. | 65·5 |
| 12 | Bakers' Flour .. .. | 13·30 | 26·0 | 9·7 | 2·6 | 6 G.Y. | 67 |
| 13 | III. Flour .. .. .. | 12·94 | 32·0 | 12·1 | 2·6 | 20 G. | 81·5 |
| | SPRING AMERICAN : | | | | | | |
| 14 | Weakest Break Flour (No. 37, Fig. 54) .. .. .. | 13·50 | 34·0 | 12·0 | 2·8 | 8 G. | 71·0 |
| 15 | Strongest Break Flour (No. 38, Fig. 54) .. .. .. | 13·40 | 40·0 | 13·9 | 2·8 | 16 G.Y. | 72·0 |
| 16 | Strong Flour from last Reduction of Middlings (No. 39, Fig. 54) .. .. .. | 11·61 | 33·0 | 11·3 | 2·9 | 18 G.Y. | 98·0 |
| | WINTER AMERICAN : | | | | | | |
| 17 | Weakest Break Flour (No. 21, Fig. 54) .. .. .. | 12·75 | 15·0 | 5·3 | 2·8 | 1·5 G. | 64·0 |
| 18 | Strongest Break Flour (No. 22, Fig. 54) .. .. .. | 12·51 | 30·0 | 10·4 | 2·8 | 10·0 Y. | 67·5 |
| 19 | Strong Flour from last Reduction of Middlings (No. 23, Fig. 54) .. .. .. | 11·30 | 29·0 | 10·2 | 2·8 | 15·0 Y. | 91·0 |

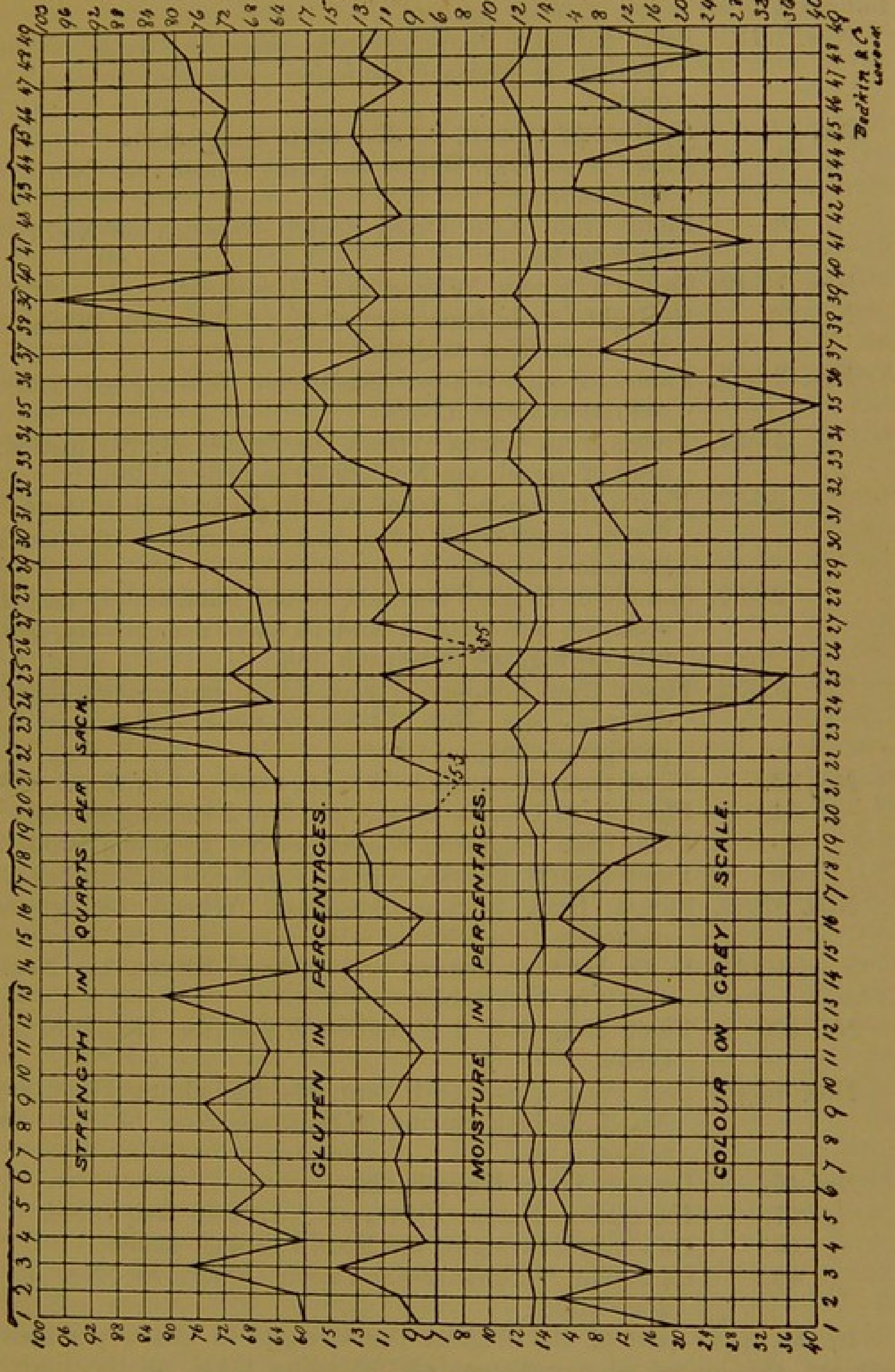


FIG. 54.

In Fig. 54 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. |
| 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 breadmaking 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 368. |
| ,, 31-32. | Flours from Bombay Wheat, milled respectively dry and damped, see Nos. 31-32 in flour tables, and also paragraph 367. |
| 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 strength in quarts per sack is set out, the lowest observed strength, 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 strength. These strengths are in each case those determined by the use of the strength burette and viscometer in the manner already described.

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 strength (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 strength, rather more in gluten, but a decided improvement in colour. No. 3, the 5th Break flour, is much stronger, 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 strength and gluten but of good colour. The 2nd reduction produces a flour of improved strength 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 strength, 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 strength and gluten, while the colour somewhat falls off. The 6th reduction flour is rather higher in strength, while the gluten is once more rather less in quantity. The flour from the 7th reduction, No. 9, shows an increase in both strength 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 strength, 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 strength, 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 strength low. No. 22, which was the strongest Break flour, shows a slight increase in strength, 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 strength 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 of strength. 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 has a comparatively low strength, 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 strength; the colour has fallen off. The flour from the last reduction of middlings registers the enormous strength 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.

**367. 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.

It is well known that whereas some millers add but a small quantity of water to such wheats as those from India, others use water in excessive amounts, undoubtedly with the object of increasing their yield of flour by causing it to absorb excessive moisture. A common method of damping such wheats is to treat them with a certain proportion of water; say, from five to ten per cent. of the weight of the wheat. The grain is then allowed to stand about twenty-four hours before grinding. During this time a portion of the water will be absorbed, and a portion will have evaporated. The opinion of many millers is that the absorbed water penetrates no further than the bran, except to a very small extent, and therefore that no great increase in yield of flour is produced by absorption of water by the endosperm.

In connection with this subject the author has recently analysed a number of samples of Indian and other hard wheats, dry and damped, and also the flours produced therefrom. For the milling data, he is indebted to various millers who have been at the pains to specially grind these samples of wheat. Subjoined are descriptions, together with the analytic results :—

DRY AND DAMPED WHEATS AND FLOURS.

| | Description. | Moisture. | Crude Gluten. | | | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|
| | | | Wet. | Dry. | Ratio. | | |
| A | Flour from No. 1 White Bombay Wheat, milled dry .. | 13·20 | 26·0 | 9·05 | 2·9 | 6·5 G. | 71·0 |
| B | Flour from Middlings of same Wheat, milled dry .. | 12·52 | 22·0 | 8·13 | 2·7 | 5·0 G.Y. | 70·0 |
| C | Flour from same wheat, with 12 per cent. of water added 24 hours before grinding .. | 13·74 | 27·0 | 9·6 | 2·9 | 9·0 G. | 67·5 |
| D | Flour from No. 1 White Bombay Wheat, milled dry .. | 12·51 | 23·0 | 8·3 | 2·8 | 14·0 G. | 68·0 |
| E | Flour from same Wheat, with 7·8 per cent. of water added | 13·57 | 22·0 | 8·3 | 2·7 | 12·0 G. | 64·0 |
| F | Wheat, No. 2 Club Calcutta cleaned and dry .. .. | 11·58 | 17·0* | 6·3 | 2·7 | .. | .. |
| G | Same Wheat, with 4·2 per cent. of water added .. .. | 12·51 | 15·0* | 5·7 | 2·6 | .. | .. |
| H | Wheat, Persian, cleaned and dry .. .. .. | 11·15 | 27·0* | 9·6 | 2·8 | .. | .. |
| I | Same Wheat, with 4·2 per cent. of water added .. .. | 13·30 | 17·0* | 7·24 | 2·3 | .. | .. |
| J | Flour from dry Calcutta, F. .. | 11·16 | 20·0 | 7·4 | 2·6 | 14·0 G. | 75·0 |
| K | Flour from damped Calcutta, G. | 11·32 | 22·0 | 8·4 | 2·6 | 14·0 G. | 74·0 |
| L | Flour from dry Persian, H. .. | 11·31 | 29·0 | 10·5 | 2·8 | 20·0 G. | 73·0 |
| M | Flour from damped Persian, I. | 12·03 | 30·0 | 9·8 | 3·0 | 20·0 G. | 73·0 |

*Duplicates of this series of Wet Glutens gave 17·0, 15·0, 26·0, and 17·0 per cent.

In the case of the first series of samples, A, B, C, the undamped wheat was ground on stones, and the flour separated from the middlings, which were in their turn reduced to flour, the two being kept separate. For the preparation of sample C a quantity of wheat was taken, sufficient to make a sack of flour, and 12 per cent. of water added. After standing 24 hours the wheat was milled; the results quoted, C, are those of the Straight Grade flour.

The quantity of water added was large; everyone will be first most interested in the percentage of moisture present in the flour. This has, however, only been increased from 13·20 to 13·74 per cent., giving a difference of 0·54 per cent. Evidently, then, of the water added to the wheat only a minute portion entered the flour. In this particular instance the yield of flour, as a result of damping the wheat, was only increased to the extent of half per cent. by soaking with 12 per cent. of water for 24 hours, so far as actual absorption of water by the flour was concerned. Of the water added to the wheat but $\frac{1}{24}$, or 4·1 per cent., found its way into the flour.

The next question is the quality of the flour when produced. In the first place analysis shows that the gluten was higher in the damped flour; this was probably due to the mellowing effect produced by the absorption of a small quantity of water. The same result would occur by letting the dough stand somewhat longer before extracting the gluten. It is a well-known fact that from hard wheat flours, such as Indian, very little gluten is obtained if the extraction is performed immediately the flour is wetted. Turning to the strength, the result of damping was that the strength fell off from 71 to 67·5 quarts per sack; these measurements were made by the viscometer after the dough had stood one hour. This means a loss of strength of 3·5 quarts of water per sack, or 8lbs. 12oz. of water per 280lbs. of flour, which just equals 3 per cent. The absorption, therefore, by the flour of 0.5 (½) per cent. of water, previous to milling, resulted in a diminution of the water-absorbing power of the flour, when doughed, of 3 per cent. This is due to the fact that the absorbed water deteriorated the strength-giving constituents of the flour. Considering next the question of colour, the damped wheat flour showed a colour of 9·0 G. against a colour of 6·5 G. in that milled dry.

The results of analyses of samples A and C are set off in Figure 53, Nos. 31 and 32.

In passing, it may be mentioned that 1 quart of water per sack equals almost exactly 0·9 per cent. (0·89).

Samples D and E were specially ground by another miller; the one was milled dry, to the other 7·8 per cent. of water was added. The actual quantities were 15½ pints to four bushels of the cleaned wheat, weighing 62lbs. per bushel. Again, first considering the water, the addition of 7·8 per cent. resulted in causing an increase of that present in the flour by just 1 per cent., this being about ⅛ of that added, or, more exactly, 13·6 per cent. In this case the flours, from both the damped and dry wheats, yielded the same percentage of gluten. The damped wheat flour was again the weaker of the two, showing a falling off of four quarts per sack; compared with the previous series, the loss in strength is rather more, but does not bear so high a proportion to the amount of water absorbed as in that instance. Here, a gain in moisture of 1 per cent. has resulted in a loss of water-absorbing power of 4 quarts to the sack, or 3·6 per cent. The colours of the two flours were respectively 14·0 G. for the dry, and 12·0 G. for that from the damped wheat. The former was also decidedly branny.

The flours and wheats marked F to M were forwarded to the author by a third miller, so that the different series represent results gained by three millers situated in different parts of the country, and working absolutely independently of each other. They thus have the advantage of representing not only the method of damping employed by one man, but those of several. In preparing sample G of damped Club Calcutta, a quarter of the wheat was cleaned, and then weighed 480lbs. To this, 2 gallons (20lbs.) of water were added. After 24 hours the wheat was re-weighed, and was then found to weigh 495lbs.; loss by evaporation, 5lbs. The wheat was then once more passed through a cleaning machine (nine-inch Victoria, with scourers and two strong air blasts). After this, the wheat was ground high on stones, and the middlings reduced on rolls, purified and dressed, and then mixed so as to produce a straight grade flour.

The damped Persian was prepared in precisely the same manner, but suffered no appreciable loss by evaporation.

The dry wheats were forwarded to the author in bags, the damped samples in tin canisters. The whole were further protected by enclosure in sacking.

In these wheats, the quantity of water added amounted to 4·2 per cent., being considerably less than that employed in the previously recorded experiments. Here, determinations have been made of the water in the damped wheat itself, as taken immediately before grinding; that is, on being the second time weighed. Taking first the Calcutta wheats, as there had been a loss of 5lbs. by evaporation, the added water still to be accounted for amounted to about 3 per cent.; analysis revealed, however, a difference of only 1 per cent. With the Persian wheat, there was no appreciable loss by evaporation, and on analysis the damped wheat contained rather over 2 per cent. more moisture than that sent dry; the wheats were in each case ground prior to estimating moisture. In each sample, therefore, there was 2 per cent. of added water which was unaccounted for. Circumstances caused some delay between the receiving of these wheats and their analysis, the author therefore asked the miller to kindly treat fresh lots of wheat and to forward samples. These were accordingly treated exactly as before, and sent in the same manner. They were dispatched on the one evening and their analysis commenced the next morning, consequently no great changes in their humidity could have occurred. Determinations of moisture were made, both in the whole wheats, and in the meals produced by grinding in a hand mill. The whole wheats were kept in the hot-water oven for five days. The following are the results :—

| | First Samples (from previous table). | Second Samples. | |
|---|---|---|---|
| | Meal. | Meal. | Whole Wheat. |
| Calcutta, dry....... ... | 11·58 | 10·33 | 10·31 |
| Calcutta, damped...... | 12·51 | 12·40 | 13 00 |
| Persian, dry............ | 11·15 | 11·44 | 11·49 |
| Persian, damped ...... | 13·30 | 13·58 | 14·60 |

Comparing the two sets of samples, when tested as meals, there is a very close agreement, except in the case of the dry Calcutta; the discrepancy must be due to either error of analysis, or else actual difference in the degree of moisture of the wheat when analysed on the two different occasions. The flour from the dry wheat was found to contain 11·16 per cent. of water; this closely agrees with what might have been expected, if the wheat to start with contained 11·58 per cent. On the other hand, the determination of moisture in the meal of the second sample closely agrees with that of moisture in the whole wheat; there is therefore very strong collateral evidence in support of the correctness of the analysis. Taking the two sets of determinations in the second samples, the dry wheat and the meal therefrom agree to the second place of decimals; but, in the damp samples, the meals in each case run considerably lower than the whole wheat estimations. This shows that, even in the process of hand grinding, a damped wheat loses a considerable quantity of moisture. Tracing the history of the 4·2 per cent. of added water, about 1 per cent. was, in the case of the Calcutta, lost by evaporation ; no appreciable amount was lost by the Persian, and consequently the damped sample of that wheat shows a proportionately greater increase of moisture.

The determinations of gluten in the respective wheats gave some very remarkable results. It must be remembered that they stood bottled for some days before these estimations were made, consequently any water added had full opportunity of effecting any changes within its power. In the Calcutta wheats the damping has caused a slight diminution in gluten ; this diminution is still more marked in the Persian samples, the wet gluten falling off from 27 to 17 per cent. The dry gluten from the damped Persian wheat is 2·36 lower than that from the same wheat allowed to remain dry. It is curious also to note the remarkably low ratio of wet to dry gluten in this latter sample. To make assurance doubly sure, duplicate estimations of these glutens were made. The lower proportion of gluten in damped Persian wheat is in accordance with its greater capacity for absorbing water when damped. The changes are not shown to a like extent in the flour, because, although the wheats may have absorbed water when damped, but little of this water is to be found in the finished flour.

Turning next to the flours, that from dry Calcutta wheat contained 11·16 per cent. of water, while the flour from the damped wheat yielded on analysis 11·32 per cent. The difference between the two is 0·16 per cent., while 4·2 per cent. of water had been added. Of the added water, therefore, $\frac{1}{26}$, or, more exactly, 3·8 per cent., found its way into the flour. The flour from the damped wheat was 1 quart per sack less in strength than was that of the wheat milled dry. The damped wheat flour gave 8·4 against 6·5 per cent. of gluten yielded by the flour from the dry wheat. In colour the two samples were both 14·0 G., there being absolutely no appreciable difference between them.

The examination of the damped Persian wheats showed that they absorbed moisture more readily than do Calcutta wheats ; the greater absorption in this latter instance is also borne out by determinations of moisture in the flour. The difference in moisture between the dry and damped Persian wheat flours is 0·72 per cent. ; this amounts to an absorption of about $\frac{1}{6}$, or, more exactly, 17·1 per cent. of the total water added to the wheat. The gluten of the damped wheat flour was 9·8 against 10·5 per cent. in the flour from the dry wheat. Turning next to the strengths, notwithstanding the fact that the damped wheat flour contained more moisture and less gluten than did that from the dry wheat, yet the strengths were precisely the same. In colour, both the Persian wheat flours registered 20·0 G. ; the two on being tested were indistinguishable.

With regard to these latter four flours, baking tests were made on them, with the following results. Water was in each case added in the proportion of the number of quarts to the sack given in the previous table :—

| | Calcutta. | | | | Persian. | | | |
|---|---|---|---|---|---|---|---|---|
| | Dry. | | Damped. | | Dry. | | Damped. | |
| | lbs. | oz. | lbs. | oz. | lbs. | oz. | lbs. | oz. |
| Flour .. .. .. | 3 | 0 | 3 | 0 | 3 | 0 | 3 | 0 |
| Water .. .. .. | 2 | 0 | 1 | 15¾ | 1 | 15¼ | 1 | 15¼ |
| Salt .. .. .. | 0 | 0½ | 0 | 0½ | 0 | 0½ | 0 | 0½ |
| Yeast .. .. .. | 0 | 0¾ | 0 | 0¾ | 0 | 0¾ | 0 | 0¾ |
| Sugar .. .. .. | 0 | 0¼ | 0 | 0¼ | 0 | 0¼ | 0 | 0¼ |
| Dough .. .. .. | 5 | 1½ | 5 | 1¼ | 5 | 0¾ | 5 | 0¾ |
| After fermentation .. | 5 | 1½ | 5 | 0¾ | 4 | 15 | 5 | 0 |
| Loss during fermentation .. | 0 | 0 | 0 | 0½ | 0 | 1¾ | 0 | 0¾ |
| Bread .. .. .. | 4 | 9¼ | 4 | 9 | 4 | 8 | 4 | 8¼ |
| Loss in oven .. .. | 0 | 8¼ | 0 | 7¾ | 0 | 7 | 0 | 7¾ |

In each case the dough from dry wheat flour fell off in stiffness more during fermentation than did that from the damped wheat. This was specially noticeable in the case of the dry Persian wheat flour; the dough, after fermenting some three hours, had become decidedly "sloppy." (This falling off in stiffness is not necessarily accompanied by loss of weight). When baked, the loaf from the damped wheat flour was in each case of better colour; there was very little difference between the heights of the two loaves from the Calcutta flour, but in the case of those from the Persian the damped flour yielded a much better risen loaf, which, as shown above, was slightly the heavier of the two. In flavour, the bread from flours of the damped wheats was in each case superior. One observer to whose judgment the loaves were submitted (without information as to their respective identities), remarked that the dry wheat flour loaves were more "wheaty" in taste.

Having stated with the utmost care the whole of the details of this series of experiments, there now remains to formulate the conclusions to be drawn therefrom. In the first place the experiments fairly cover the whole of the ground; the wheats selected have extended from those of usual dryness to excessively moist samples of their kind. The quantities of water added have varied from the lowest to some of the highest percentages commonly used for *bona fide* damping purposes. The milling portion of the experiments have not been made under the writer's direct supervision, but he is nevertheless assured that they have been carefully and efficiently performed. He takes this opportunity of thanking those gentlemen who have devoted so much time and trouble to helping him in the attempt to throw some light on this most important question. Of the water added to the wheat, a portion, more or less, evaporates during the time the grain is standing. The amount depends on the degree of humidity of the atmosphere; as wheat and flour both absorb vaporous moisture, and again lose it, with comparative readiness. This property undoubtedly accounts for slight discrepancies that are at times observed in moisture determinations in wheat. Carefully considering the whole of the circumstances affecting this particular series of samples, the writer has arrived at the conclusion that any such variations are so slight that they do not in the least affect the main question at issue.

The damped wheat is, before grinding, passed through a scourer; in this machine the greater part of the added moisture is probably dissipated. As grinding wheat, whether by stones or rolls, develops heat, moisture is lost during this operation, particularly as, with artificially damped wheats, the moisture does not apparently penetrate far into the endosperm, but mostly lodges within the bran. That the moisture of such damped wheats is not held with the tenacity of that of wheats in their normal condition is shown by the much greater loss of moisture caused by hand-grinding the wheats after damping, as compared with that of the dry wheats. This point came out strongly in the moisture determinations previously given, as being made on the whole wheats and the meals therefrom. It is stated, on the authority of Mège Mouriès, that, on placing wheat in water for 24 hours, the moisture penetrates to the heart of the endosperm. Whatever results may have been obtained by actually submerging wheat and allowing it to soak, no evidence is forthcoming of any but the slightest penetration of moisture to the heart of the endosperm as a consequence of the ordinary artificial damping of hard wheats as a preliminary to milling.

Summing up the results of the series of experiments made—

**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.**

Partly from the foregoing experiments, and partly from a study of the general properties of wheat and its analogy to other seeds, the conclusion is drawn that **the proportion of water absorbed into the endosperm during the damping of wheat does not increase with the degree of dryness of the grain.** The present experiments do not afford *direct* proof of this statement, but nevertheless furnish important evidence in its favour. In the first place, if the converse of this proposition holds good, it would naturally be expected that the flour, K, from the driest sample of Indian wheat would have absorbed a considerably larger percentage of water, than had the flour C, from the dampest sample of Indian wheat. Such is not the case, for the percentage of absorption by the flour, K, is less (3·8) than that by the flour, C, (4·1). It may be objected that these flours were produced from two different varieties of wheat, and that therefore no comparison can be instituted between them. But if a very dry wheat *does* absorb moisture more readily when wetted, than does a sample that is damper to start with, it might reasonably be supposed that the absorption would at least have been greater, rather than less, with the Calcutta sample than that from Bombay, especially as these samples were treated in the same manner. Again, if the drier the wheat, the more rapid the absorption of moisture, then the damper the wheat, the slower must be the absorption of moisture. Taking the flour from damped Calcutta, it absorbed but 3·8 per cent. of the added water; then if the wheat had only been say 2 per cent. moister to start with, the flour must have absorbed considerably less even than 3·8 per cent. of the water added, which would be an infinitesimal proportion. This does not follow from a comparison between two different samples, but is a direct deduction from most carefully made comparative experiments on one and the same wheat. Therefore, the advocates of the hypothesis that water-absorbing power diminishes with increased dampness of the original grain, must be prepared to admit that if this Calcutta wheat had only been a little damper, the water-absorbing power of the endosperm would have reached a vanishing point. The view, that the drier the wheat the more rapid the absorption of moisture, is at first sight a perfectly natural one, as it is a general rule that the drier a hygroscopic substance is the more readily does it absorb water, and the endosperm of wheat consists principally of starch which is highly hygroscopic. But in the case of a wheat grain the endosperm is enclosed within the bran, and that altogether alters the conditions. The starch of very dry wheats may be more hygroscopic, but the bran is also less permeable to moisture as a result of its extreme dryness; and consequently the dry wheat grain may offer even greater opposition to the absorption of water than would the same wheat when somewhat damper. On high botanical authority, this is a property of dry seeds generally, for on placing such dry seeds in water, the rate of absorption by the endosperm, within certain limits, increases as the absorption itself proceeds.

In connexion with these experiments, it must on the other hand be pointed out that, in the case of the two series of samples milled from Bombay wheat, that which in the undamped state produced the drier flour, yielded, on damping, a flour which had absorbed a higher proportion of the added water than had the other. So far, this would seem to afford evidence that the drier wheat had more absorbing power; but bearing in mind that the sample was independently treated, and also the very cogent reasons adduced in support of the view that the proportion of water absorbed does not increase with the dryness of the grain, it is far more likely that the difference in the case of samples D and E results from E having been differently treated to the other damped samples.

It must be remembered that any differences of opinion which, in the absence of absolutely direct proof, may legitimately exist as to whether the views above advocated should meet with acceptance, have no connection whatever with the statement so conclusively established, namely, that in artificial damping of wheats, but a small proportion of the water finds its way into the flour. That fact, in the absence of evidence to the contrary, has been indisputably proved, and is perfectly independent of the opinions advanced in the immediately preceding paragraphs.

**368. 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 albuminoids degraded by moisture, prevents excessive diastasis of the starch, on the flour being treated with water. The soluble albuminoids, 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 Albuminoids... | 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 Bischof, appears to lose the faculty of forming gluten. (Jour. Chem. Soc., 1882, p. 537, Abstracts.) The author can confirm this statement, having recently 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 previously examined samples, the results of which are recorded in paragraph 350, 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. | Strength in Quarts per Sack. | Same after 24 hours in Dough. |
|---|---|---|---|---|---|---|---|
| | | Wet. | Dry. | Ratio. | | | |
| Undried Flour (No. 28, Fig. 54) .. .. | 13·4 | 29·0 | 10·3 | 2·8 | 12·0 G. | 67·0 | 65·0 |
| Flour after 2 days drying (No. 29, Fig. 54) .. | 10·3 | 31·0 | 10·7 | 2·9 | 12·0 G. | 74·5 | .. |
| Flour after 16 days drying No. 30, Fig. 54) .. | 6·5 | 32·0 | 11·6 | 2·8 | 12·0 G. | 86·0 | 82·0 |

These flours are set out in Figure 54, 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 strength 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 strength 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 strength 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 strength tests were made; they show that the original flour fell off during that time 2 quarts, while the dried flour lost 4 quarts in strength. 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 told by a baker that he found, as a result of storing Hungarian flour, that its strength 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 about three times the extent of the water lost by evaporation. In all probability, similar drying of damp wheats would have a like effect.**

**369. General Relationship existing between Strength, Gluten, Moisture, and Colour of Flours.**—Under this heading may be considered such flours included in the diagram, Figure 54, 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 strength 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 strength and gluten were low, and moisture high; the colour is fairly good. The flour from kiln-dried Scotch wheat is also low in strength 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 strength 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 strength and gluten are both diminished thereby. The flours 33-36 are marked by their very high percentage of gluten; notwithstanding this, their strength 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 strength 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 strength is high; the gluten, medium; moisture, low; and colour, good. Pillsbury's Straight runs high in strength, rather less gluten than the preceding; moisture, medium. The last flour, No. 49, is of special interest as being the strongest 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 strengths 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 strength with moisture, the dryness of a flour does not necessarily correspond with its strength, although in many instances a connexion may be observed between them. With one and the same flour, increase or decrease of moisture influences the strength 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 strength and gluten.

In judging the value of a flour from the analytic data given in this diagram, the strength 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. Strength 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 a measure of the colour of the bread made therefrom; apparent discrepancies between the colours of the flour and that of the bread are frequently observed, but these are probably due to irregularities in the breadmaking process. The same flour will produce bread of many shades of difference in colour, according to whether it be properly or improperly manipulated. If his bread be low in colour, the first point on which the baker should satisfy himself is whether the fault be inherently due to the flour, or to his method of breadmaking.

**370. 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.

In order to test the action of germ on flour, some mixtures were prepared on Tuesday, February 26th, 1884. It was first necessary to decide on a flour which should be entirely degermed. For the purpose, the Hungarian flour, from the Economo mills, Trieste, AAAAA., was selected. The germ used was the ordinary flattened germ of roller milling processes. There was, consequently, not the same intimate admixture which exists when germ and flour are absolutely ground up together. One series of samples made up consisted of the following mixture:—

| | | |
|---|---|---|
| Flour | ... ... | 200·0 grams. |
| Germ | ... ... | 15·4 ,, |
| Water | ... ... | 15·4 ,, |

Another set of samples contained:—

| | | |
|---|---|---|
| Flour | ... ... | 200 grams. |
| Water | ... ... | 15·4 ,, |

These mixtures were put in stoppered bottles and then tied down; the bottles were kept in a cellar, and so throughout the summer were in a cool and fairly constant atmosphere. The object of the experiment was to determine whether the flour which contained the germ deteriorated more rapidly under the influence of moisture than that which was germ free. An extreme case was purposely taken for the first experiment, because if no decided action had resulted under the most unfavourable conditions, it might fairly be assumed that none would follow when the circumstances approached more closely to those under which flour is stored in practice. On April 1st, two bottles were opened and samples tested for acidity and soluble albuminoids. On September 15th, two other bottles were taken and their contents carefully analysed. Both had become mouldy, and had acquired a most disagreeable odour; the odours of the two were, however, of a different character—that of the flour and water only was of a musty nature, while the smell of the mixture of germ, flour and water was strongly rancid, resembling that of rank butter. The mixture containing the germ was far deeper in colour than that of flour and water only. The subjoined table gives the results of various analyses :—

| No. | Description of Sample. | Moisture. | Acidity. | Soluble Extract. | Soluble Albuminoids. | Wet Gluten. | Dry Gluten. | Ratio. |
|---|---|---|---|---|---|---|---|---|
| 1 | Hungarian Flour .. | 12·62 | 0·18 | 4·66 | 0·93 | 29·0 | 9·83 | 2·9 |
| 2 | Same Flour on Sept. 15th. | .. | 0·29 | 4·42 | 1·02 | 28·0 | 9·33 | 3·0 |
| 3 | Flour & Water, April 1st. | .. | 0·22 | .. | 1·52 | .. | .. | .. |
| 4 | Flour, Water, and Germ, April 1st. .. .. | .. | 0·63 | .. | 1·94 | .. | .. | .. |
| 5 | Flour & Water, Sept. 15th. | 21·15 | 0·20 | 5·50 | 3·46 | 19·5 | 6·3 | 3·0 |
| 6 | Ditto, calculated to Flour without added water | 15·07 | 0·21 | 5·92 | 3·72 | 21·0 | 6·78 | .. |
| 7 | Flour, Water, and Germ, Sept. 15th. .. .. | 27·37 | 1·56 | 9·42 | 8·49 | Absent | Absent | .. |
| 8 | Flour and Germ, mixed on Sept. 15th. .. | .. | .. | 6·31 | 1·81 | .. | .. | .. |
| | *After digestion for 6 hours at 28° C. :* | | | | | | | |
| 9 | Flour only .. .. | .. | 0·27 | 8·64 | 1·28 | .. | .. | .. |
| 10 | Flour and Water .. | .. | 0·76 | 12·57 | 11·63 | .. | .. | .. |
| 11 | Ditto, calculated to Flour without added water | .. | 0·81 | 13·53 | 12·52 | .. | .. | .. |
| 12 | Flour, Water, and Germ | .. | 1·98 | 15·33 | 12·73 | .. | .. | .. |
| 13 | Flour and Germ, mixed on Sept. 15th. .. | .. | 0·58 | 10·31 | 1·93 | .. | .. | .. |

The first column to attract the attention of the miller will most likely be that headed "Gluten." It will be noticed that during the eight months the pure flour has lost a little in gluten, while the soluble albuminoids have slightly increased. In the flour and water the gluten has fallen to about $\frac{7}{10}$ of its original amount; when wet it was almost semifluid, and did not rise at all in the aleurometer. In the case, however, of the flour, water and germ, the gluten had entirely disappeared. This and other experiments show conclusively that the gluten of grain is destroyed by the action thereon of the germ in the presence of water. As might be expected, the disappearance of gluten is accompanied by a rise in the quantity of soluble albuminoids. These were estimated in each case by the ammonia process; the results obtained by that method are not to be depended on as absolutely correct; they must, therefore, only be viewed as comparative. The flour and water mixture contained less acid when estimated on September 15th than did the flour when then examined; the acid in the mixture containing germ also, had, however, risen enormously. The soluble extract in both Nos. 5 and 7 has increased, but to a greater extent in No. 7. The results are somewhat complicated in No. 7 by the presence of the germ, because that substance also yields soluble extract and albuminoids on analysis. It is difficult to make an exact correction for these on the present analyses, but there is no doubt that, making all allowance for the germ, the soluble albuminoids and extract from the flour itself are considerably increased by its presence. Samples Nos. 9-13 are ten per cent. solutions of the same mixtures as 2, 5, 7 and 8, maintained at a temperature of 28° C. (82° F.) for 6 hours and then analysed. The acidity, soluble albuminoids and extracts, are in every case higher than before digestion; an inspection of the figures will show how the results are affected by the presence of water and germ respectively.

In the estimations made on the flour, water, and germ, on September 15th, the soluble albuminoids are almost as high as the total soluble extract: this applies equally to the sample examined after digestion as well as that examined before. The large increase may be due to the albuminous bodies being converted into compounds which yield a larger proportion of their nitrogen as ammonia, when subjected to distillation with alkaline permanganate, than is the case with bodies of the pure albumin type. It is also probable, that by a species of fermentation, the soluble carbohydrate had been more or less converted into volatile bodies.

These experiments were followed by a series in which the proportions of added material were much lower. The same brand of flour was selected; its strength was about 77 quarts per sack.

The following mixtures were made and bottled—

F. Flour only.
F.W. Flour 97·5 parts, water 2·5 parts.
F.G. Flour 97·5 ,, germ 2·5 ,,
F.G.W. Flour 9·5 ,, germ 2·5 ,, water 2·5 parts.

These samples were also set aside in a cellar, and allowed to remain untouched for twelve months. Their appearance had not considerably altered; the F.W. smelt musty, while the mixtures containing germ had developed a rancid odour. The following are results of determinations made after the twelve months:—

| Description. | Moisture. | Crude Gluten. | | | Strength in Quarts per Sack. |
|---|---|---|---|---|---|
| | | Wet. | Dry. | Ratio. | |
| F. ... ... | 11·78 | 31·0 | 10·59 | 2·9 | 78·0 |
| F.W. ... ... | 13·48 | 30·0 | 9·70 | 3·0 | 72·5 |
| F.G. ... ... | 11·42 | 33·0 | 10·89 | 3·0 | 77·5 |
| F.G.W. ... ... | 13·30 | 24·8 | 8·50 | 2·9 | 71·0 |

The water alone had somewhat reduced the percentage of gluten, and had also affected the strength to the extent of 6 quarts. The germ alone had caused the yield of gluten to be somewhat higher: the same effect has been observed in several other similar tests. It is somewhat difficult to say from whence the increase is derived, as the germ itself yields no gluten. It is probable that the fat of the germ is absorbed and retained by the gluten during the washing process; and also that the germ cellulose so closely adheres to the gluten as to render difficult their mechanical separation. The germ has not sensibly affected the strength. Turning next to the mixture of F., G., and W., the gluten is considerably less, thus showing that water and germ, conjointly, are capable of inducing greater changes than either taken separately. The strength has, in this latter case, diminished to 71 quarts per sack. An attempt was made to make colour estimations, but the mixture was not sufficiently homogeneous to admit of any readings being taken. In experiments such as these the germ is shown to have an injurious action, particularly in the presence of water. It must be remembered that here a very high-class flour was being used: with a lower quality of flour, and the germ ground into it instead of being mixed in the above imperfect fashion, the effect of its presence would, without doubt, be considerably intensified.

**371. 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.

**372. 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 albuminous 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 albuminoids 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 gelatinise 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 albuminoids, 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.

**373. Tabulated Results of Flour Analyses.**—The following tables contain analyses of flour selected from among those made by the author during the past two years. Flours have been selected which are of interest from 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.

## FLOURS USED IN PREVIOUSLY QUOTED VISCOMETER EXPERIMENTS.

| No. | Name and Description. | Moisture. | Soluble Extract. | Soluble Albuminoids. | Crude Gluten. | | | Ash. | Fat. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wet. | Dry. | Ratio of Wet to Dry. | | | |
| 1 | No. 2, Calcutta (No. 42, Fig. 54) ... | 12·60 | 5·40 | 0·90 | 28·1<br>21·5 | 9·68<br>8·15 | 2·9<br>2·6 | 1·2 | 1·50 | 71·5 |
| 2 | Odessa (No. 34, Fig. 54) ... ... | 11·60 | 4·90 | 0·60 | 49·5 | 16·18 | 3·0 | 0·76 | 1·04 | 70·0 |
| 3 | Saxonska (No. 36, Fig. 54) ... .. | 11·80 | 5·00 | 1·20 | 53·0 | 17·20 | 3·1 | 0·75 | 0·92 | 70·5 |
| 4 | Australian (No. 33, Fig. 54) ... ... | 11·30 | 4·50 | 1·20 | 42·0 | 14·20 | 3·0 | 0·54 | 1·00 | 68·0 |
| 5 | Town Whites ... ... ... .. | 11·76 | 6·60 | 1·06 | 35·0 | 13·10 | 2·6 | ... | ... | 70·0 |
| 6 | Town Households ... ... ... | 11·80 | 5·20 | 1·14 | 39·5 | 13·09 | 3·1 | ... | ... | 72·0 |
| 8 | Patent Flour from American Hard Fyfe Wheat (No. 40, Fig. 54) ... ... | 12·60 | ... | ... | 40·0 | 13·42 | 2·9 | ... | ... | 71·0 |
| 9 | Bakers' Flour from American Hard Fyfe Wheat (No. 41, Fig. 54) ... ... | 13·16 | ... | ... | 42·0 | 14·54 | 2·8 | ... | ... | 73·0 |
| 10 | A A A A A Hungarian Flour ... ... | 11·22 | ... | ... | 33·0 | 11·35 | 3·0 | ... | ... | 78·0 |
| 11 | English Wheat Flour ... ... ... | 14·02 | ... | ... | 22·0 | 7·8 | 2·9 | ... | ... | 63·0 |

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 Albuminoids. | Crude Gluten. | | | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wet. | Dry. | Ratio of Wet to Dry. | | |
| 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. 54) ... ... ... | 13·80 | ... | ... | 22·0 | 7·94 | 2·7 | 2.5 G. | 63·0 |
| 14 | Flour from Old White English Wheat (No. 15, Fig. 54)... ... ... | 14·00 | ... | ... | 29·0 | 9·82 | 3·0 | 9·0 G. | 62·0 |
| 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<br>44·0 | 15·8<br>16·3 | 3·0<br>2·7 | ...<br>... | ...<br>... |
| 19 | Straight Grade from Winter American Wheat ... ... ... ... | 11·88 | 3·37 | 1·52 | 30 00 | 9·76 | 3·0 | 7·0G. | ... |
| 20 | Patent from ditto ... ... ... ... ... ... | 11·96 | 3·04 | 1·08 | 24·00 | 8·20 | 2·9 | 3·0G.Y. | ... |
| 21 | Straight Grade from Minnesota Wheat ... ... ... ... ... | 12·29 | 4·57 | 0 98 | 31·00 | 10·68 | 2·9 | 14·0G. | ... |
| 22 | Patent from ditto ... ... ... ... ... | 12·10 | 4·49 | 1·46 | 29·00 | 9·76 | 3·0 | 7·5G.Y. | ... |
| 23 | Best Patent from No. 1 Duluth Spring Wheat, Roller Milled (No. 43, Fig. 54) ... ... ... ... ... ... ... ... ... | 13·02 | ... | ... | 34·0 | 11·35 | 3·0 | 8·0Y. | 71·5 |
| 24 | Second Patent from the same Wheat (No. 44, Fig. 54) ... ... ... | 13·00 | ... | ... | 36·0 | 12·4 | 2·9 | 12·0Y.G. | 72·0 |
| 25 | Remaining Flour from same Wheat (No. 45, Fig. 54) ... ... ... | 12·76 | ... | ... | 39·0 | 13·4 | 2·9 | 20·0G. | 74·0 |
| 26 | Straight Grade from Azima Wheat ... ... ... . ... ... | 12·36 | ... | ... | 39·0 | 12·7 | 3·0 | 14·0G.Y. | 71·5 |
| 27 | Straight Grade from very choice Californian Wheat (No. 20, Fig. 54) .. | 12·1 | ... | ... | 21·0 | 7·13 | 2·9 | 2·0G. | 64·0 |
| 28 | Flour from Taganrog Wheat, ground on French Stones, dressed on Silk Reel, Cloth, Nos. 9, 10, 11, and 12, Swiss (No. 35, Fig. 54) ... | 13·24 | ... | ... | 48·0 | 15·43 | 3·1 | say 40 G. | 70·0 |
| 29 | Flour from Varna Wheat (No. 25, Fig. 54) ... ... ... ... | 11·22 | .. | ... | 35 0 | 11·17 | 3·1 | say 35 G. | 71·0 |
| 30 | Flour from Varna Wheat, slightly heated in hold of vessel (No. 24, Fig. 54) | 13·60 | ... | ... | 22·0 | 7·65 | 3·0 | say 30 G. | 65 0 |
| 31 | Flour from No. 1, White Bombay Wheat, 12 per cent. of water added 24 hours before grinding (No. 31, Fig. 54) ... ... ... ... | 13·74 | ... | ... | 27·0 | 9·6 | 2·9 | 9·0G. | 67·5 |
| 32 | Flour from No. 1, White Bombay Wheat, milled dry (No. 32, Fig. 54) | 13·20 | ... | ... | 26·0 | 9·05 | 2·9 | 6·5G. | 71·0 |
| 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 | 5·0G.Y. | 70 0 |
| 34 | Flour from Red Californian Wheat, No. 254 ... ... ... ... | 10·70 | .. | ... | 29·0 | 10·0 | 2 9 | 12 G.Y. | 73·5 |
| 35 | Patent Flour from Manitoba Hard Fyfe Wheat (No. 49, Fig. 54) ... | 12·90 | ... | ... | 30·0 | 10·8 | 2·7 | 9·0G. | 82·0 |
| 36 | Bakers' Flour from ditto ... . . ... .. ... ... ... | 13·50 | ... | ... | 31·0 | 11·7 | 2·6 | 16·0G. | 77·0 |

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 strength rapidly falls off. The Indian wheat samples are referred to at length in paragraph 367. 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 strength. 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.

## WELL-KNOWN BRANDS AND VARIETIES OF FLOUR.

| No. | Name and Description. | Moisture. | Soluble Extract. | Soluble Albuminoids. | Crude Gluten. | | | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wet. | Dry. | Ratio of Wet to Dry. | | |
| 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 | 2·36 | 29·5 | 10·22 | 2·8 | ... | ... |
| 42 | Porter's Strong Baker's 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 "O O O O, Boss" Flour ... ... ... ... ... ... | 11·36 | 3·77 | 0·82 | 36·50 | 12·20 | 2·9 | ... | ... |
| 45 | Washburn's "O O" Flour ... ... ... ... ... ... ... | 12·37 | 3·57 | 1·06 | 29·20 | 11·70 | 2·6 | 11·0 G. | ... |
| 46 | Washburn's "O O O" 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 "A A A" 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 |
| 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. 54) ... ... ... ... | 10·86 | ... | ... | 30·3 | 9·86 | 3·0 | 7·0 Y. | 77·0 |
| 53 | ,, ,, 1. ... ... ... ... . . ... | 10·76 | .. | ... | 26·0 | 8·97 | 2·9 | 7·0 Y. | 77·0 |
| 54 | ,, ,, 2. ... ... ... ... ... ... | 11·18 | ... | ... | 28·0 | 9·20 | 3·0 | 6·0 Y. | 71·5 |
| 55 | ,, ,, 4. ... ... ... ... ... ... | 11·06 | ... | ... | 26·0 | 8·74 | 2·9 | 10·0 Y. | 73·0 |
| 56 | ,, ,, 5. ... ... ... ... ... ... | 10·68 | ... | ... | 30·0 | 10·25 | 2·9 | 12·0 Y. | 74·5 |

WELL-KNOWN BRANDS AND VARIETIES OF FLOUR—*Continued.*

| No. | Name and Description. | Moisture. | Soluble Extract. | Soluble Albuminoids. | Crude Gluten. | | | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Wet. | Dry. | Ratio of Wet to Dry. | | |
| 57 | Hungarian Victoria Empress ... ... ... ... ... ... | 10·82 | ... | ... | 30·4 | 10·48 | 2·9 | 7·0 Y. | 76·0 |
| 58 | ,, Victoria Diamonds ... ... ... ... ... ... | 10·54 | ... | ... | 27·0 | 9·75 | 2·8 | 7·5 Y. | 75·0 |
| 59 | ,, Victoria Pyramids ... ... ... ... ... ... | 10·98 | ... | ... | 25·0 | 9·23 | 2·7 | 11·0 Y. | 74·5 |
| 60 | ,, Five Tulips, price 43/6 ... ... ... ... ... | 12·40 | 4·80 | 0·99 | 32·0 | 10·05 | 3·0 | 11·0 Y. | 73·0 |
| 61 | ,, Three Stars, price 43/6 ... ... ... ... ... ... | 12·87 | 3·92 | 0·77 | 30·0 | 9·43 | 3·0 | 8·0 Y. | 73·5 |
| 62 | ,, Victoria Diamonds, price 42/6 ... ... ... ... ... | 12·82 | 4·00 | 0·70 | 30·5 | 9·30 | 3·0 | 6·0 Y.G. | 72·0 |
| 63 | Pillsbury's Crown ... ... ... ... ... ... ... ... | 12·84 | ... | ... | 41·3 | 16·46 | 2·5 | 20·0 G. | 73·0 |
| 64 | Stannard's Crown (No. 14, Fig. 54) ... ... ... ... ... | 12·80 | ... | ... | 37·0 | 14·20 | 2·6 | 5·0 G. | 61·0 |
| 65 | Supers, Taylor's, London ... ... ... ... ... ... ... | 13·54 | ... | ... | 35·0 | 11·83 | 2·9 | 5·5 G.Y. | 63·5 |
| 66 | Whites, ,, ... ... ... ... ... ... ... | 13·40 | ... | ... | 37·0 | 12·07 | 3·0 | 10·0 G.Y. | 64·0 |
| 67 | Households, ,, ... ... ... ... ... ... ... | 13·50 | ... | ... | 40·0 | 13·00 | 3·0 | 18·0 G. | 64·5 |
| 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 |
| 69 | Flour from rolled middlings of Varna and Taganrog Wheats ... ... | 13·46 | ... | ... | 34·0 | 11·55 | 2·9 | 18· G.Y. | 67·6 |
| 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 |
| 71 | Ure & Son's Minnesota Straight ... ... ... ... ... ... .. | 12·70 | ... | ... | 34·0 | 12·0 | 2·8 | 15·0 G. | 78 |
| 72 | Glasgow Milled "Spring" Straight ... ... ... ... ... ... | 12·71 | ... | ... | 33·0 | 11·7 | 2·8 | 17·0 G. | 72·5 |
| 73 | Glasgow Milled Minnesota Patent ... ... ... ... ... ... | 12·60 | ... | ... | 33·0 | 11·3 | 2·9 | 14·0 Y. | 73·5 |
| 74 | Pillsbury's Straight (No. 48, Fig. 54) ... ... ... ... ... | 12·30 | ... | ... | 35·0 | 13·0 | 2·7 | 23·0 G. | 78 |

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 strength testing apparatus, 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.

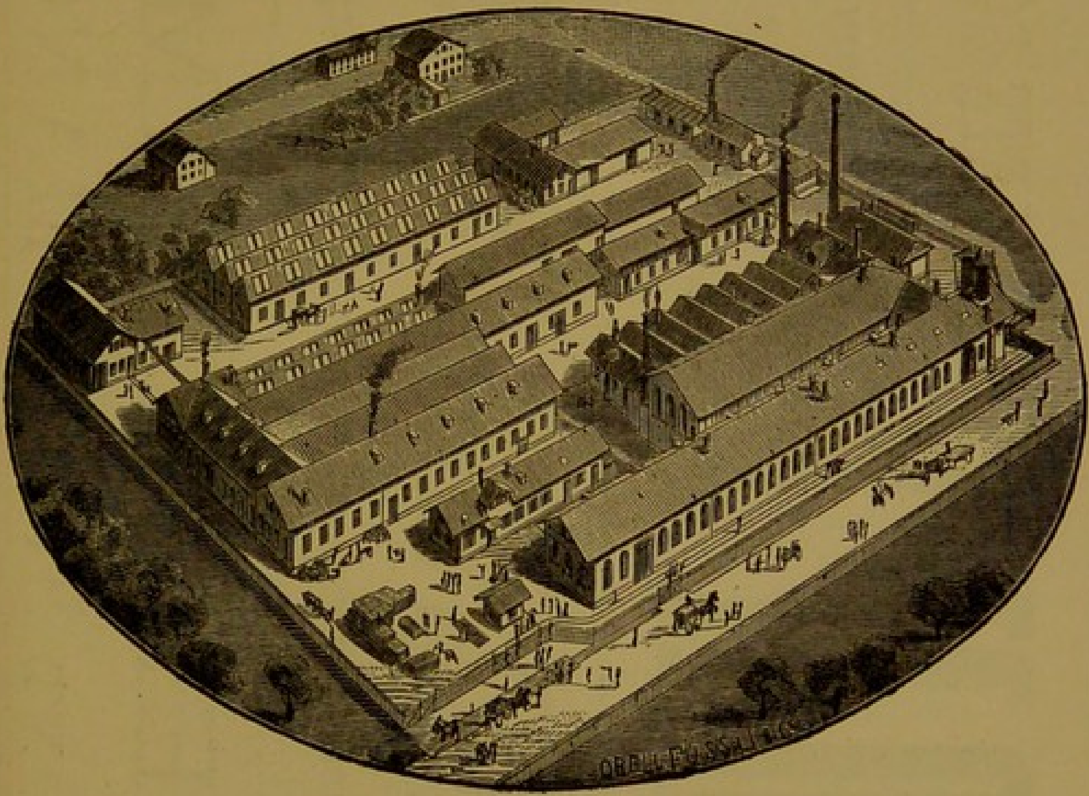
## FLOURS, ILLUSTRATING SUPPLIES OF LARGE TOWNS.

| No. | Name and Description. | Moisture. | Soluble Extract. | Soluble Albuminoids. | Crude Gluten. Wet. | Crude Gluten. Dry. | Crude Gluten. Ratio of Wet to Dry. | Ash. | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|---|---|---|
| | **London.** | | | | | | | | | |
| 75 | Households, RR, Red on White Diamond; J. & H. Robinson, Deptford Bridge Mills | 11·04 | 6·2 | 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 | 13·5 | 4·2 | 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 | 5·0 | 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 | 11·1 | 5·53 | 1·4 | 29·0 | 9·37 | 3·1 | ... | ... | ... |
| 81 | Country Whites | 12·7 | 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 |
| 83 | ,, 32/6 ,, ,, | 12·90 | 3·44 | 0·69 | 27·8 | 9·20 | 3·0 | 0·44 | 9·0 Y.G. | 66·0 |
| 84 | ,, 30/6 ,, ,, | 12·68 | 3·80 | 0·55 | 25·5 | 8·89 | 2·7 | 0·52 | 4·5 G.Y. | 68·0 |
| 85 | ,, 28/6 ,, ,, | 12·66 | 4·01 | 0·64 | 26·3 | 9·24 | 2·7 | 0·64 | 5·0 G.Y. | 68·0 |
| 86 | ,, 26/6 ,, ,, | 13·04 | 4·04 | 0·75 | 30·2 | 10·25 | 3·0 | 0·64 | 10·0 G.Y. | 67·0 |
| 87 | Flours from one Milling firm. price 36/6 ,, ,, | 12·78 | 3·64 | 0·76 | 25·0 | 8·31 | 3·0 | 0·46 | 1·5 G. | 62·0 |
| 88 | ,, 32/6 ,, ,, | 13·20 | 4·01 | 0·72 | 24·9 | 8·73 | 2·8 | 0·44 | 2·0 G. | 65·0 |
| 89 | ,, 30/6 ,, ,, | 12·84 | 3·76 | 0·72 | 25·4 | 8·82 | 2·9 | 0·42 | 4·5 G. | 62·0 |
| 90 | ,, 28/6 ,, ,, | 12·98 | 3·20 | 0·65 | 28·0 | 8·72 | 3·2 | 0·50 | 7·5 G. | 63·5 |
| 91 | From one firm. price 36/6 ,, ,, | 13·20 | 3·76 | 0·48 | 28·0 | 9·38 | 3·0 | 0·40 | 2·0 G.Y. | 62·5 |
| 92 | ,, 30/6 ,, ,, | 12·52 | 3·40 | 0·79 | 29·1 | 10·2 | 2·9 | 0·50 | 4·0 G.Y. | 64·0 |
| 93 | From one firm. price 32/6 ,, ,, | 11·58 | 3·68 | 0·44 | 25·0 | 9·53 | 2·6 | 0·52 | 4·25 G.Y. | 70·0 |
| 94 | ,, 28/6 ,, ,, | 12·06 | 4·12 | 1·04 | 27·0 | 9·10 | 3·0 | 0·46 | 6·0 G.Y. | 66·0 |
| 95 | High Grade, price 36/6 ,, ,, | 12·84 | 3·32 | 0·61 | 30·3 | 9·30 | 3·2 | 0·50 | 4·5 G.Y. | 65·0 |

FLOURS, ILLUSTRATING SUPPLIES OF LARGE TOWNS—*Continued.*

| No. | Name and Description. | | Moisture. | Soluble Extract. | Soluble Albuminoids. | Crude Gluten. Wet. | Crude Gluten. Dry. | Crude Gluten. Ratio of Wet to Dry. | Ash. | Colour. | Strength in Quarts per Sack. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 97 | Stone Milled, price 32/6 ... ... ... | | 12·72 | 4·48 | 1·20 | 29·2 | 9.52 | 3·0 | 0·46 | 8·0 G.Y. | 61·0 |
| | **Birmingham.** | | | | | | | | | | |
| 98 | Extras ... ... ... ... ... | | 12·66 | .. | .. | 29·0 | 9·34 | 3·1 | .. | 5·0 G. | 71·0 |
| 99 | Flours from one firm .. ... ... | | 13·01 | .. | .. | 28·0 | 9·40 | 2·9 | .. | 5·0 G. | 70·0 |
| 100 | | | 13·08 | .. | .. | 30·0 | 11·10 | 2·7 | .. | 16·0 G. | 74·0 |
| 101 | | | 13·25 | .. | .. | 31·0 | 11·20 | 2·8 | .. | 12·0 G. | 73·5 |
| 102 | From one firm. | Superfines ... ... ... | 13·00 | .. | .. | 27·0 | 9·50 | 2·7 | .. | 5·0 G. | 70·0 |
| 103 | | Fines ... ... ... ... | 12·60 | .. | .. | 30·0 | 10·60 | 2·8 | .. | 8·0 G. | 73·0 |
| 104 | Superfines ... ... ... ... . | | 12·96 | .. | .. | 28·0 | 10·20 | 2·7 | .. | 10·0 G. | 73·5 |
| 105 | From one firm. | Superfines ... ... ... | 12·70 | .. | .. | 30·0 | 11·10 | 2·7 | .. | 14·0 G. | 74·0 |
| 106 | | Plain Tie ... ... ... | 13·47 | .. | .. | 29·0 | 10·35 | 2·8 | .. | 6·5 G. | 70·0 |
| 107 | Superlative, Minnesota ... ... ... | | 13·55 | .. | .. | 33·0 | 11·50 | 2·8 | .. | 6·0 G.Y. | 70·5 |
| 108 | From one firm. | Seconds ... ... ... | 12·62 | .. | .. | 25·0 | 9·50 | 2·6 | .. | 14·0 G. | 69·0 |
| 109 | | Pink Tie ... ... ... | 12·92 | .. | .. | 27·0 | 9·95 | 2·7 | .. | 14·0 G. | 71·0 |
| 110 | | Plain Tie ... ... ... | 13·41 | .. | .. | 31·0 | 11·36 | 2·7 | .. | 18·0 G. | 70·0 |
| 111 | Standard ... ... ... ... ... ... | | 13·40 | .. | .. | 24·0 | 8·60 | 2·8 | .. | 4·0 G. | 70·0 |
| 112 | From one firm. | Whites .. ... ... ... | 12·36 | .. | .. | 31·0 | 11·30 | 2·8 | .. | 14·0 G. | 72·5 |
| 113 | | Seconds ... ... ... | 12·57 | .. | .. | 31·0 | 10·80 | 2·9 | .. | 17·0 G. | 71·5 |
| 114 | | Seconds ... ... ... | 13·45 | .. | .. | 32·0 | 10·60 | 3·0 | .. | 15·0 G. | 68·0 |
| 115 | | Seconds ... ... ... | 13·07 | .. | .. | 29·0 | 10·0 | 2·9 | .. | 13·5 G. | 68·0 |
| 116 | | Seconds ... ... ... | 13·20 | .. | .. | 30·0 | 10·5 | 2·9 | .. | .. | 68·0 |
| 117 | From one firm. | Seconds ... ... .. | 13·42 | .. | .. | 30·0 | 10·9 | 2·8 | .. | 18·0 G. | 75·5 |
| 118 | | Pink Tie ... .. ... | 13·15 | .. | .. | 29·0 | 10·5 | 2·8 | .. | 15·0 Y. | 77·5 |
| 119 | | Seconds ... ... ... | 13·52 | .. | .. | 31·0 | 11·0 | 2·8 | .. | 15·0 G. | 72·0 |

These flour supplies of large towns 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 the above list.


ORELL FÜSSLI & Co.

## CHAPTER XVII.

### BREADMAKING.

**374.** 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.

**375. 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 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 albuminoids of flour. 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. 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.

**376. Water.**—A great deal of speculation exists as to the action on bread of water from different localities. 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.

It has been asserted that processes which in some districts produce bread of a certain character fail to produce the same results in other localities. Bakers are themselves likely to know better than the writer whether such is the fact. The flour and yeast being the same, the difference has been ascribed to the water. One notable case in point occurred some little time ago, when a London baker is said to have worked with Hungarian flour and Vienna assistants, and yet to have found himself unable to produce the article known as Vienna bread. The fault being ascribed to the water, a Vienna baker, J. F. Behret, asserts that it is really due to other causes, and that neither the flour nor the water are the culprits. 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 albuminoids than would a soft water, and consequently the action on the starch would most likely be less; there would therefore be less discolouration of the bread. Not only would the quantity of albuminoids dissolved be smaller, but with the same quantity in solution their action would be checked by the presence of the soluble lime salts. As a consequence, 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.

The assertion is also frequently made by many English bakers that they cannot work successfully with flour barms similar to those used in Scotland. The fault here is also commonly ascribed to the water. It is far more likely that a want of acquaintance with the practical details of the process is the real cause of the failure. Flour barms are successfully employed in France, Scotland, and Ireland: it is therefore improbable that any reason exists why they should not succeed in England, which lies in the centre of these other three countries. Messrs. Stevenson, of Glasgow, now have a bakery on the Scotch system at work in London.

Within the range of ordinary drinking waters the foreign substances present may slightly affect the amount of extract obtained from malt in mashing, or may slightly retard fermentation; but beyond this they can neither prevent the effectual mashing of malt, nor the subsequent alcoholic fermentation of the wort, or of a flour barm.

**377. Objects of Breadmaking.**—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 breadmaking processes, in that it not only produces gas, but also effects other important changes in certain of the constituents of flour.

**378. Description of various processes of Breadmaking.**—The methods employed in the manufacture of bread differ in various parts of the country: it will be well to first give accounts of the actual processes employed in different localities, and then to describe the nature of the chemical changes occuring, and the principles involved.

**379. The Ferment.**—Among many bakers the first step in breadmaking is to make a "ferment;" this consists of potatoes, boiled and mashed with water into a moderately thin liquor. To this the yeast is added, and the fermentation allowed to proceed for some time before the next step is taken.

**380. The Sponge.**—A portion only of the whole of the flour that it is intended to convert into bread is taken and made into a slack dough with the ferment: this constitutes the "sponge."

**381. The Dough.**—The remainder of the flour, together with more water, is added to the sponge: this constitutes the "dough."

Occasionally the whole of the water is used for the ferment; a portion of the flour is added at the sponge stage, and after some time the remainder at the dough stage.

### London Practice.

**382.** Descriptions follow of the methods in common use in London for making bread, and which represent what is commonly styled "London Practice." The first account is by Bennett, and was given in a Report to the Secretary of State in 1862, and is quoted by Richardson in his recent work "On the Healthy Manufacture of Bread." The whole of the following quantities are calculated to a sack of flour.

**383. 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.

**384. Bischof's Methods with Compressed Yeast.**—Bischof, 30, Brooke Street, Holborn, E.C., has recently arranged some excellent recipes for making bread, with compressed yeast, according to London practice. ("Encore Yeast Almanack, 1886"). A condensed outline of these follows.

**385. 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.

**386. 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 one 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.

### BIRMINGHAM PRACTICE—

**387.** 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.

### MANCHESTER PRACTICE—

**388.** 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 tight. 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.

### SCOTCH PRACTICE—

**389.** 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.

**390.** "**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.

**391. "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."

**392. 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. Germany, Denmark, and Belgium send us flour largely, but of late I find the flours of the two former countries of little use for biscuits and loaf bread, owing to the large admixture of Indian wheats.

"The doughs, of whatever flours composed, will be made by 4.30 or 4.40 A.M., and are allowed to lie for ¾ hour, then turned, dry dusted, and kneaded from one end of the trough to the other and back again; and in another ¾ 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, 1½ 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, 1½ 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 will 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."

REVIEW OF PANARY FERMENTATION—

**393.** 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.

**394. 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 |
| Albuminoids ... ... ... ... | 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 albuminoids, dextrin, and 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 albuminoids 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 albuminoids 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; one patented and sold by Hancock, of Birmingham, 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.

**395. 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 albuminoids. The yeast consists essentially of *saccharomyces*; but bacterial life is also present in greater or less quantity. 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, little or 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 albuminoids 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. 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 breadmaking 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 albuminoids, and a limited diastasis of the starch by the albuminoids 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 breadmaking. 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 breadmaking 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 the evolution of gas; experiments having shown that a malt wort which, on careful microscopic observation, showed no signs of the presence of yeast cells, but was swarming with *bacteria*, yet gave off a considerable quantity of gas on being placed in the yeast apparatus. (See paragraph 289, chapter XI.) It must be remembered that the *soupçon* of slight buttermilk flavour is a valued characteristic of Scotch bread. In breadmaking, 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 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 of 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.

**396. 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 to a great extent lost in obscurity; but they have, nevertheless, a most important scientific justification. The reader will by this time be familiar with the division of flours into strong and weak varieties. The strength 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 strength 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 weakening goes on during panification. Still, defining "Strength" as the measure of actual water-absorbing power, **the relative capacity of resistance of flours, to a falling off in strength during fer-**

mentation, 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. It seems probable that by measuring the stability of flours, by means of the viscometer, it would be possible to arrange them in the order of the time they would require to be in fermentation, and thus to afford the baker a guide in selecting his flours, and determining the relative durations of his sponge and dough stages. It is possible that the same instrument might be so adapted as to enable the stiffness of a dough to be measured by means of it from time to time during fermentation. This, coupled with a table based on experimental comparisons of determinations with the instrument, and actual baking tests, may at some time in the future enable the baker, who so wishes, to estimate with rapidity and accuracy the point at which fermentation will have attained maturity. The author hopes at some time in the future to publish the results of experiments made in this direction.

**397. 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 albuminoids 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 breadmaking 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 when working with these yeasts, although those bakers who have been in the habit of using potatoes will probably, by preference, for some time at least, continue the practice. But with the absence of such pressing necessity, and with the knowledge that in some towns, specially noted for the high class of their bread, the habit of using potato ferments is rapidly becoming extinct, bakers are likely, in the future, to give up the use of such ferments.

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 half-a-pound of yeast may be sufficient to ferment a sack of flour, yet three-quarters 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; while any saving in yeast is more than compensated by a less yield of bread.

**398. Management of Sponging and Doughing.**—In order to ensure 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 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 liquid. 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 acts more severely on the yeast than on the disease ferments which may be present; consequently during the time taken by the yeast to recover itself, its very inactivity becomes the foreign ferment's opportunity, and a chilled dough too often results in a sour loaf.

**399. 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 271) 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 with advantage be deferred to the dough stage.

In the Scotch methods of breadmaking, 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.

**400. 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 the 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 occured. 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 270, 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.

**401. 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. At this temperature the starch cells will have burst; the coagulable albuminoids will have been coagulated, and their diastasic power entirely destroyed. The composition of bread, compared with that of flour, is dealt with subsequently.

**402. 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. loaves an hour 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 forty minutes in any well constructed oven.

**403. Glazing.**—On the admission of steam to an oven the dextrinising of the starch of the crust goes on even more rapidly than ordinarily; the effect is to produce a glazed surface on the outside of the crust: this operation is familiar to bakers as that by which French or Vienna rolls are glazed. The steam, on being admitted to the oven, soon gains the same temperature as the interior of the oven itself, that is, 450-500° F. The bread is thus enveloped in an atmosphere of dry or superheated steam: this retards the rapid evaporation from the exterior of the crust, which is thus kept moister; with, as before explained, the more rapid conversion of the starch into dextrin. The steam is usually generated in a boiler placed as near as convenient to the oven: its pressure is immaterial, but may conveniently be about 25 to 30 lbs. per square inch.

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.

As is well known, the ordinary baker's oven is heated to the baking temperature *before* the bread is introduced: the baking is then conducted at the expense of the heat of the brickwork of the oven. After baking one or more batches the oven will have become so cool as to require re-firing before it can properly bake any more bread. In an oven of this type the bread is therefore baked in what is practically an air-tight hot box: the evaporation from the dough speedily charges its atmosphere with steam, and this acts in the same manner, though to a less degree, as steam when injected into the oven. This proper confining the steam within an oven is a point of great importance; for with an "oven which loses her steam" the bread bakes slowly and is dry and chippy. In consequence, it is absolutely necessary that oven doors and other fittings should fit with extreme accuracy. Messrs. Graham & Sons, the well-known manufacturers of oven fittings, justly make it their boast that if a strip of tissue paper be shut any where between the door and its frame it is impossible to withdraw it whole. This end is secured by cutting a groove in the frame, into which fits a bead on the door; this and careful grinding both of the face of the door and its frame ensures a very perfect fit.

**404. "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, except possibly as an auxiliary, 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. The author's advice is, however the oven be heated, let it during the actual time of baking be kept as air-tight as possible, letting the bread be baked by *radiant* heat, and not the mere contact of heated gases.

**405. 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.

**406. Souring of Bread.**—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. An investigation of the previous history of the bread will show that the one has been fermented with a sound, the other with an unhealthy yeast. 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. In illustration there may be cited a most striking instance of this souring of a loaf of bread, which a short time ago came under the notice of the author. While in a friend's room on one of the upper floors of some London offices, a batch of four loaves of bread, just hot from the oven, was brought in. The loaves were in every way triumphs of the baker's art—they smelt perfectly sweet, and evinced not the slightest vestige of any sour odour. One loaf was broken from the batch and taken, while still warm, to a crowded room, containing perhaps from 300 to 400 people; the room was also not ventilated in the most efficient manner. After remaining in this room about two and a half hours the loaf was broken, and emitted a decidedly sour odour. The three loaves which had been kept in the cool office in pure air were found next morning to be perfectly fresh and sweet. The only difference between these loaves was that one had cooled slowly in the warm atmosphere, the other rapidly in a pure atmosphere. Even in the space of two hours an acid fermentation had been set up.

The foregoing paragraphs will have shown what are at least some of the causes for bread becoming sour; a summing up of these, together with suggestions as to remedies, will appropriately follow the next paragraph.

**407. Sanitary Aspects of Bakehouses.**—This is a most important problem, not only to the baker, but also to the general public. The following paragraphs contain suggestions as to what should be aimed at, and what avoided, in bakehouse-building management. Many will probably feel that the adoption of such suggestions as are given would be to them impracticable. That they are not utopian is shown by their being in every case based on practical experience of the nature and arrangements of the best managed bakehouses in the kingdom. It must be remembered that the general public is now demanding, none too soon, that the whole operation of breadmaking shall be conducted with the most scrupulous cleanliness. The bakers who will in the future command success are those who move in advance of this perfectly reasonable demand.

The right and proper position for a bakehouse is on the ground floor: it is to be deplored that much of our bread is baked in cellars. Circumstances may render it impossible for individual bakers to manage otherwise than to have the bakery perhaps underneath the shop; but wherever this arrangement has to be adopted it must be viewed as an unfortunate necessity, not as a thing to be commended or justified. In large towns the plea is that space is so valuable that it is impossible to devote the ground floor to the purposes of a bakehouse. In such cases, undoubtedly, the correct principle of supplying bread is that the bakehouse should be in the suburbs, and depôts, for sale only, in the more crowded thoroughfares. Evidence is not wanting that, as an unavoidable effect of economic laws, the business of breadmaking is already tending in this direction. The smaller baker can best justify the continuance of the present system by absolute cleanliness and healthiness of the arrangements and management of his premises. Let him remember that a vigilant and competent man can superintend a small business, giving personal supervision to every detail; a thing which is much more difficult, if not impossible, with operations conducted on a larger scale.

The bakehouse should be well lighted, for there is no greater enemy to dirt than light. As sudden draughts are so prejudicial to fermentation, there should be sufficient space to permit of efficient ventilation without strong currents of cold air. The bakehouse itself may be covered with glazed tiles, which should be carefully washed from time to time; or, in place of tiles, the recommendation of a practical baker may be followed, and the bakery lime-washed. Notice that lime-wash is to be used; not a mixture of size and whiting. Size, being a nitrogenous body of animal origin, is peculiarly liable to decay, and may thus become the harbour of ferments, which are pretty sure to contain among their number some whose action will be injurious. Whiting is a carbonate of lime, and is practically without action on ferments. Lime-wash that has been made from recently slacked quicklime, contains lime in the caustic state, and so is fatal to any ferments with which it comes in contact. A bakery should frequently be thoroughly cleaned down and white-washed. The lime brush must find its way into every nook and cranny.

A sufficient supply of hot and cold water must be provided; the former usually being obtained from a boiler heated by the waste gases from the oven.

No drains directly connected with the sewer must be permitted in the bakehouse. Wherever there is a sink fixed, the waste pipe must be carried from it through the wall, and allowed to discharge over an efficiently trapped drain, with which it is not in contact. The floor should be either well bricked or made of concrete, in such a manner as to prevent any spilled water lying in pools or soaking into the earth beneath. If the ovens are fired from within the bakehouse, sufficient provision must be made to prevent either coal-dust or ashes finding their way over it. Any pouring of waste water, either on the coal or into the ash-pit, should be sternly prohibited.

If, perforce, the bakehouse is in the basement, then special provision must be made for sufficient ventilation: the nature of such provision must depend on circumstances. If possible, the bakehouse should open on to a fair-sized area at either back or front; this enables a current of fresh air to be admitted, while openings guarded by gratings should be made near the top of the walls to facilitate the escape of the vitiated air. The remarks about drains apply with even more force to underground bakeries: situated as they are, they are even more liable to incursions of foul gas from sewers, if any drains open direct into them. The rule without exception should be, carry all waste pipes out of doors, and let them discharge over a well-trapped drain.

Whether the bakehouse be above or underground, no accumulation of ashes, scraps of dough, or rubbish of any description, must be tolerated for a moment.

Workmen's offices and conveniences should be provided absolutely apart from the bakehouse. Closets must on no account open into the bakehouse: the objection does not apply so powerfully to washing appliances, but even those are far better in a separate room. Except in those situations so absolutely unfitted for a bakehouse, that every square inch of space has to be utilised for the bakehouse itself, the provision of such accommodation can easily and cheaply be made.

Ferment tubs and similar vessels should be washed with hot water every time after use; they are all the better for being occasionally steamed out with a jet of naked steam from the boiler. This may be led down by a piece of flexible hose to the bottom of the tub, which must be covered over so as to keep the steam in during the operation. Troughs and boards should be scraped clean each day; no vestiges of dough must be permitted to remain either in the corners of the troughs or cracks of the boards. Once a week they should be washed and scrubbed and then wiped as dry as possible: they must then be left open in the warm bakehouse so as to drive off the last vestiges of moisture. Damp troughs and boards have a great tendency to become sour.

**408. Remedies for Sour Bread.**—As one possible cause for sour bread is a want of absolute cleanliness, it should be seen that the above precautions, or their equivalent, 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, 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 to get sponging and doughing over quickly, and work at a low temperature. 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. Summing up, sour bread is caused by the presence of the germs of the specific ferments which produce acidity; without these, bread cannot turn sour; secondly, these germs of foreign ferments may be introduced along with the yeast, or may be present in fragments of old dough in the troughs and other utensils, or may be floating about in the atmosphere of the bakehouse through want of cleanliness and inefficient ventilation. The production of acidity is favoured by the use of weak, unhealthy yeast, unstable flours used with excess of water, fermentation being conducted at too high a temperature, insufficient baking, and cooling in a warm, impure atmosphere.

**409. Working with Unsound or very Low Grade Flours.**—In the older literature of breadmaking 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 albuminoids 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 albuminoids, 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 albuminoids 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 breadmaking 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.

**410. 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 breadmaking in the ordinary manner impossible with it, can be converted into eatable loaves; but if necessity arises for recourse to such flours for breadmaking, 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 prejudice 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—

$$\underset{\text{Lime.}}{CaH_2O_2} + \underset{\text{Carbon Dioxide.}}{CO_2} = \underset{\text{Calcium Carbonate.}}{CaCO_3} + \underset{\text{Water.}}{H_2O}$$

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.

**411. Special Methods of Breadmaking.**—There are certain special processes employed for bread-making which must next be described.

**412. "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.

**413. 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 $\frac{1}{3}$ 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, $\frac{1}{2}$ 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. This mode of breadmaking seems now to have largely given place to methods more nearly allied to Viennese and English processes.

**414. Other Theories of Panary Fermentation—Mège-Mouries.**—Among descriptions of the phenomena of panification, that by Mège-Mouries, written in 1860, and translated for "The Miller" in 1881, is of interest, as an account of the views held before the development of the Science of Fermentation as at present understood. During the process of leavening, Mège-Mouries recognised that alcoholic and acid fermentation proceeded simultaneously. Quoting his own words, "the acid fermentation produces the acid requisite for dissolving a portion of the gluten, and rendering it suitable for forming an alcoholic ferment under the action of the alcoholic ferment already formed." He further goes on to state that the gluten develops the alcoholic ferment, and the casein, the lactic ferment; also that cerealin, if introduced, rapidly produces a large quantity of lactic acid. This "acid dissolves the gluten, which thus becomes a lactic ferment." A more exact knowledge of the phenomena of fermentation, for which we are indebted to Mège-Mouries' illustrious countryman, Pasteur, shows the untenability of these opinions; as it is now known that fermentation is the work of distinct organisms, and not a peculiar property of albuminous compounds in certain phases of decomposition. Mège-Mouries asserts that the diastasic action of the embryous, or cerealin membrane, resists a temperature of 212° F.; in making this statement he is, however, at variance with other observers, whose experiments have been made with every precaution for exactitude. The reader is referred to chapters VII. and VIII. for a detailed account of diastasic action generally. Mège-Mouries' researches marked a distinct step of advance in the scientific knowledge of flour and breadmaking; but a quarter of a century has elapsed since they were first published, and during that time more recent discoveries have so modified scientific views of fermentation that Mège Mouries' explanations could not now be accepted. His statements of fact are nevertheless of great value, and it is specially interesting to notice his insistance on the diastasis produced during panification by the cerealin of the inner membrane of the bran. The thorough removal of this integument by modern milling processes, coupled with the universal employment of yeast in this country instead of leaven, causes his remarks on this subject to no longer have the practical bearing they possessed when first written. The student of the history of the science of wheat and wheat-bread will find Mège-Mouries' papers well worth reading.

**415. Recent Researches by Chicandard.**—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."

The author has shown that the saccharine matters of flour are in themselves sufficient to account for all gas evolved during fermentation, and that active fermentation ceases with the total disappearance of the sugar: there is no need therefore for the hydrolysis of the starch, as a preliminary to alcoholic fermentation. 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. Chicandard looks upon bread fermentation as being due to bacterial fermentation of the gluten present: such fermentation is a concomitant of putrefaction, and does cause the slow evolution of gas. To a certain extent in leavened dough the gas may be thus produced, but no such explanation is possible of the fermentation of a mixture of flour and water only, with pure yeast. Previously quoted experiments have demonstrated that the functioning of living yeast is positively inimical to bacterial development, although the albuminous contents of ruptured yeast cells afford a suitable *nidus* for bacterial growth. 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. These results are absolutely contradicted by the author's experiments on fermentation of aqueous extract of flour; these show conclusively that all the sugar disappears, and, what is of equal importance, that the yeast does not evolve gas from the albuminoids. That Chicandard found precisely the same amount of dextrose at the end of seven days as he found at the commencement is remarkable, considering that during the whole of that time more or less starch is being converted by diastasis into dextrin and saccharine compounds. Chicandard points out that during panification the yeast cells gradually disappear; the best explanation known to the author, of this phenomenon is that advanced by Thoms, who avers that, as yeast cells function in dough, they disappear through the breaking down of the cell-walls. This view has been adopted in the present work. With the same observer's opinion that yeast, in dough, functions on the albuminous rather than the saccharine matters, the author cannot agree, for the reasons given in the conclusions he has drawn from his own experiments.

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.

**416. 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.

**417. 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. Those which effervesce on the addition of water consist of an acid and a carbonate, usually the bicarbonate or acid carbonate of soda; the acid employed is generally tartaric acid. 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 tartrate is sometimes termed "Rochelle Salts."

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 latter body is thus formed :—

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

One of the carbonates of ammonium is also sometimes used as a source of carbon dioxide gas; a solution of the bicarbonate, on being heated, is decomposed according to the following equation :—

$$\underset{\text{Ammonium Bicarbonate.}}{2(NH_4)HCO_3} = \underset{\text{Ammonium Carbonate.}}{(NH_4)_2CO_3} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon Dioxide.}}{CO_2}$$

The commercial ammonium carbonate is a sesquicarbonate; it, however, continuously evolves ammonia, being slowly changed into the bicarbonate.

In the manufacture of baking powders, the tartaric acid or cream of tartar, 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. 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.

From time to time various substitutes for tartaric acid in baking powders have been proposed: among these is the bisulphate of potash, $KHSO_4$; a baking powder, containing this as its active acid ingredient, was some short time ago patented and extensively advertised under a special name, very similar to "tartaric acid." Sulphate of potash, which is produced when this substance is neutralised by sodium bicarbonate, is a powerful purgative, and so is absolutely unfitted for introduction into bread. Alum is at times also used as an adulterant of baking powder.

As substitutes for tartaric acid or cream of tartar in baking powders, phosphoric acid, and the acid or biphosphates of lime, potash and ammonia are now employed: these substances are cheaper than the 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.

**418. Self-Raising Flour.**—The articles sold under this name consist of flour, mixed with acid 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.

**419. 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.

**420. 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 albuminoids, 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.

**421. 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 breadmaking 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 their being no such peptonisation of the albuminoids 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 breadmaking 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 albuminoids 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.

**422. 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.

**423. 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 albuminoids, 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. Other experiments show that the constituents of bran are digested by man only to a very slight degree. 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 albuminoids 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.

**424. 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 breadmaking qualities. The albuminoids 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.

**425. 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.

The more advanced bakers demand that the miller shall grind his wheats separately, and so enable the baker to mix and blend the flours in the manner which suits him best. It is on the face of it evident that if a miller mixes hard Indian and soft English wheats together, and then mills them, that if each maintains its distinctive character in the flour, the gluten of the one must have arrived, during panification, at its mature stage long before that of the other. The demand has in consequence arisen, that millers shall send into the market straight run flours from single wheats. That these are not simply theoretical views is shown by the practical fact that this demand for single wheat flours is a very real one. American millers are credited with sending to this country flours which are made from strictly one wheat only. In consequence, those millers who are so situated as to feel this competition most severely, are now milling and supplying separately straight run flours from Spring American and Winter American wheats. Having his single wheat flour, instead of one from what the advanced baker views as an incongruous mixture, he uses it at whatever stage of his fermentation process that he deems fit. The baker, in being thus able to exercise his own judgment, is not handicapped in his efforts to produce the best possible loaf of bread from the flour. **With competent bakers, there can be no reasonable doubt that, given flours from various wheats, better bread may be obtained when the baker judiciously adds the separate flours from the single wheats at the proper stage of fermentation, than if he were simply supplied with one straight-run flour from the whole of the wheats mixed before grinding.** The first great difficulty here is the competent baker: to do his own mixing the average baker requires to master principles that at present are almost, if not entirely, unknown to him. The author sometime ago urged upon some millers, during the course of conversation, that they, instead of making an all-round flour by adding some of one wheat for strength, some of another for colour, of another for flavour, and so on, should at anyrate divide their wheats so as to produce a strong and a weak flour, separate from each other. One miller present made the very cogent reply that he had at one time attempted this, and had introduced to his customers two varieties of flour, the one of which was made from hard strong wheats, the other from soft weak ones; he also made suggestions as to how they should be used. On after inquiry he found that, to start with, his flours had generally been mixed indifferently with those of other millers, and consequently any distinctive properties they may have possessed were altogether lost. Another objection made by a baker was that he didn't want all this trouble of mixing one lot of flour now, and adding another after: what he required was one good flour, of which he could use one part for his sponges and another for his doughs. Coupled with this request was the significant hint, that to retain his custom these conditions must be complied with. Now, evidently, it would have been worse than useless for this miller to have attempted to supply single wheat flours. There are arguments of the strongest description in favour of the baker using a single wheat flour, or at anyrate a flour made from closely allied wheats; but before the miller can advance to meet this requirement it is absolutely essential that a sensible proportion of bakers, as a class, shall have realised the advantage of working with such flours, and shall have made themselves acquainted with the methods of their manipulation. Much good has already been effected by the organs of the baking trade in calling attention to the advantages of single wheat flours: further benefits will be conferred on bakers by these journals in continually supplying practical information as to how single wheat flours are best treated, and how superior the results that are thus obtained. The author prophesies that when bakers, as a whole, are prepared for such a very great change in the system of milling in vogue in this country, they will find the millers not their natural enemies, but quite prepared to meet their wishes in this respect. At present, millers have to deal with the simple fact, that by mixing their wheats they can produce a flour from which their baker customers can make a fairly good loaf of bread; whereas, were they to supply separate flours from the same wheats milled singly, the majority of bakers would totally fail to make an equally good loaf, and the miller who was rash enough to make the experiment would find the greater part of his trade depart from him.

In connection with this general question of single wheats *versus* mixtures, there are several points of interest which in passing may be mentioned. In the first place, is a straight-run flour from a single wheat absolutely uniform within itself? Turning back to chapter XVI., paragraph 366, an account is there given of the different flours produced during gradual reduction. Taking first the Liverpool milled flour from a mixture, the flours produced by the earlier breaks, and also the first reduction of middlings, were very weak, registering only 60 and 61 quarts by the viscometer. On the other hand, the flour from the fifth break had a strength of 77, and that from the seventh reduction of middlings of 75 quarts. Here then is a difference of about 15 quarts between the highest and the lowest strength flours produced by gradual reduction. The whole of these flours when mixed yielded a straight grade flour having a strength of 67 quarts. Similarly with Spring American wheat, there is a difference in strength between the weakest flour (with 71), and the strongest flour (with 98), of gradual reduction, of 27 quarts; the straight grade flour produced at the same time was not examined, but in all probability had a strength of about 78 quarts. When milling Winter American wheats, the weakest flour had a strength of 64, and the strongest, 91 quarts, giving again a difference of 27 quarts. There is in each case a difference between the strongest and the weakest flours from the same wheat, greater than is observed between any ordinary flours sold in British markets. The reason why this difference exists must be sought for in the fact that the flours come from different parts of the wheat grain—consequently we are driven to the conclusion that even from one variety of wheat the flours from various parts of the grain are not uniform in character. Every single wheat flour is therefore of itself a mixture of a number of flours of different strengths. Of course different flours may have different strengths, and yet their doughs may all fall off in stiffness at about the same rate when allowed to stand; or in other words, their glutens may soften at about the same rate. In order to gain information on this point, some stability tests were made on the various flours from Spring and Winter American wheats already referred to. In order to determine the stability, the doughs, after mixing, were allowed to stand for six hours in a water-bath, at a temperature of 25° C. (77° F.); at the end of this time they were tested with the viscometer. The stability figures represent the number of quarts per sack the respective flours took in order, after thus standing, to make a dough of the standard consistency. The following are the results:—

| | Strength. | Stability. | Falling off. |
|---|---|---|---|
| Spring American Flours— | | | |
| Weakest Break Flour ... ... | 71·0 | 66·5 | 4·5 |
| Strongest " " ... ... | 72·0 | 67·5 | 4·5 |
| Flour from last reduction of Middlings | 98·0 | 84·5 | 13·5 |
| Winter American Flours— | | | |
| Weakest Break Flour ... ... | 64·0 | 57·0 | 7·0 |
| Strongest " " ... ... | 67·5 | 61·0 | 6·5 |
| Flour from last reduction of Middlings | 91·0 | 75·0 | 16·0 |

Looking first at the Spring American flours, the two break flours both fall off at the same rate, but the third flour falls off at exactly three times the speed. The Winter American flours behave in just the same manner, the break flours being very nearly alike, while the middlings flour falls off between twice and three times as rapidly as do the others. If therefore a straight-run flour from Spring American wheats be taken, it is shown to contain within itself flours whose permanence in the dough stage differs most widely: the same, too, holds with the different constituents of Winter American straight-grade flour. Consequently, even with straight-run flours, it cannot be said that they are throughout absolutely uniform in their capacity for resistance to the softening actions which proceed during panary fermentation. Nevertheless, it equally follows that the whole of the flour more closely approaches the average, in a single wheat flour, than in a flour from a mixture of widely differing wheats. To explain by reference to the flours above quoted, the difference between the highest and lowest amount of falling off in the various Spring American flours is 9; the same figure also represents the difference in the case of the Winter American flours. But if a mixture of Spring and Winter American wheats were milled, the difference between the two extremes would be 11·5 as against 9 in either wheat milled separately. Assuming that absolute uniformity is essentially desirable in any one flour, the separate milling of single wheats, while not entirely attaining this end, yet approaches more nearly to it than the milling of mixtures is likely to do.

In connexion with the same subject, another argument requires consideration: the action and reaction of different wheats on each other while lying together in a mixture is often cited as affording evidence having an important bearing on the question of blending wheats. Millers frequently state that, if in a mixture, hard-dry Indian and soft and comparatively moist English wheats are allowed to lie together for some time, they will be found to much more closely approach each other in character. The one will have become softer and moister, while the other will have become harder and drier. From this it is inferred that if the mixture be milled, the particles of flour from each particular wheat gradually assimilate in character. But if it can be shown that the particles of one and the same wheat, which have been enclosed within the same outer coating of bran since the grain had an individual existence, do not sufficiently influence each other to render all the particles alike in strength and stability, then it is difficult to believe that, in grains lying simply side by side, any influence of the one can extend to the other sufficiently to effect such an assimilation of the two in character, as cannot be produced by the various particles of one and the same grain on each other. Considerable interest would attach to making such a mixture, allowing it to lie, and then separating the two wheats and milling them separately. Such an experiment might be made with comparative ease by taking a small grained hard wheat, and a large grained soft wheat: they might then, after lying the requisite time, be easily separated by a grading or sizing machine. If any miller reading this should care to make this part of the experiment, the author will be very pleased to make a series of tests on the flours. The probable results would be that while each wheat might be somewhat modified, yet it would still retain most of its original character.

Another question arises—Although the different portions of the endosperm, when *in situ* in the wheat grain, retain distinctive characters, may they not rapidly lose these when converted into flour; and further, would not the flours from different wheats also quickly assimilate in character when subjected to intimate admixture? That this idea is uppermost in the minds of certain writers on milling questions is shown by the fact that the old position is now somewhat dropped, and that it is admitted that wheats should be allowed to assimilate before being milled. But while any perfect assimilation of wheats is exceedingly unlikely, the balance of evidence is also against an admixture of flours acquiring uniformity. After mixing, it is, of course, impossible to again separate the flours, and test them individually; but evidence of another kind is obtainable. Strong and weak flours have been mixed, and then allowed to stand some time. Such mixtures do not in the baker's hands yield such good bread as do the separate flours when respectively used in the sponge and dough stage. So far as indirect evidence of this kind goes, it is against the theory that flours assimilate when allowed to stand together in a mixture. We are consequently led to the conclusion that when incongruous wheats are milled together, the particles of each retain their respective charcteristics in the flour produced, and that when such a flour is fermented one portion arrives at the stage of dough maturity considerably earlier than the other.

It may be asked, what under such circumstances is the attitude that bakers and millers should adopt on this subject? So far as the author may advise from his standpoint, it is that the bakers should seize every opportunity of practically studying the behaviour of single wheat flours in the bakehouse; as they thus get acquainted with their various demeanours, they will be in a position to judge as to how far they may advantageously substitute them for flours from mixed wheats. Millers will feel the difficulty of absolutely committing themselves to single wheat flours to be a very real one. With the different wheats that find their way into the corn markets at various seasons of the year, single wheat milling would be rendered an expensive operation. In this matter, like many others, the question of price is an important factor; it is very doubtful whether bakers generally would be willing to give the price for flour that flours from high-class single wheats can command. There is, however, one real step in advance that millers might make, and that is to mill separately a strong wheat blend and weak wheat blend. The incongruity of mixtures of Indian and soft English would then be avoided. For the hard wheat mixtures, the various hard wheats that come into the market from time to time would be selected, and from these a fairly uniform flour for sponging purposes might be made. In the same way from the weak wheats a doughing flour might be milled. This would be a very near approach to the principle which suggests the use of single wheat flours, and would still enable the miller to have a number of wheats from which to make his selection. But even this step in advance will require for its success the intelligent co-operation of the bakers.

Although not within the scope of this work, it must not be forgotten that the question is not purely a scientific one; it has also an important economic side, not only from the narrow view of the purchases of individual millers, but also on the broader ground of political economy. Further, it should be remembered that those whose capital is involved in the purchase of wheat will of necessity have the principal voice in deciding whether wheats shall be milled separately or conjointly. It is very likely that in the future the problem will be partly solved by both milling and baking being performed by the same person to a far greater extent than is now the rule.

# CHAPTER XVIII.

## MODERN BAKING MACHINERY AND APPLIANCES.

**426. 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 insistance 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.

**427. Financial Considerations.**—Thanks to the efforts of baking engineers, the prime cost of kneading machinery has recently been considerably reduced; so that such appliances can be erected in even bakehouses with a comparatively small trade, at no very great capital outlay. Against such expenditure must be placed as a set-off, that with the lessening of the amount of manual labour required, the bakery staff may be proportionately reduced, or what is the more probable alternative, a larger trade will be done with the same staff. As the attention of the public becomes more and more directed to the hygienic aspect of breadmaking, the demand for machine as against hand-made bread is sure to increase: this is a consideration not to be lost sight of in comparing the relative advantages of a machine and a hand-made bread trade.

**428. Working Considerations.**—To those who have been accustomed to work in a particular manner, the revolution in methods introduced with machinery, may from simple want of familiarity make the more novel processes appear strange and inconvenient. Much of this feeling arises from the natural difficulty in overcoming habits of long duration. There is often, however, a more serious cause than this at work: history repeats itself, and just as hand workers in the past, in their ignorance, opposed the introduction of weaving machinery, so now, undoubtedly, there is intense prejudice against baking machinery in the minds of journeymen bakers. This is unfortunate, for even to the journeyman, the substitution of machinery for hand-labour is an advantage, because it makes his work more healthy and less laborious. The journeyman's dread is that with a diminution in the amount of manual labour required, fewer hands will be employed. But like other such changes, this one is not likely to take place with sufficient rapidity to sensibly affect the baking labour market: against any such slow diminution in the number of bakers employed, the fact must be remembered that, with the introduction of machinery, the journeyman bakers' occupation becomes a more skilled trade. As a consequence his status will improve, and his earnings increase: even now a baking foreman, who is competent to take charge of machinery, commands higher wages than one without such knowledge. Still the fact has to be recognised that journeymen generally are averse to the use of machines, and that in many cases they wilfully allow dough to spoil that has been machine-made in order to show the inferiority of machine to hand work. The remedy here is plain: any respectable baking engineer after having erected a machine plant will be only too glad to prove its thorough efficiency to the master and workmen, by practically showing them how to make good bread with it. The proprietor having satisfied himself that the machinery is capable of doing its work in accordance with the representations of the vendor, should insist on good work being done with it. Workmen should be given plainly to understand that, if they are incompetent to successfully use the machines entrusted to their care, their places will be filled with others who possess the requisite ability. It is well known that in Scotland, kneading machines have been extensively used for some years: they are there found to answer well and to turn out some of the best made bread in the world.

**429. Classification of Machinery.**—The operations of kneading and working dough afford the strongest argument in favour of the introduction of machinery into the bakery; but with its advent there are other purposes to which it can be applied. The principal machines employed in a bakehouse are flour sifting machines, sponge stirrers, and dough kneading machines. In addition to these, machinery is at times used in the manipulation of ferments. Although the oven is not a machine in the ordinary sense of the word, the modern improvements and inventions in these appliances also merit description. Our present work is confined to flour manufacture and breadmaking, but the baker who unites confectionery with breadmaking will find, with the introduction of a main shaft into his bakehouse, that a number of other minor, but most useful machines, can also be driven from it. These include currant washers and driers, egg-whisks, and many others.

The description of biscuit-making machinery lies outside the scope of our present work; otherwise the accounts which follow would naturally include detailed references to the well-known and efficient plants supplied by T. & T. Vicars, of Seel Street, Liverpool.

**430. Ferment Treating Machinery.**—The annexed figure, No. 55, represents a combination of machines used for the purpose of treating quickly and efficiently large quantities of potato ferment. It has been already explained that these ferments require to be cooled as rapidly as possible to the fermenting temperature. The first plant of this description for bakers' use was made to the order of Mr. Feaist, of Hastings. It combines a sifting machine, pump, and refrigerator.

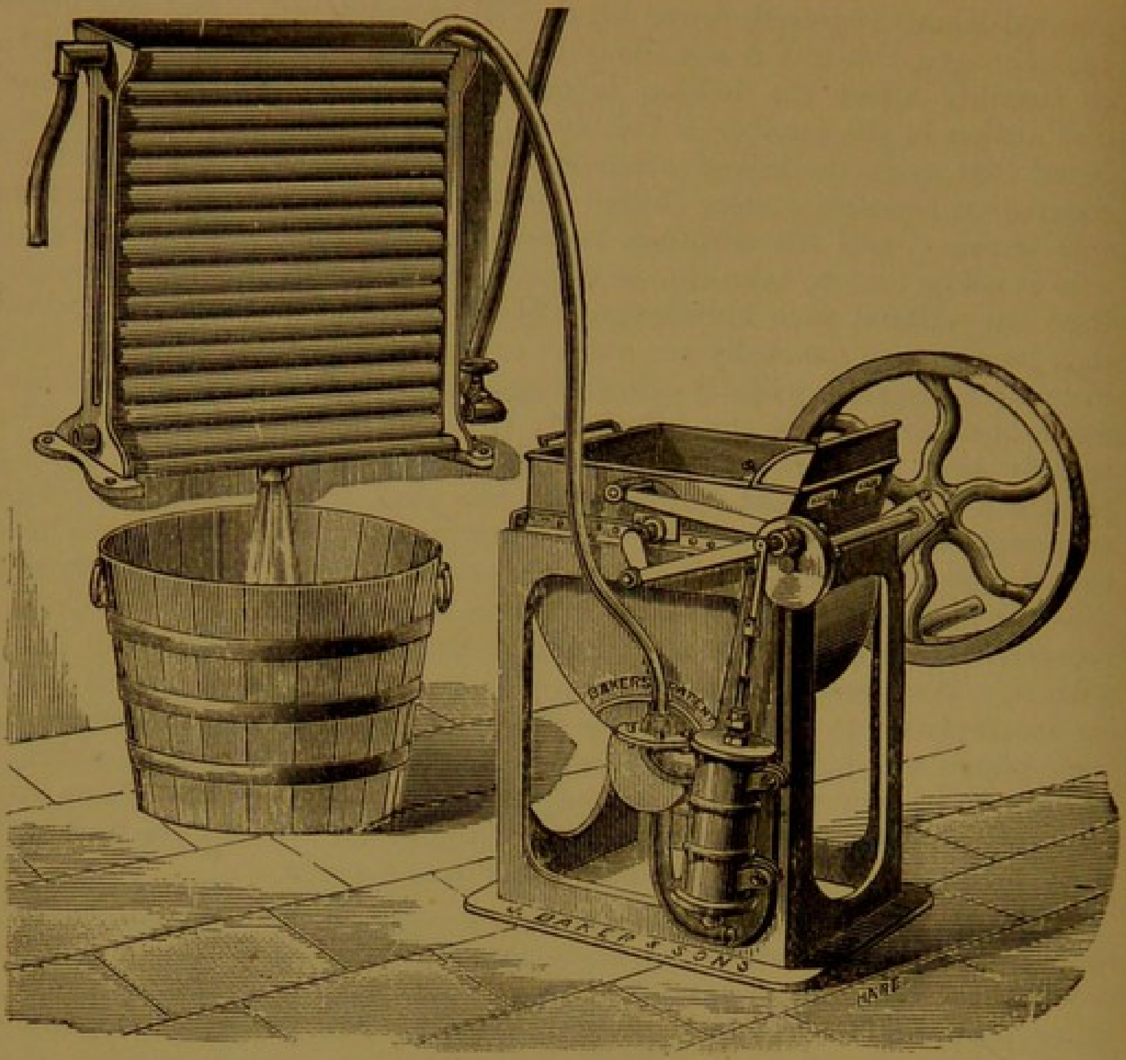


FIG. 55.—FERMENT SIFTER AND REFRIGERATOR.

The stand on the right hand side of the figure contains both the pump and sifter, the boiled potatoes and liquor are poured in at the top; on turning the hook handle shown, the starchy matter of the potatoes is worked through the sieve by means of an agitator, which passes to and fro immediately above the meshes, the skins remaining on the sieve. The pump shown at the bottom right hand corner is worked simultaneously with the agitator of the sieve, and raises the liquid to the top of the refrigerator, shown to the left. The refrigerator consists of a horizontal series of pipes, through which a current of water can be passed. The pump delivers the ferment into a trough at the top of the refrigerator, from which it descends as a thin stream over the outside of the water pipes, it is again collected at the bottom, and passes in a single stream into the ferment tub arranged for its reception. This operation serves the double purpose of both rapidly cooling and also ærating the ferment, thus ensuring a healthy fermentation.

**431. Flour Sifting Machines.**—The object of these is to remove any foreign matters, as tyers or pieces of wood, from the flour, by passing it through a sieve. Any lumps that may be caused in the flour by a sack having been accidently wetted are also thus separated. Sifting also "enlivens" the flour. When flour has been tightly packed in the sacks or bags for some time it forms a compact mass, which mixes into the dough with somewhat of difficulty. The passing through a sieve divides the flour once more into fine particles, and thus causes it to knead all the more easily and readily. It is also very possible that the flour thus gets more ærated, and so conveys air into the dough, which in its turn acts as a stimulant on the yeast, and so causes more energetic fermentation.

In fixing flour-sifting machines they should be so placed that the only passage by which flour can find its way from the flour room to the doughing machines is through the sifter. This plan ensures the whole of the flour being sifted.

Descriptions follow of various makers' machines.

**432. Bakers' Flour Sifter.**—This machine may be worked either by power or by hand; it may be fixed either on a floor above, or immediately over an ordinary doughing trough. Figure 56 gives an illustration of this machine fixed in a flour room on an upper floor, and leading into a "Thomson" kneading machine beneath.

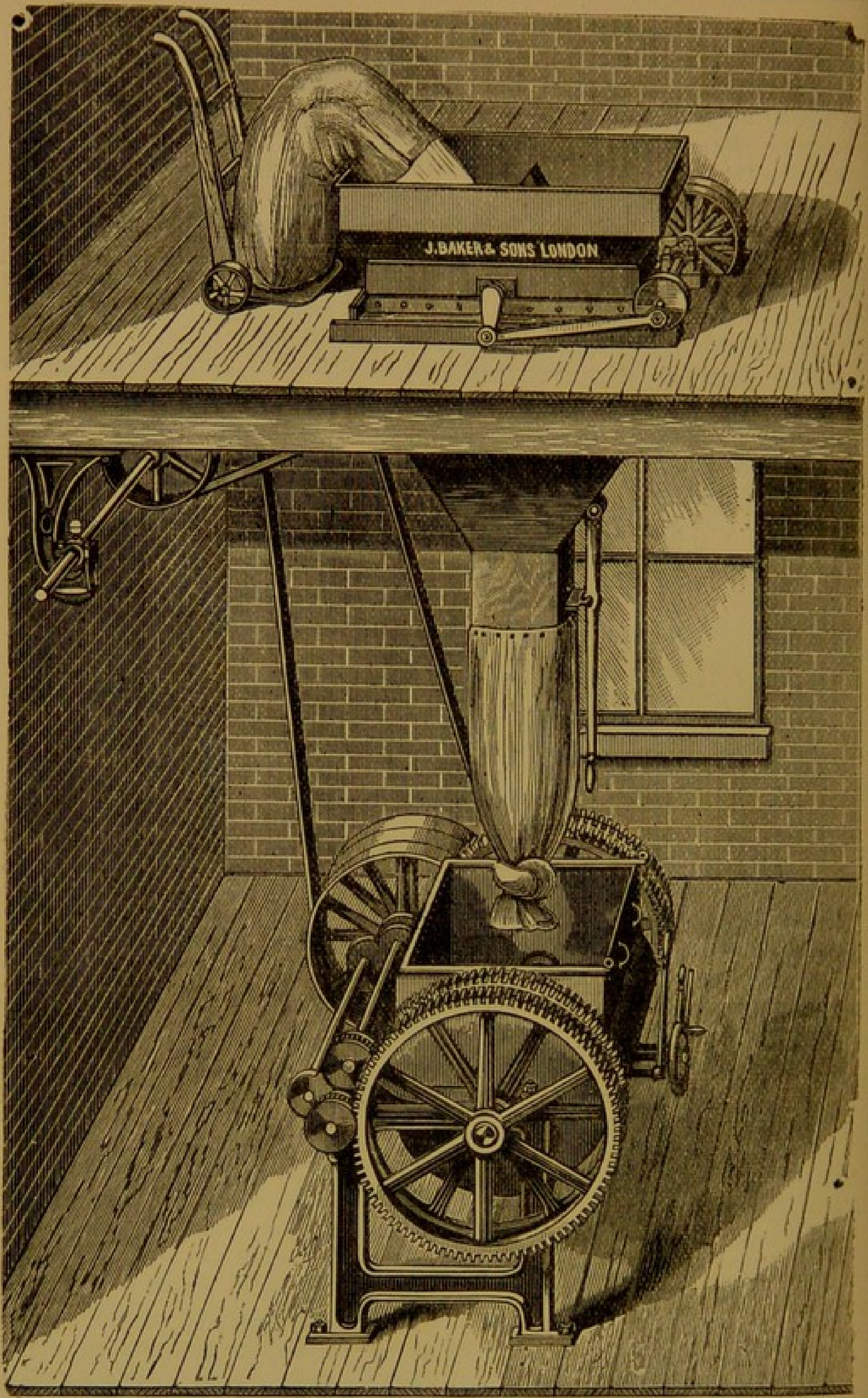


FIG. 56.—BAKERS' FLOUR SIFTING MACHINE, ARRANGED OVER "THOMSON" KNEADER.

The general arrangement of these machines, when actuated by power, is here very clearly shown. To the left of the figure may be seen one of the hanging brackets, which, depending from the joists of the upper floor, carry the driving shaft. From a pulley on this shaft a belt is carried to the fast and loose pulleys shown on the right hand side of the sifter. It will be noticed that this latter shaft has a crank and connecting-rod fixed to the end nearest the observer: this connecting-rod gives a reciprocal (forward and backward) motion to an iron quadrant, or "agitator," fixed inside the machine. Immediately underneath this quadrant is fixed the wire sieve, shaped to the arc of a circle. The machine being set in motion, the flour is tilted in from the sack, as shown in the drawing. The agitator moves rapidly to and fro, closely above, but without touching the sieve, and in so doing, works the flour through the machine with great rapidity.

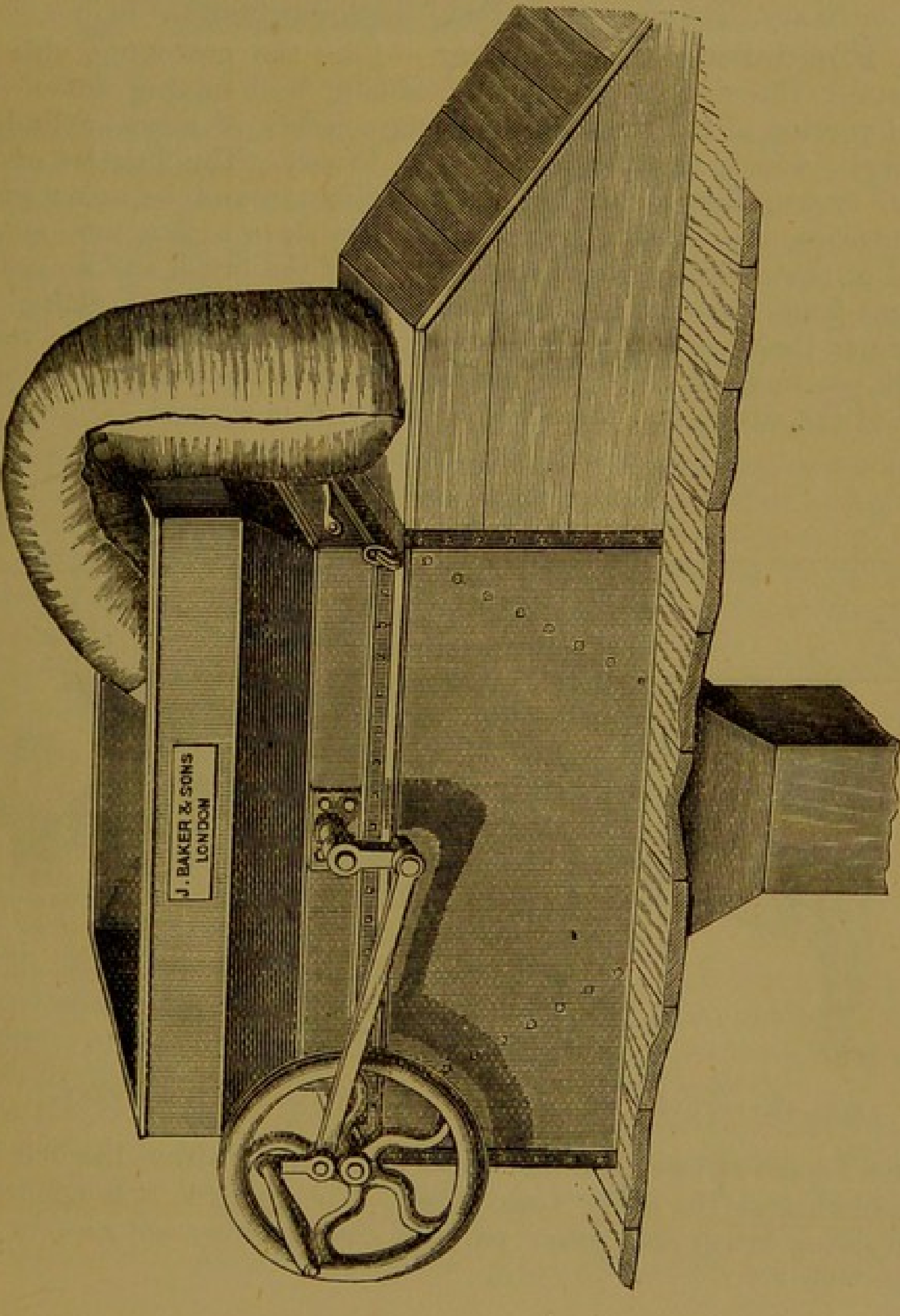


FIG. 57.—BAKER'S PORTABLE FLOUR SIFTER, ARRANGED FOR HAND-POWER.

In Figure 57 the same machine is shown arranged to work by hand in the flour room, above either kneader or trough. This form is moveable, and may be placed immediately on the trough in the bakehouse if wished.

Another advantage of these machines is that, when desired, they very thoroughly mix flours. On pouring into the machine, simultaneously, flours of two or more different qualities, they are delivered in one uniform stream into the doughing machine or trough beneath.

The makers claim that the sifted flour is doughed in one-third less time than with the flour unsifted, and that the sifting is done with a speed far greater than had ever previously been attained; so that the operation of sifting, instead of increasing, actually diminishes the time necessary for the changing of flour into dough. They also claim that the various sizes and forms of their machine enable them to meet not only all ordinary, but even exceptional requirements.

**433. Pfleiderer's Flour Sifter.**—Like the preceding, this machine serves the double purpose of sifting and mixing flour. The essential portion of the sifting apparatus consists of a semi-cylindrical sieve, above which is fixed a revolving brush. The bristles of this brush are arranged in a spiral or screw-fashion around its axle: as the brush revolves, the bristles rub against the sieve with a motion compounded of that resulting from the rotation of the brush and an onward movement from one end to the other, due to their spiral setting. In this manner the flour is forced through the sieve at a rate, it is stated, of a sack per forty to sixty seconds, according to the mesh of the sieve, the size of the sifter, and the speed at which it is worked.

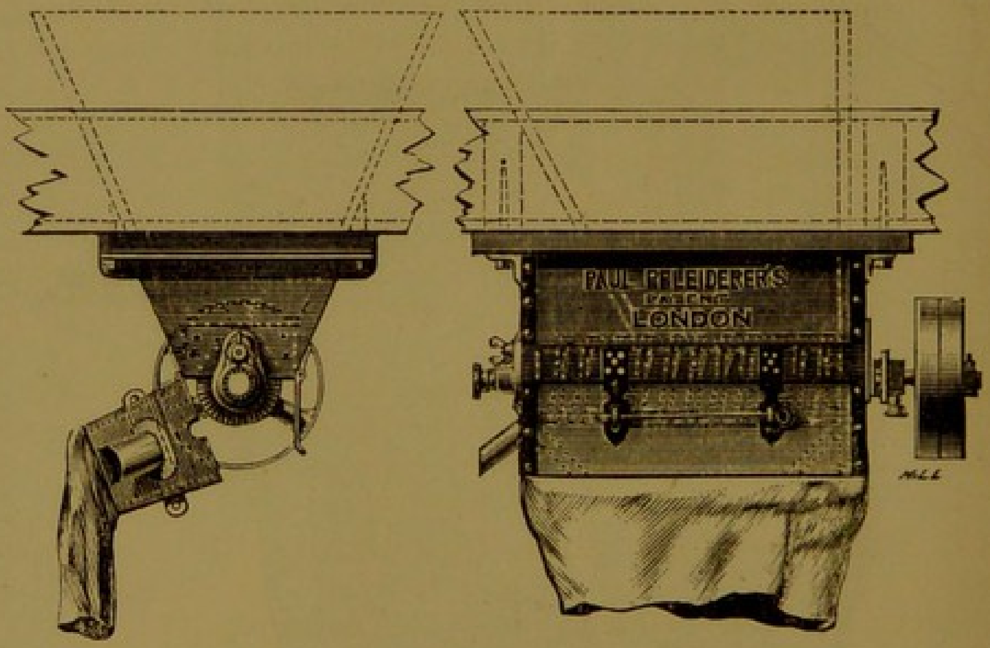


FIG. 58.—SECTIONAL VIEWS OF PFLEIDERER'S FLOUR SIFTER.

Figure 58 shows two sectional views of this flour sifter, the one being longitudinal, and the other transverse. The general arrangement of the revolving brush and other parts of the machine are clearly illustrated.

FIG. 59.—PFLEIDERER'S FLOUR SIFTER FIXED UNDER FLOOR.

This figure gives an illustration of the external appearance of the same machine, fixed below the floor of flour room, and arranged so as to deliver into either kneader or trough placed beneath.

**434. Sponge Stirrers.**—In Scotland, it has been the custom to set sponges in large tubs: a machine, termed a "sponge stirrer," has been devised for the purpose of rapidly mixing the barm, flour, and water together. The principal portion of the machine is a vertical spindle, so fixed that it can readily be lowered into the tub, placed to receive it: the lower end of the spindle is provided with a point and shoulder which rest in a socket fixed in the bottom of the tub. The spindle is balanced by a weight attached to the one end of a chain which passes over a pulley and is fastened to the top of the spindle. The machine is driven by means of a belt-pulley and bevil gearing. A number of horizontal blades, fixed to the lower portion of the spindle, by revolving in the tub, speedily ensure the efficient stirring of the sponge.

These machines do not now seem to be used to so large an extent as formerly: bakers, who have kneading machines, now frequently prefer to set the sponges in the machine.

**435. Kneading Machines.**—Several highly successful machines for doughing and kneading purposes are now in the market. Among the best known are those of Pfleiderer, Thomson, and Melvin. These have been selected as examples for description.

**436. Pfleiderer's Doughing Machine.**—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 reader is in the first place referred to Figure 60, in which the arrangements of these 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. Attention is called to the two revolving kneaders, the axes 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.

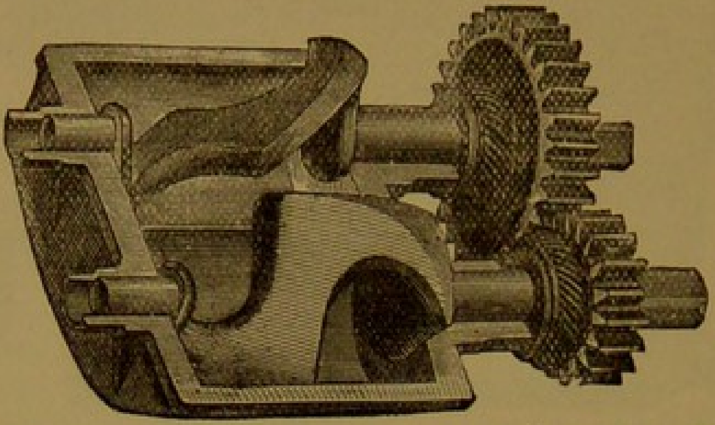


FIG. 60.—WORKING MODEL OF PFLEIDERER'S DOUGH MIXER.

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.

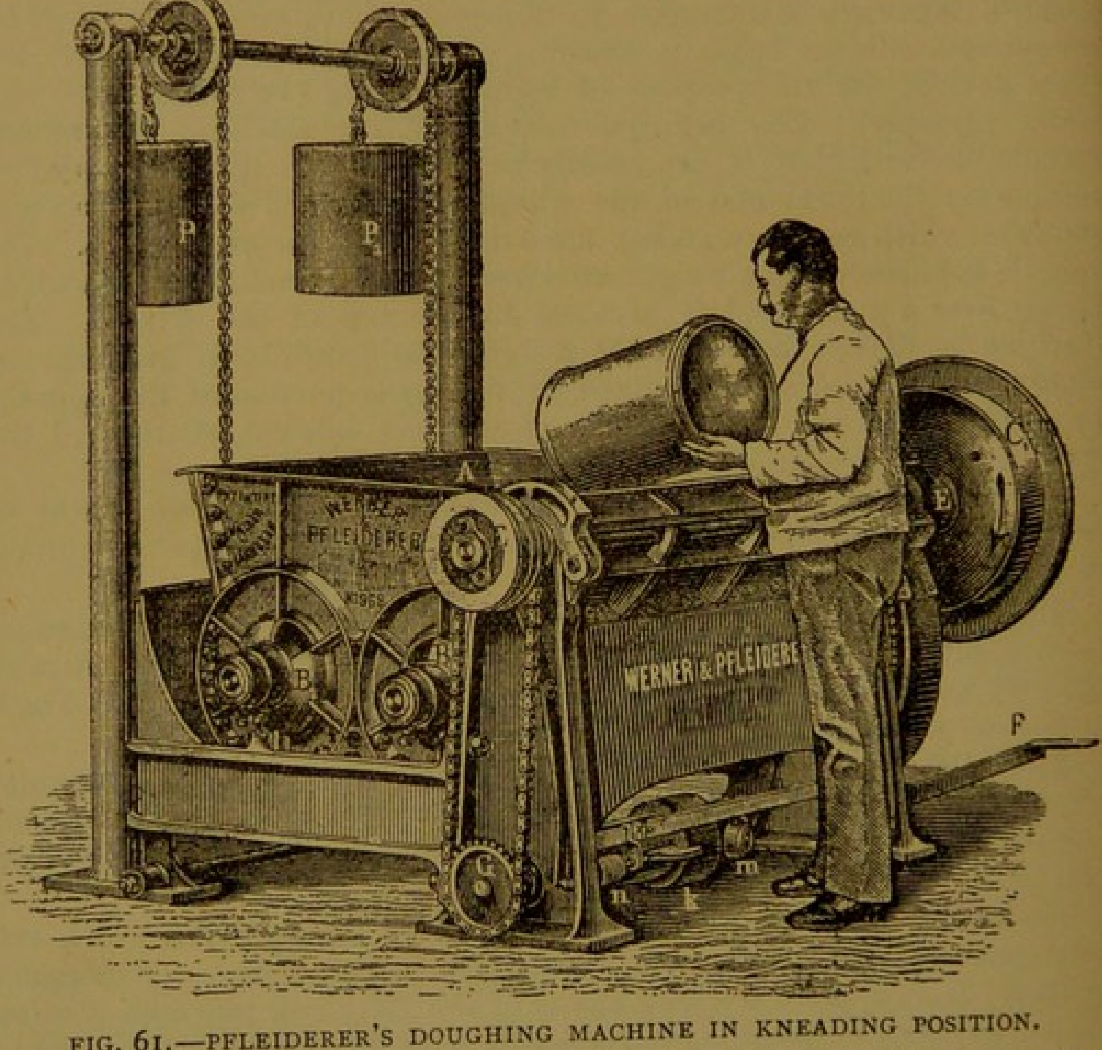


FIG. 61.—PFLEIDERER'S DOUGHING MACHINE IN KNEADING POSITION.

Turning next to the machines of sufficiently large dimensions for bakehouse use, an illustration of one of these is given in Figure 61. Figure 62 is also a view of the same machine 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, C.C.; one of these is driven by an ordinary, 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 C.C. 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 lever F, to be worked by the foot, tilts the machine when required. 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.

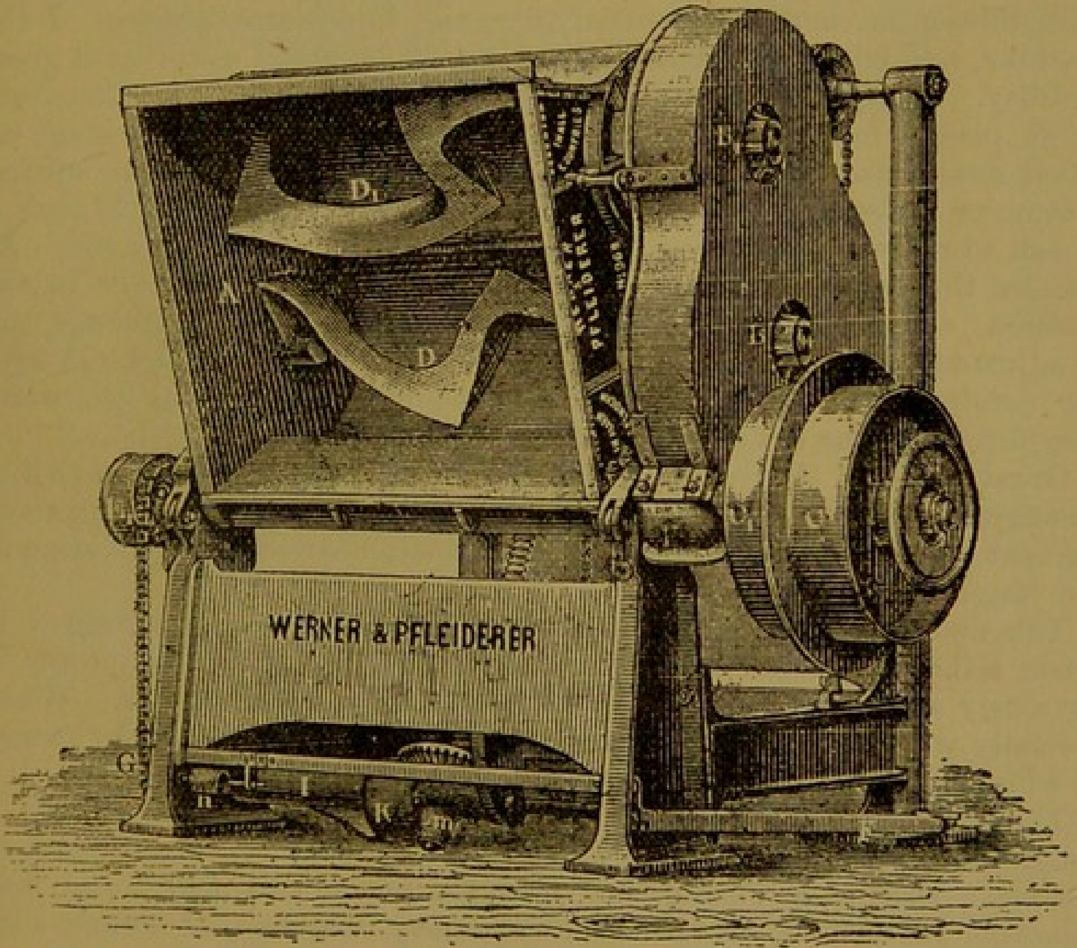


FIG. 62.—PFLEIDERER'S DOUGHING MACHINE, TILTED FOR DISCHARGE.

In Fig. 62, the position of the blades D.D. is clearly shown: in general configuration they resemble those of the smaller machine in Fig. 60. The foregoing brief description, together with a study of the engravings, will render clear the more important points of construction of these machines.

In making dough the flour is first inserted, and then the requisite quantity of water; the blades are in the first place caused to revolve, so that at the top of the revolution they approach each other. The machine works best with just sufficient flour to entirely cover the blades before the mixing commences. An endeavour must now be made to describe the results produced by the movement of the blades; this is a matter of some difficulty. 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 lodgement 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 figure 62; 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 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.

This machine is made in a number of sizes, and may be obtained to work either by hand or by power: the former source of power is obviously only applicable to the smaller types of machines. When specially wished, the machine is supplied with a steam jacket, by means of which it can be warmed before use.

The makers claim for it that it is equally applicable to the mixing of dough of any required degree of stiffness, whether for bread, cake, or biscuits: that it is exceedingly strongly made, and will stand considerable rough usage without serious injury, although, of course, such treatment is to be deprecated. 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.

For further information the reader is referred to the makers of the machine.

**437. The "Thomson" Kneading Machine.**—An end view of this machine, together with flour sifter, is shown in Figure 56. The machine consists essentially of an iron trough, which is usually galvanised, and in which revolve two kneading arms, whose arrangement is shown in the following figures, Nos. 63 and 64, which give longitudinal and transverse sections through the machine.

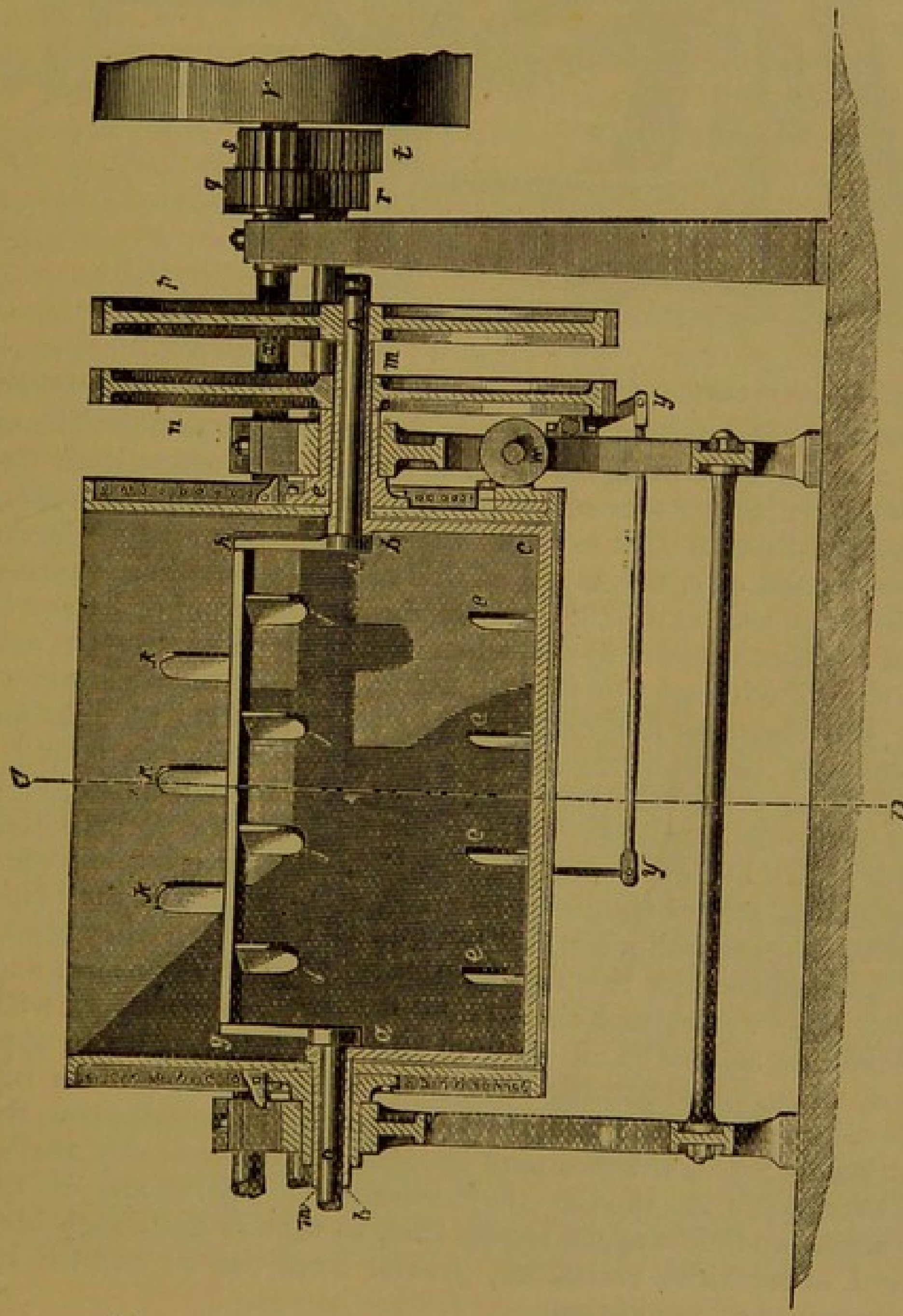


FIG. 63.—LONGITUDINAL SECTION THROUGH THOMSON KNEADING MACHINE.

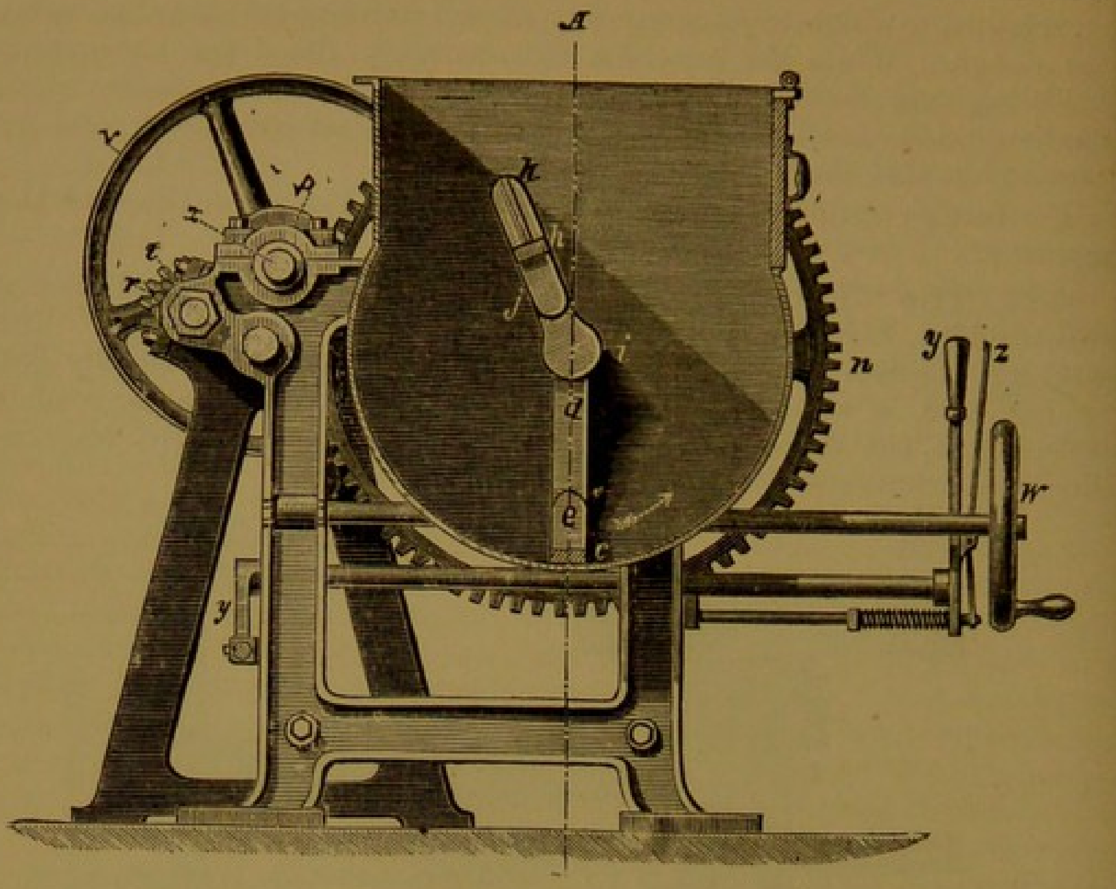


FIG. 64.—TRANSVERSE SECTION THROUGH THOMSON KNEADING MACHINE.

The lettering throughout these two figures is the same. The outer kneader, marked *a b c* in figure 63, is so shaped as to adapt itself closely to the semi-circular bottom of the trough, within which it revolves as nearly as possible to the surface without touching. As shown in transverse section at *c*, the metal of this arm is about three-quarters of an inch in thickness, and is of uniform dimensions from end to end; so far, therefore, this kneader would, when revolving, pass knife-like around between the dough and the trough, doing little or no work upon the former. But from the inner surface of *c* there projects at right angles to it a series of blades, *e e*, each of which is set obliquely on *c*. The second kneader, *g h i*, revolves within *a b c* on the same centre, *i*; from *g h* there projects inward a series of blades, *j j*, and outwards another series, *k k*. The blades, *e e*, of the outer kneader interlace in working with the blades, *k k*, of the inner kneader. The whole of the blades of these series are set obliquely to the direction in which they meet the dough. These kneaders revolve independently of one another, and are capable of the following motions—1st, either may be set at work with the other remaining at rest; 2nd, they may be caused to revolve in opposite directions, when, by differential gearing, the one rotates more rapidly than the other, and so the two meet with each successive revolution at different points; 3rd, the two may be locked together at any angle, and caused to revolve as though they were one. By means of special gearing a fast and slow speed is provided, so that as the dough becomes stiffer and offers more resistance, greater force can be exerted by reducing the speed of revolution.

A glance must now be taken at the outer gear of the machine: on its main shaft at *v*, figure 63, are fixed three pulleys—one, the middle one, being loose, and the other two fast. These provide for the machine being at rest, or for its revolution in opposite directions. The small pinions, *q r s t*, constitute the gear, by which a slow motion is obtained when required. The inner kneader, *g h i*, is driven by the toothed wheel, while the outer kneader, *a b c*, is attached to a sleeve, *m m*, which encircles the shaft *o*, and is driven by the wheel *n*. The rod, *y y*, at the lower part of figure 63, is a part of the reversing gear. This is seen more clearly in the transverse section, figure 64, this rod is there shown to be connected to a handle, marked also *y*; to this handle is attached a locking spring, *l*. By placing the hand upon this lever handle and moving it into either of three set locks, the several movements of which the machine is capable are obtained. The different positions in which the kneaders are, when these changes are made, cause the many varied actions that can be given to the dough. Another lever works the fast or slow speed, or loose stop pulley. The handle, *w*, figure 64, is for the purpose of tilting the machine.

The makers claim that, by means of this machine, they obtain powerful mixing motions, which have a real kneading action, corresponding to the pressure of the hand or arm, and allowing the dough to have relief or spring; also, that the machine works with a low driving power, and discharges its contents at the finish more easily and cleanly than from an ordinary bakers' trough. They further claim that their machine, while kneading the dough in the shortest possible time, is so devised as to reduce the danger of damage to the dough, as a result of overworking, to a minimum.

**438. Melvin's Kneading Machine.**—As in other machines, the trough is adapted in shape to the revolving kneaders, of which, in Melvin's machine, there are three, set on separate shafts.

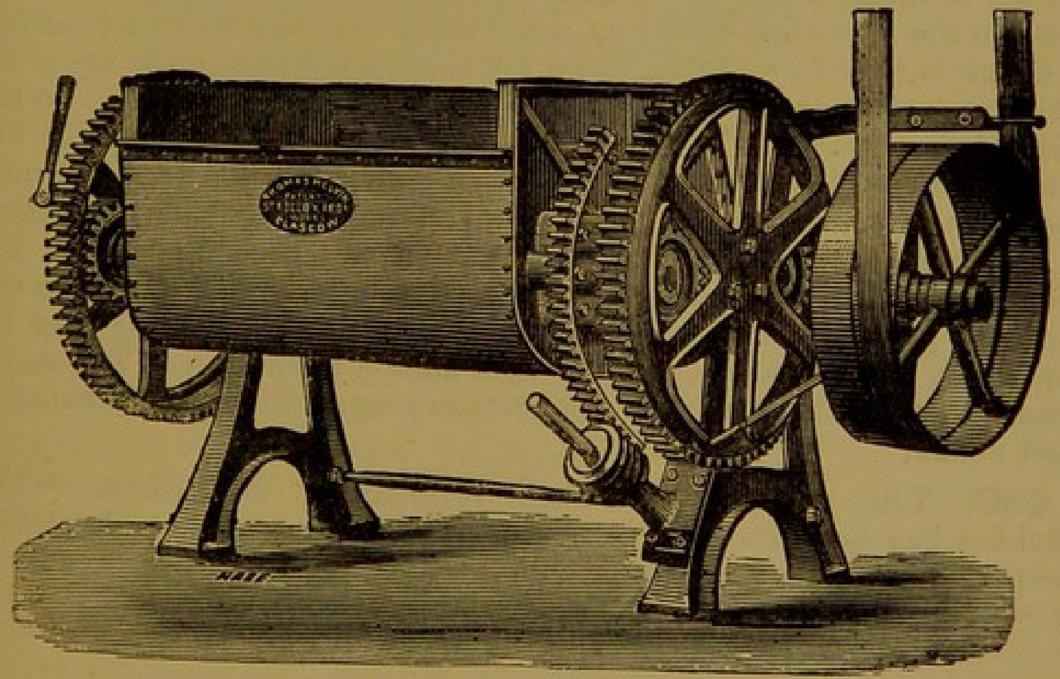


FIG. 65.—MELVIN'S DOUGH MIXER.

Figure 65 illustrates the external appearance of this machine. Its interior is shown in Figure 66, from which it may be seen that there are three actions, each action being represented by a separate set of blades, which receive motion at each end of the machine by means of gearing.

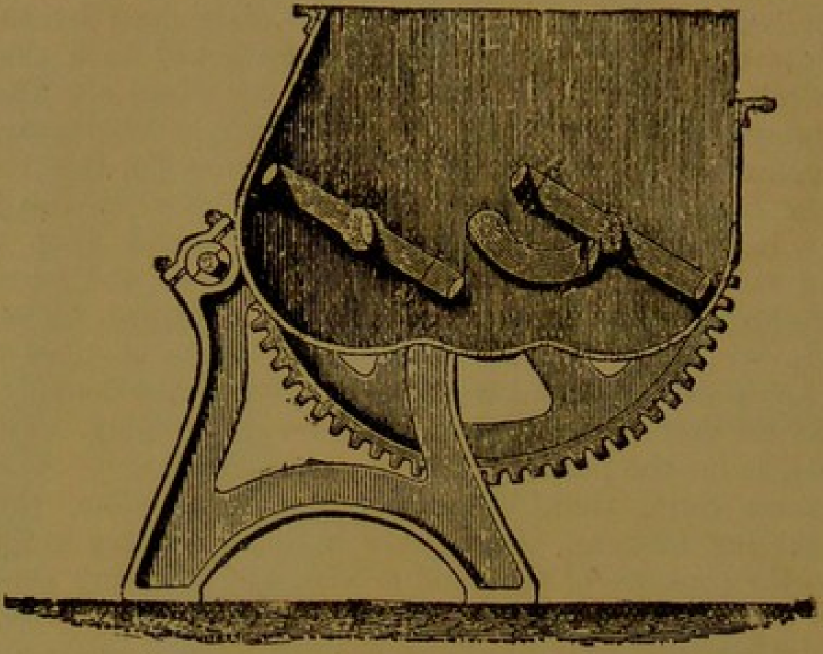


FIG. 66.—SECTION THROUGH MELVIN'S MACHINE.

The three radii described by the several sets of blades in their rotation all intersect one another, so as to prevent there being any dead centres in the mass of dough. Their rotative action is such that there is a continuous overlapping movement of one set over the other, above the central line of the axes of the machine. At the latter point the blades pass each other in opposite directions, side by side, and at the bottom of the machine they pass obliquely to each other. These actions produce the following effects on the dough, viz.: the whole top surface of dough is raised into folds, which are thrown the one on the top of the other, and then drawn downward into the centre of the mass. While this is being done, the outer portions are carried upwards by the two outside sets of blades, to be in their turn folded and carried downwards at the centre. The blades, where they pass in the centre, have a cutting or dividing action, and at the bottom they have a pressing action. The overlapping movement constitutes the kneading process, while the cutting and pressing mixes. The dough is discharged by tilting over the trough by worm gearing, worked by a handle at the side. The maker claims that all these actions are necessary essentials in the making of good dough.

**439. The "Drum" Dough-Kneading Machine.** — This machine has been recently introduced by Baker & Sons. The mixing receptacle consists of a drum or cylinder fixed horizontally.

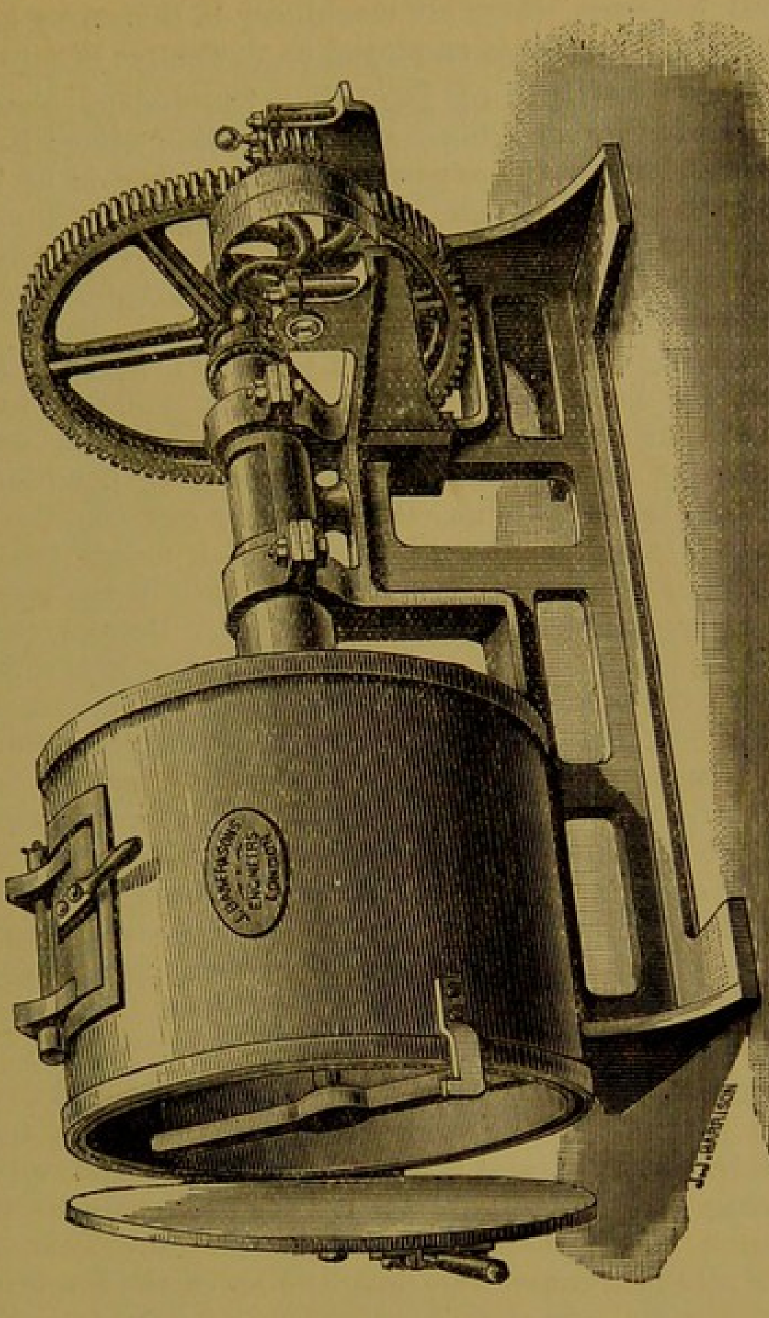


FIG. 67.—DRUM DOUGH-KNEADING MACHINE.

Through the right hand end of the drum, as shown in figure 67, passes a horizontal spindle carrying one kneading arm, which is just visible through the partly open door at the left hand, or outside end of the drum. In use, this end door is closed, the flour and water are then introduced through the door fixed on the top of the cylinder, and shown in the figure. The kneading arm is then caused to revolve, and in so doing is also made to travel longitudinally from the one end of the cylinder to the other. When the dough is sufficiently kneaded the end door is opened, and the kneader, in working, discharges the dough through this from the cylinder.

The makers claim that with only one kneading arm, instead of several, there is a great reduction in the amount of power required; that at the close of the doughing operation, the kneading arm being to the front, the machine can be easily cleaned. They specially recommend it for adoption in small bakeries, where all machinery is driven by hand, or where only a very small engine is employed as the source of power.

**440. Killing or Felling of Dough.**—Discussions occur from time to time as to whether doughing machines kill or otherwise injure dough. As a result of careful experiments the author is of opinion that it is possible to injure dough by *overkneading* it in a machine. The tenacity of dough may be sensibly reduced by too much kneading; or, in other words, a stiff dough can be reduced by overkneading to the consistency of a dough originally made much slacker. Be it noticed that this is a result of overkneading, not of proper kneading. A batch of dough, which by hand requires, say, twenty minutes to knead properly, can be sufficiently kneaded in the machine in, say, four minutes. Now, if by hand-work the dough receives a minute's too much kneading, that is only an excess of five per cent. on the proper time; but a minute's overkneading in the machine means twenty-five per cent. excess over the proper time. The minute in the one case is five times more serious an error than in the other. Besides, the baker working by hand knows by the feel of his dough when it is sufficiently kneaded; and with the machine he has to judge in a different manner. It is so much easier work, too, to watch the machine overkneading a sample of dough than to do it one's self. The remedy for this evil is to drive the machine not too quickly, and to stop working immediately the dough is sufficiently kneaded. The necessary time may be ascertained very closely once and for all by a careful experiment made with the machine. It is a compliment to the makers of doughing machines generally, that the principal complaint against them is not that they are inefficient, but that they are liable in a very short time to do their work too thoroughly. The remedy for this fault is simple and obvious.

**441. Cleaning Doughing Machines.**—It is essential that these machines be kept perfectly clean: each day after using, every fragment of dough should be removed, and the machine scraped and wiped out. The machine being absolutely clean it is a very good plan to wipe its interior with some clean waste and best cotton oil. This is quite tasteless, and the oily film causes the dough to leave the machine more completely.

**442. Ovens.**—The space at disposal renders it impossible to give more than a brief account of ovens; a few typical ones of modern make have been selected for description.

**443. The Bailey-Baker Oven.**—This oven is fired by an external furnace, so arranged that the heated products of combustion lead directly into the oven. An idea of its construction may be gained from a study of the accompanying illustration, Figure 68, which gives a longitudinal section.

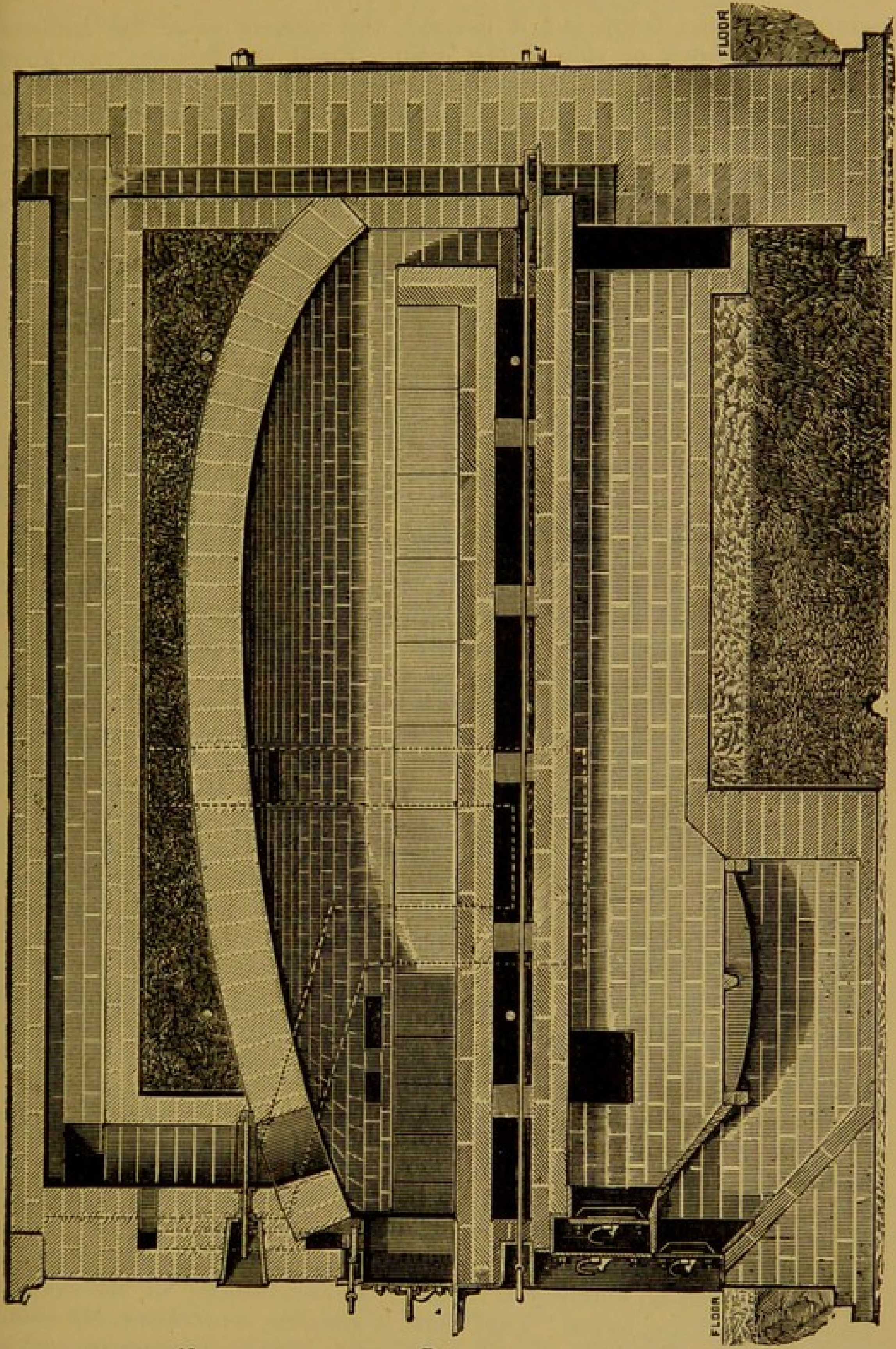


FIG. 68.—BAILEY-BAKER OVEN, LONGITUDINAL SECTION.

Starting from the front of the oven at the floor-line, there is first the ash-pit: above this is the furnace, extending about two-fifths of the length of the oven. From this it will be seen that the furnace is arranged at the front, but if desired, the makers place the furnace either at the back or side of the oven. From the furnace two flues start, one from either side, and communicate with the two front corners of the oven's interior. Another flue proceeds to the back of the oven, and subdivides so as to discharge into its two back corners. These flues provide for the heating of the oven by the admission of the heated gases from the furnace simultaneously at the four corners : in order to provide for the maintenance of a draught through the oven, a main exit flue leads from immediately above the oven door to the chimney. There is also provided a flue leading direct from the furnace to the chimney, so that any momentary slight smoke or dust caused by the addition of fresh fuel to the furnace need not be admitted to the oven. Another flue to which the inventors attach considerable importance, and which they term the "siphon" flue, leaves the oven from the middle of one of its sides, close to the crown, takes a downward path until considerably below the sole of the oven, then bends forwards and upwards toward the main flue, into which it enters above the damper. The object of this flue is to permit the slow escape of gas without loss of heat. All the flues are provided with dampers, so that, at the discretion of the baker, all or any may be opened or shut at will. Reference to the illustration shows that there is a space between the sole of the oven and the crown of the furnace: this constitutes a hot-air chamber, which at the back communicates with the interior of the oven.

This oven is specially designed for use with coke or hard smokeless coal (anthracite), of which the inventors state (referring to the coke), a sack per twenty-four hours is required. The heat of the oven may be regulated with extreme nicety by opening or closing the ashpit door, as with the open door more rapid combustion goes on in the furnace. By means of the dampers the hot-air from the furnace can be directed through the flues described into the oven at all or any of the four corners, thus raising its temperature to baking heat with great rapidity. These arrangements permit the baker to first thoroughly heat his oven, and then, closing the dampers, to conduct the baking of his bread by "solid" or radiant heat in a closed oven: he may then at will admit a flash heat so as give a "bloom" to the crust. During the time that the oven is closed, the heat of the furnace raises the temperature of the air in the hot-air chamber beneath the sole: this hot-air by convection finds its way all over the oven, and so serves to raise the temperature throughout equably and gently. The inventors claim that in this manner the oven can, if wished, be made to bake entirely by external heat.

The makers and inventors claim for this oven that the greatest possible quantity of all the heat produced is used, so that the cost of fuel is reduced to the lowest practicable amount; that as no firing is done within the oven no scuffling is required, as the interior of the oven is free from dust and ashes. That there is absolute control over the oven, thus permitting the baker to use more or less heat as he requires, and to direct it to whatever part of the oven he wishes: further, that he may have either a solid or a flash heat at will. That batch after batch may be baked continuously, and with perfect regularity of production. That when the oven is required at a low temperature for the baking of certain goods, the change can be effected in very little time, and that as soon as desired the oven can again be raised to the normal temperature with great rapidity.

**444. The "Mason" Continuous Baking Hot-Air Oven.**—This oven may be made either Single or Two-Decker; the latter term signifying that the one oven is placed immediately above the other. They are heated by a furnace at the base, which can be placed on any side of the structure, but by preference at the back, so that all dust and ashes may be kept out of the bakehouse. When wished, these ovens can be supplied fitted with travelling plates, enabling the whole of the batch to be set or drawn at once, and thus securing uniformity of colour and baking. In the two-decker the tram-lines for the travelling plates are so arranged that they can instantly be transferred from the top to the bottom oven, and *vice versa*, as required. The accompanying illustration, Figure 69, gives a longitudinal section through the two-decker oven.

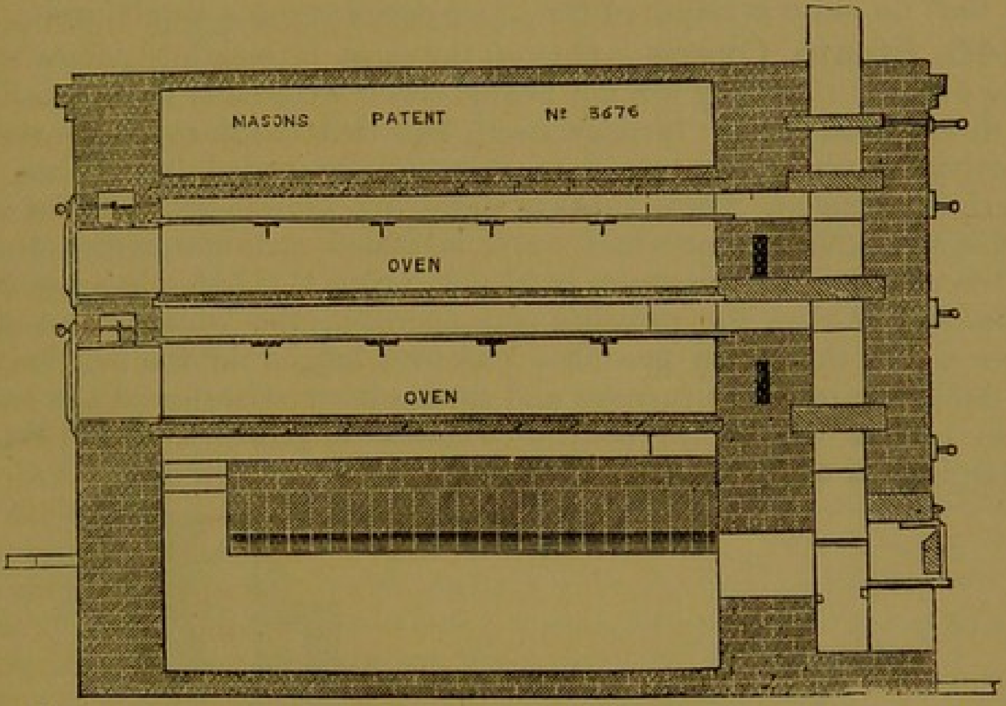


FIG. 69.—LONGITUDINAL SECTION THROUGH "MASON" TWO-DECKER OVEN.

Referring to the Figure, it will be seen that the furnace is at the back of the ovens and is so arranged as to be quite independent of them. In order to prevent direct radiation of heat from the furnace chamber through the back of the oven, a cold-air chamber is placed between: as a result of this arrangement the inventor states that it is possible to keep the back of the oven at a lower temperature than is the front. Further reference to the Figure shows that the heated gases pass from the furnace chamber through a main flue, and first come into contact with the oven-sole at the front, and then pass to the back of the oven, and from thence between the crown of the lower and the sole of the upper oven: continuing their course, the heated gases next pass over the top of the higher oven and from thence to the chimney. By means of dampers and special arrangements of the flues the heat may, when it is desired, be applied to both top and bottom of each oven, or to either top or bottom only, or the heat may be directed straight up the chimney. In this way the heat of the oven is kept under direct control of the baker. As the oven is entirely heated externally, it is absolutely impossible for any dust or smoke whatever to find its way from the furnace to the oven. From the cleanliness point of view it is a very great advantage to have the oven furnace outside the bakehouse, and thus to do entirely away with the introduction of coal and ashes into the bakehouse itself.

The inventor and patentee claims that this oven has its greatest heat at the front of the oven, where it is most required, that the temperature is under complete control, and that the baker can apply heat to either the crown or sole of the oven as he may wish. That the only part of the oven liable to repair is the furnace chamber, which is easily accessible, and that there is no destruction going on within the ovens themselves. That the oven being heated from the outside, no dust or ashes are introduced in the bakehouse. That the consumption of fuel is very small, and that no more is required for a two-decker than a single oven.

**445. Steam Ovens.**—One of the most interesting points about these ovens is that they are not heated either externally or internally by the direct heat of the furnace itself, but that the furnace converts a quantity of water, contained in hermetically sealed iron tubes, into superheated steam. These tubes in their turn radiate heat into the oven.

It is well known that when water is boiled at atmospheric pressure the temperature of the steam is 212° F. (100° C.), but when the steam is confined so that the pressure may increase, the boiling point of the water and of the steam produced rise to a height determined only by the temperature of the furnace and the limit of resistance of the boiling vessel. Thus the boiling point of water at a pressure of 420 lbs. per square inch is 447·6° F. (230·9° C.)

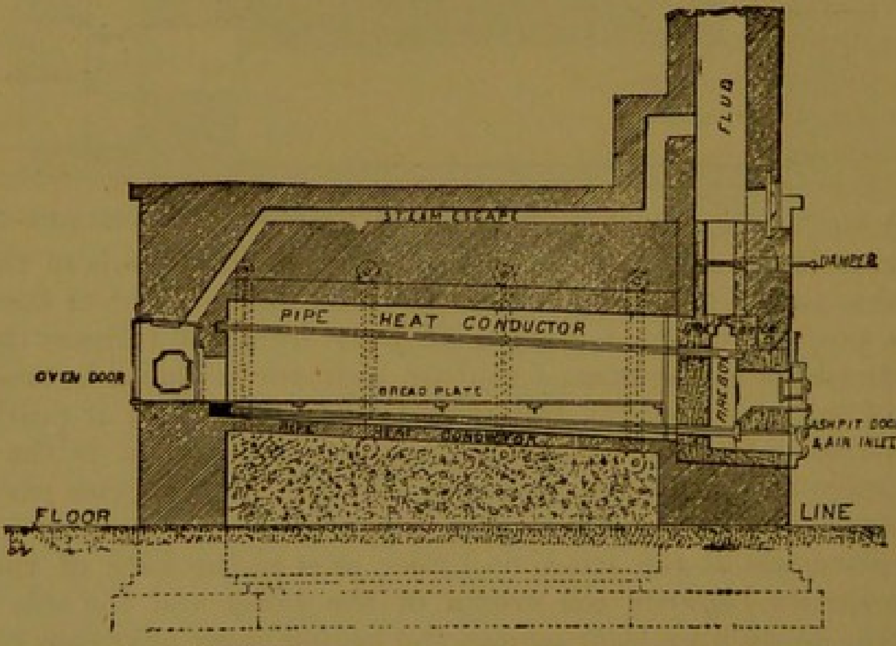


FIG. 70.—PERKIN'S STEAM OVEN—LONGITUDINAL SECTION.

The above is an illustration of Perkin's steam oven, this firm being the original patentees of the principle of applying superheated steam to the heating of ovens. Reference to the illustration shows that the oven is fired at the back, thus keeping the bakehouse free from coal and ashes. A back view of the oven is given in the following figure, No. 71.

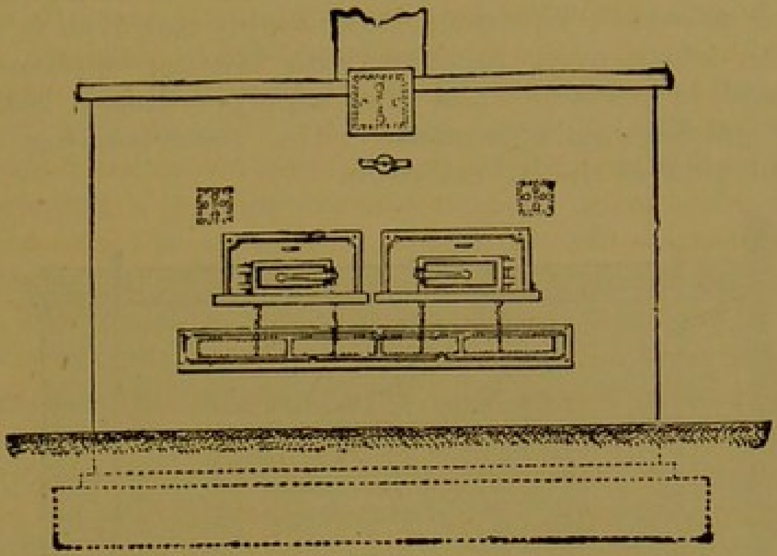


FIG. 71.—BACK VIEW OF PERKIN'S STEAM OVEN.

These diagrams are self-explanatory, so far as the furnace, ashpit, and their fitttngs are concerned. An air-chamber is fixed between the furnace and back of the oven, so as to prevent the oven being overheated at the back by the direct heat of the furnace. From the furnace two parallel series of pipes proceed; these are arranged, the one series underneath the bread plate or sole, the other just below the crown of the oven. These pipes are made of iron, each being complete in itself, and having an external diameter of 1⅜ inch, and internal diameter of ⅝ inch, leaving ⅜ inch as the actual thickness of the metal. They are tested at a pressure of 3000 lbs. per square inch. Before being closed each pipe is partly filled with water; with the heat of the furnace this water is converted into superheated steam, and so, by proper regulation of the heat, each pipe is raised throughout to a temperature of from 450° to 500° F., thus giving the oven an equable solid, or radiant, baking heat. A flue, fitted just inside the oven door, is provided for the escape of steam during baking; this may be opened or closed by means of a damper. It must be clearly understood that this flue simply provides for the escape of steam evolved from the bread, not for any escape from the steam pipes of the oven. These latter being once filled and sealed up require no further treatment until worn out.

As this oven is entirely closed off from the furnace it is impossible for any dust or fumes from the fire to find their way inside: on the other hand, it follows that the goods cannot be subjected to a flash heat. The oven is exceedingly simple in construction, but its initial cost is great, through the expense of the iron-work.

Nevill, the well-known London baker, employs steam ovens on a slightly different principle: his are arranged so that the pipes are heated by the circulation of a current of steam through the whole series. The advantage of having each pipe distinct from the others is that should one become leaky and disabled it does not interfere with the proper working of the others.

**446. Thompson's Gas Oven.**—This oven is a fresh departure from those previously described, inasmuch as gas is used as fuel instead of either coal or coke. Thompson Bros. supply this oven in small sizes, in which the whole oven, together with heating appliances, is self-contained, and is portable; and also supply ordinary bakers' ovens, fitted with gas-heating apparatus. The accompanying illustration shows a front view of the bakers' oven.

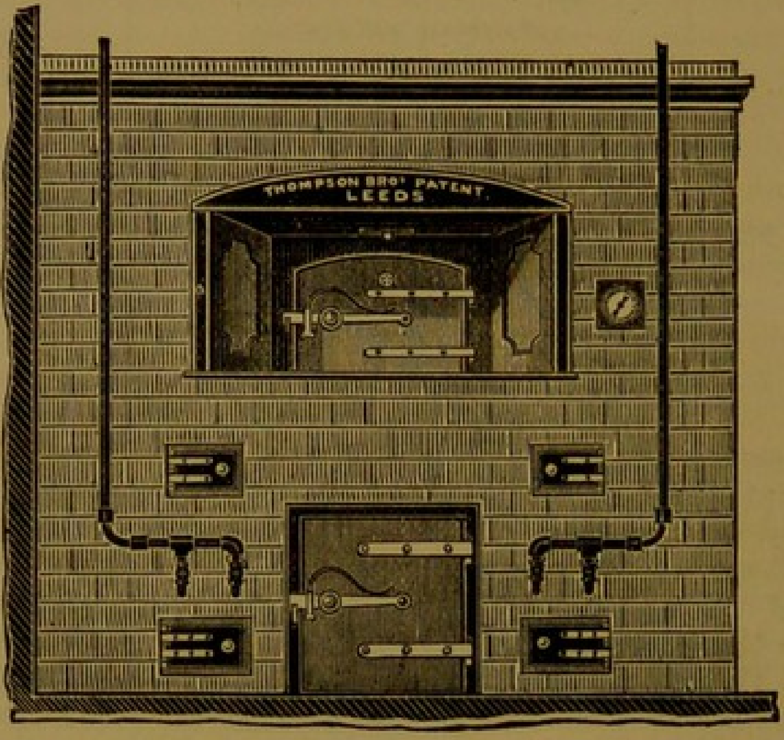


FIG. 72.—THOMPSON'S GAS-HEATED BAKERS' OVEN.

These ovens are brick and tile built, and are heated by gas on the regenerative principle; that is, the waste heat from the oven is employed to heat the gas and air, used for supporting combustion, prior to their reaching the burners. This is effected by causing the pipes bringing gas and air to the flame to pass through the flue, conveying away the products of combustion. The makers apply the heat either externally or internally as desired, but find that internal heating is most generally favoured, as by means of gas a flash heat is obtained in the cleanest possible manner, as no smoke, soot, nor ashes are produced. A series of bunsen (atmospheric) burners is placed on each side of the door inside the oven, and are regulated by taps on the outside. The heated products of combustion from these burners are carried to the back of the oven, and return underneath the oven sole to the front, and thence into the main flue. By this means not only is the inside of the oven heated, but underneath also, thus ensuring both top and bottom heat. When desired for special purposes the oven is supplied with arrangements for the production of additional bottom heat.

The externally heated oven is supplied with a heating chamber placed underneath the front of the oven: the heat is conveyed underneath the oven sole, up flues at the back, and returned inside cast-iron flues to the front, and thence into the main flues.

The manipulation of the heating arrangement is very simple; the proper way is to open the dampers before lighting the gas, and to close them immediately after the gas is turned off: by carefully attending to these points it is impossible to have a failure.

The makers claim that their system of gas heating gives cleanliness, uniformity of heat, simplicity in firing, freedom from sulphur, smoke, and ashes, and retention of heat. There is also a considerable reduction in labour required. It is further claimed that the cost of heating is less than that for coal; in support of this claim the makers adduce the Official Report of the Testing Engineer of the Gas Exhibition held at the Crystal Palace, 1883; and also testimonials from well-known firms, who state the cost of heating to be nominal.

**447. Baker's Patent Oven Light.**—This is an apparatus arranged for the purpose of lighting the interior of an oven, not only while the bread is being set, but also at will while baking is proceeding.

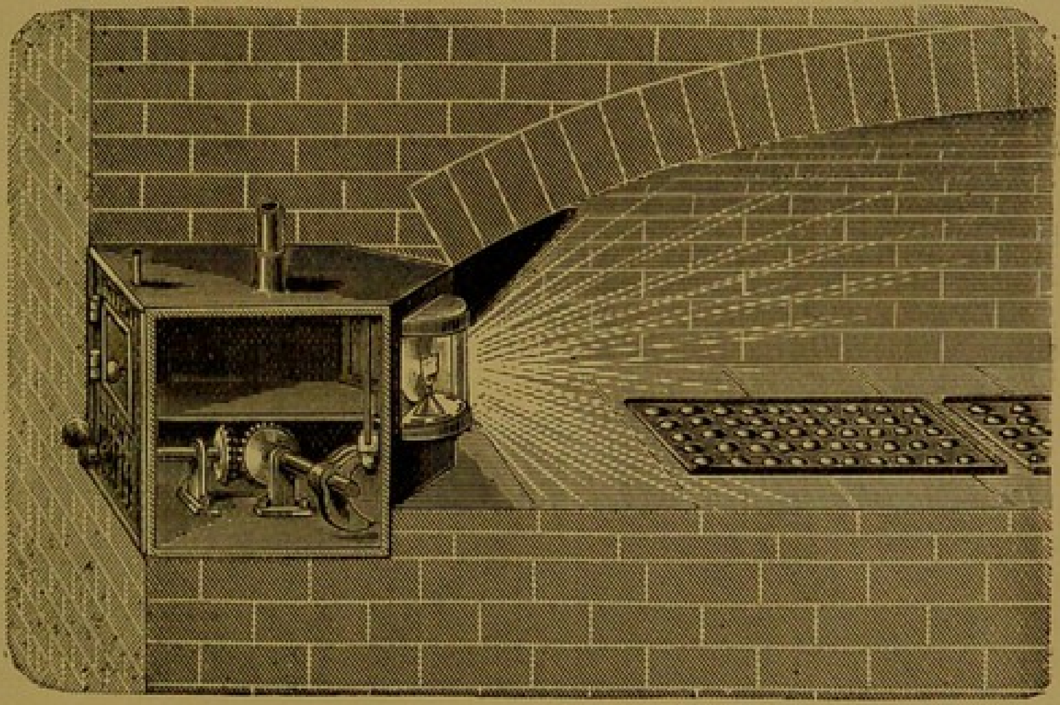


FIG. 73.—BAKER'S OVEN LIGHT.

The apparatus consists externally of an iron box so arranged as to be fitted into the wall of any baker's oven. The gas jet is fixed in a lantern with a semi-circular mica face, and a reflector behind. When not in use, this lantern remains withdrawn into the upper portion of the box; the opening being closed by a small iron door, shown in the figure just to the left of the light. On turning over the weighted handle, on the outside of the apparatus, the iron door is opened, the light is turned full into the oven, and at the same time the gas is turned full on. The reverse movement again withdraws the light, turns the gas down, and shuts the iron door opening from the light-box into the oven. The light can in this way be projected into the oven during the time that a batch is being baked. By having a small window of glass fixed in the oven door the interior can thus be inspected without opening the oven.

The makers claim the saving of gas with this light is very great, as the gas is turned down automatically when the light is not in use. The loss of heat and steam caused by opening the oven door in order to see the interior is entirely avoided. The light is ventilated, so that it is not affected by the heat or steam, and the whole interior of the largest oven is brilliantly illuminated.

**448. The Author's Personal Opinions on Ovens and Machines.**—In writing the preceding descriptions it has been the author's aim to impartially describe each particular machine or appliance referred to, giving that information which was deemed most likely to be of interest to the baker, who would wish to know something of the objects and nature of kneaders and ovens, &c., of comparatively modern invention. In order that no special point of merit of any system shall be overlooked he has asked the various makers to supply him with particulars of whatever special advantages they claim. These have been incorporated in the descriptions, but in such a way as to separate the makers' claims from purely descriptive matter. The author has carefully avoided indicating any preferences whatever of his own; those readers who desire his personal opinions or advice as to the selection of ovens and machinery may obtain the same by consulting him professionally.

# CHAPTER XIX.

## ANALYTIC APPARATUS.

**449. 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 and flours. 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.

**450. 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.

**451. 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 made by Mr. O. Wolters, of 55, Upper Marylebone Street, Portland Place, W. The speciality of this particular variety of balance is that the beam is very short; the maker claims 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.

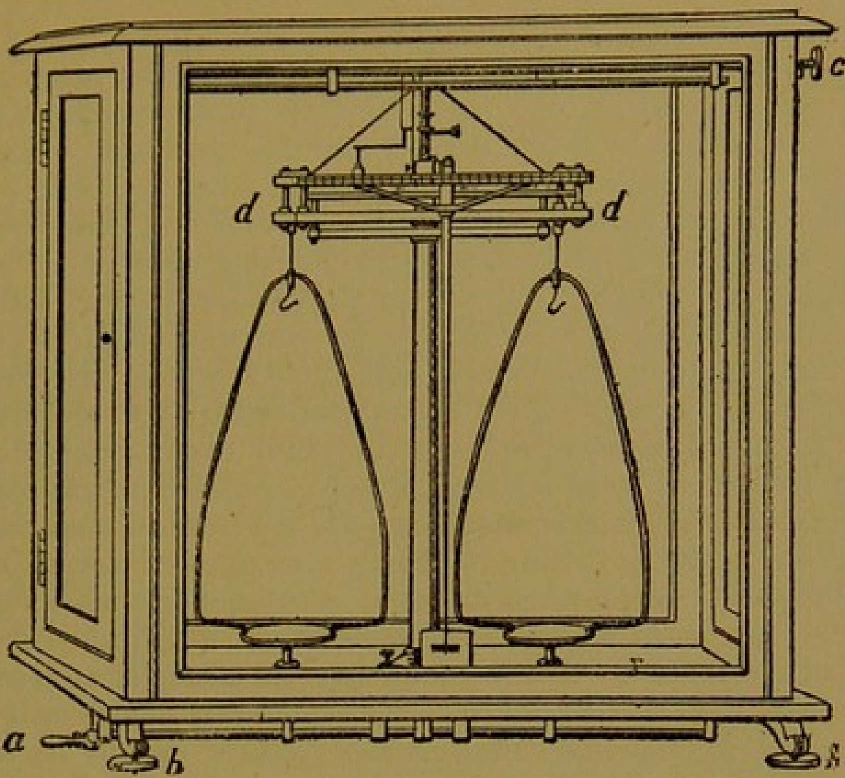


FIG. 74.—SHORT BEAMED ANALYTICAL BALANCE.

On referring to the figure 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, *b b*. 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 brass pillar, which in turn is screwed down to the botttom 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, *d d*: so, too, the end hooks carrying the pans are likewise supported by the cradle. Underneath each pan there is also a small ivory support, on which the pans rest until it is required to set the balance in action. At the bottom of the left-hand side of the figure will be noticed a small handle, *a*; this, on being slowly turned from the operator, first lowers the ivory 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 handle back again, the opposite of these movements takes place in reverse order, and each knife-edge is gently 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 shew 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 Wolter's balances there are two spirit levels at right angles to each other; the two levelling screws in front of the balance must be turned in one direction or the other until the bubble is in the centre of each of the spirit levels; the balance will then be vertical. In the next place carefully dust the beam and the pans with a camel's hair brush. Then turn the handle which actuates the balance, and allow the beam to vibrate; it will most likely swing one way or the other immediately 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 costs fifteen guineas, and 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.

**452. 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.

**453. 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 pleasureable 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 | | | | | Rider. |
| 0·001 | 0·005 | 0·01 | 0·01 | 0·02 | |
| 0 001 | | | | | |

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 75, 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.

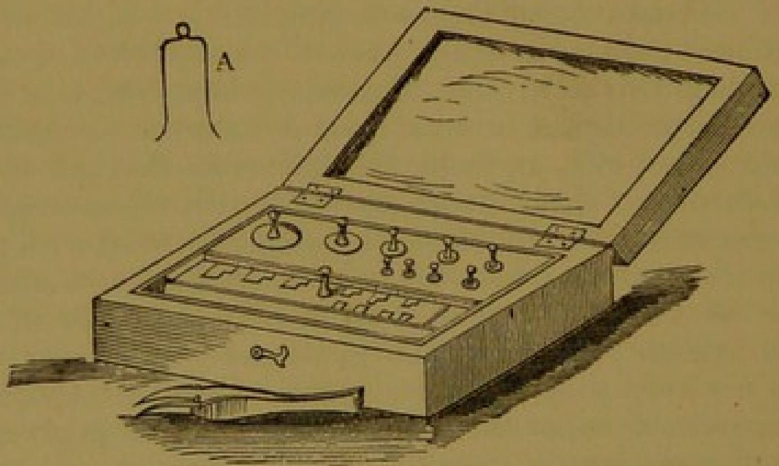


FIG. 75.—BOX OF ANALYTIC WEIGHTS.

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, *c*; this actuates a rod, at the other end of which, from a little hook, depends the rider, as shown just to the left of the centre of the beam. 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.

**454. 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 one of Wolter's balances, the left-hand side door 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 handle: 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 handle, 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 pan 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 of the 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 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 above referred to, 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.

**455. Apparatus Employed for Measuring purposes.**—These include measuring flasks, burettes, and other appliances.

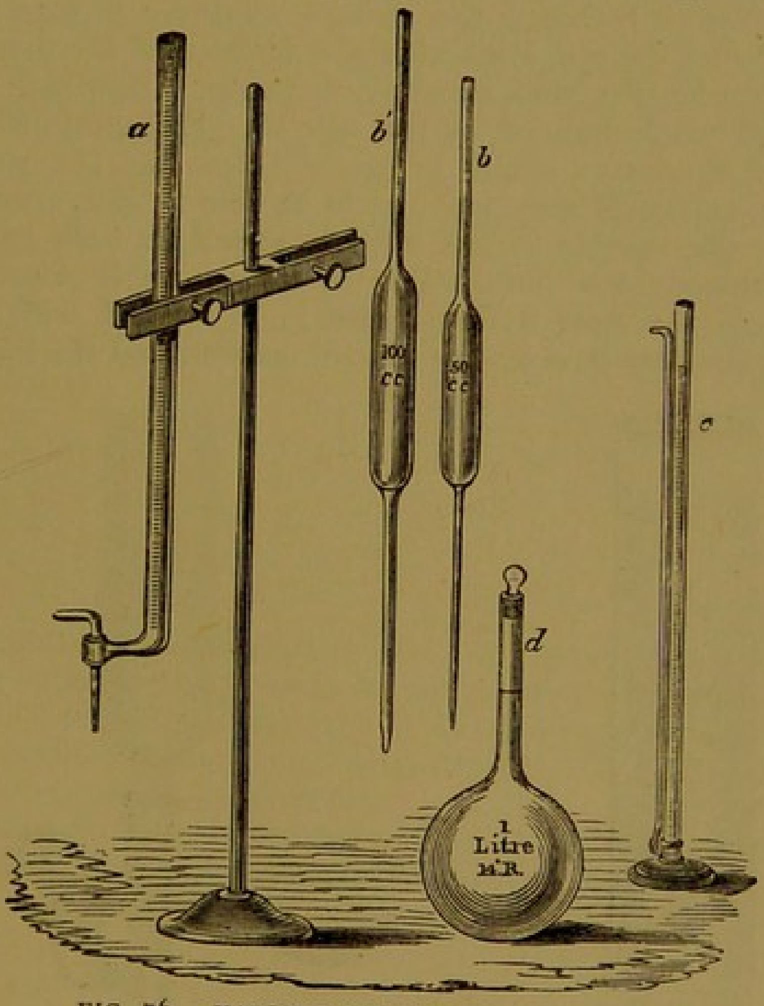


FIG. 76.—VARIOUS MEASURING APPARATUS.

**456. Burettes and Floats.**—Figure 76, given above, 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 the burette is much assisted by the use of "Erdmann's Float;" this little piece of apparatus, which is figured below (fig. 77), 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

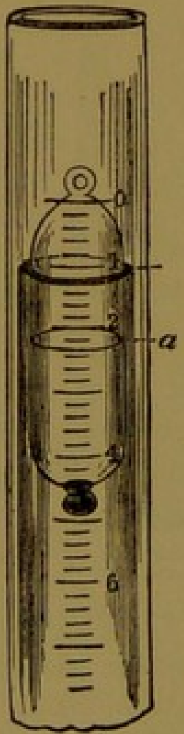


FIG. 77.—ERDMANN'S FLOAT.

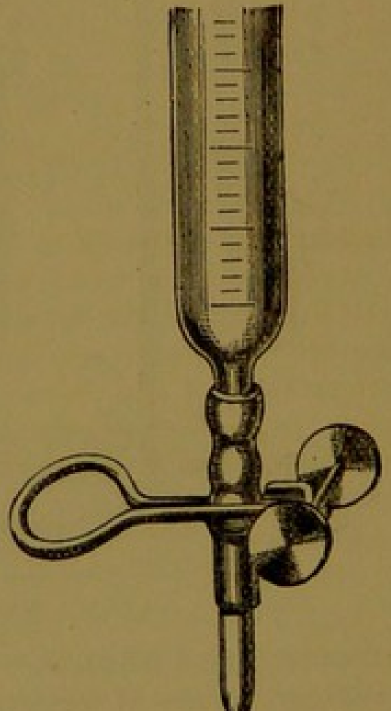


FIG. 78.—MOHR'S BURETTE, WITH SPRING CLIP.

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 78. 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.

**457. Pipettes.**—Turning once more to Figure 76, 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: 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.

**458. Measuring Flasks.**—The only other piece of apparatus that need be explained at present is the graduated flask, *d*, Figure 76; 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 XX.

## COMMERCIAL TESTING OF WHEATS AND FLOURS.

**459. 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.

**459A. Principles of Commercial Testing.**—The first question is whether or not those methods usually classed under the heading of "analytical" afford information which constitutes any ready guide in determining the purchasing value of either wheat or flour. Bearing in mind that a commercial assay (or testing) of wheat or flour must be simple, capable of speedy performance, and must yield results that shall bear directly on the question of value; the author has selected the following as the most important analytic determinations to make in order to judge the value of wheats and flours: Wheats—weight per bushel, weight of 100 grains of average size, strength, stability, colour, gluten, and moisture: Flours—the last five of the determinations for wheat. In wheats, the weight per bushel and of 100 grains are determined on the sample; for the other determinations a portion of the wheat should be ground, and the flour hand-sifted from the offal. Strength, stability, and colour should be determined in the dressed flour; gluten and moisture may be determined in either the dressed flour or the finely ground whole-meal. The strength, stability, and colour are determinations of the physical characters of the flour; the estimations of gluten and moisture are estimations of chemical constituents of the wheat or flour. The earlier part of this work will have made clear the meaning to be attached to each of these determinations; a description has also been given of the principles involved in their performance. The whole of these tests are of such a simple nature that their application will be readily understood.

**460. Practicability of Commercial Testing.**—The fact that manures and artificial cattle foods are continually bought and sold by analysis, shows that the principle is one which is capable of being worked commercially. Custom is undoubtedly the chief obstacle to its being successfully adopted in the corn and flour trade. In the open market, corn buying and selling is done from sample, and provided the bulk of the parcel tallies in appearance and general outward characteristics with the sample on which purchase is effected, the miller must trust entirely to his own judgment as to quality and yield of flour; it is well known that the opinion formed under these circumstances cannot be uniformly depended on. The difficulty is often raised that the time during which the purchase of wheat must be effected is not sufficient to permit any extended tests being made on the sample. But in reply to this objection, even now, arrangements exist by which certain allowances are claimed and made on bulk not coming up to sample. The London Corn Trade Association conducts a system of arbitration by which any such disputes and claims for allowance are heard and settled by their making an award. Supposing a system of commercial assay of wheat to be adopted for buying and selling purposes, the corn merchant would offer his samples under guarantee that their strength, gluten, &c., were so much, giving the results of assays he has had made on his behalf. In case of the buyer finding the bulk of the wheat not coming up to the seller's guarantee, he could as now refer the matter to arbitration; the only difference would be that a chemist would have a seat on the board of arbitrators, and would certify as to the respective merits of the samples in dispute, when subjected to a commercial assay. Should there grow up on the part of millers a real demand for some more definite system of valuation, as a condition of purchasing, than at present exists, the customs of the trade would adapt themselves easily enough to the altered circumstances.

But, after all, is this question of time such a serious obstacle, even as matters now stand? Provided that a real and steady demand existed for such tests, they could, with proper organisation, be made very quickly and expeditiously. The author's personal experience of wheat and flour testing enables him to state definitely that, provided it was guaranteed that a minimum of three hundred samples per year should be forwarded to him, he could furnish the results of testing within from three to four hours of receiving the samples. In special cases it might be possible to complete the testing in two hours. Supposing that such samples were forwarded by parcel post, the assays would be commenced immediately the samples were received, and the results could be communicated by telegraph. In this way sales could be effected, with the results of assays in the buyer's possession, almost, and in many instances quite, as quickly as is now done. At present such results can be forwarded very speedily after samples are received; but in order to attain such rapidity as mentioned, a sufficient number of samples would have to be received yearly to meet the expenses of the special arrangements necessary to enable the testing of such samples to be commenced on the moment of their arrival. Such tests in the numbers mentioned could be made at a fee of a half-guinea each, including the telegraphing of results. With a number of samples sent simultaneously from the one firm, and with the ultimate increase in the actual number of samples tested yearly, it is probable that this fee could be reduced. Should the demand arise, there would be no difficulty in arranging for the making of assays in the immediate vicinity of the larger markets : it would then be easily possible to take samples at the opening, say, of the Mark Lane market, assay them, and return the results before the closing. The author has so frequently been asked for particulars as to how a scheme of buying by assay would work, that he feels the foregoing information will be of interest.

The buyer of flour is in a somewhat different position to the purchaser of wheat : undoubtedly the final test of all flour is the quality of the loaf it will make ; so also this is the final test of wheat. The testing of wheat by the application of the baking test to the flour produced is evidently a method that is not under all circumstances applicable : the quantity required, and the time necessary for grinding, and then baking, are serious, if not unsurmountable obstacles in the way of the miller when purchasing his wheat. The leading bakers are, however, at present in the habit of buying their flour after making baking tests thereon : in this respect they are more favourably situated than the miller. The baking test has the advantage that the whole process is familiar to the baker, and is very nearly the exact counterpart of his baking operations on the larger scale. He feels that he can trust his judgment in the matter of the quality of a loaf of bread, but that he could not in the same way depend on the results of any system of testing however simple. With the spread of technical education, and particularly of a knowledge of the principles of chemistry and analysis, the baker will find himself able to form a correct judgment on the results also of commercial assays. The information given by such assays is of an indirect nature, but it is also frequently wider and fuller than that afforded by a single direct baking test.

While attaching the highest importance to baking tests, the author claims that the methods to be described, have the following distinct advantages—They can be made on much less flour than is required for baking, and also in much less time ; information is afforded, which could only be obtained so well, not by one but by a series of baking tests on the same flour. Thus, in the strength tests, two or three distinct tests are made on the flour with varying quantities of water ; these show not only the strength but also how the flour bears additional water, over and above the quantity required for dough of the requisite stiffness. Supposing sixty-eight quarts per sack is the quantity of water required for a certain flour, the addition of two quarts more may make the dough only slightly slacker ; with another flour, the extra two quarts would reduce the consistency of the dough perhaps two or three times as much as it did in the first : instances of this are given in chapter XVI., paragraph 351. To obtain this information from baking tests, two or more should be made with different quantities of water. So too with regard to the stability tests, they afford information as to the suitability of flours for use in the sponge or dough stage, in what is on the whole a more convenient manner than would a single baking test. Another advantage possessed by the system of testing here advocated, is that the only variable factor throughout the whole test is the flour being tested: no other substance is used which is changeable in its properties; the temperature, &c., are strictly under control; and with small quantities and special measuring instruments, both weights and volumes can be measured with extreme accuracy. Now to make bread, yeast is required, and this substance itself is so susceptible of change that bakers of long experience often have difficulty in deciding whether a bad batch of bread is due to the yeast or the flour; again, temperature and other working conditions are not so absolutely under control in baking, as in the system of commercial testing to be described.

It must not be supposed that the modes of testing, which form the subject matter of this chapter, are intended to supersede and supplant the judgment formed by the miller and baker as the result of their practical experience; it is only claimed that they constitute a useful and valuable adjunct to that experience, and often give information that is not afforded by the ordinary data on which the practical judgment is founded.

The above remarks have been made on the assumption that such commercial testings would be made by a professional chemist; doubtless, much of such work would be most profitably performed in that way, but with the spread of technical education among a younger generation of millers and bakers, they would be perfectly competent to conduct such testings for themselves.

**461. Commercial Assay of Wheat.**—Directions follow for making the various estimations already quoted as constituting a commercial assay.

**462. 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, 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;

$$\text{or, } \frac{80 \times \text{weight of wheat held}}{\text{weight of water held}} = \text{weight of wheat in pounds per bushel.}$$

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.

**463. 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.

**464. Grinding of Samples.**—It is impossible to so grind wheats by hand as to produce flours that shall compare with those yielded by the same wheats when reduced to flour by the most approved methods. But the sample may be ground so as to form flour that shall sufficiently well represent the straight grade flour of the wheat, to enable the ordinary tests of strength and stability to be applied to the flour. Further, though such hand-grinding produces a flour inferior to that made in modern milling processes, yet, as all the wheats are before testing hand-ground in a similar manner, the results obtained are comparative with each other.

Mr. Corcoran, of Mark Lane, informs the author that he is now prepared to supply special small stone mills for the purpose of grinding such samples for testing and analysis.

Whatever mill is used, first thoroughly clean the interior; then weigh the wheat and pass it through the mill; remove as much as possible of the meal from the mill, and weigh it. The stones of the mill should be so set as to make as much flour and as little middlings as possible. Dress the weighed meal through a sieve covered with about No. 9 silk, weigh both the flour and offal. This flour may be used for strength and rough comparative colour tests.

The gluten and moisture determinations may be made either in this flour or in fine whole-meal, this latter 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.

**465. Strength.**—First, refer back to chapter XVI., and carefully read paragraphs 347-351, on strength determinations. The description there given may be here supplemented by a few practical directions.

**466. Strength Burette.**—Under this heading may be described the method of testing flours by the burette only, without any other apparatus. In chapter XIX. a description of a burette is given, together with an account of Erdmann's float, as a means of reading with accuracy the height of the liquid in the burette. The strength burette, together with the viscometer, is shown in Figure 80: 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.

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 79.

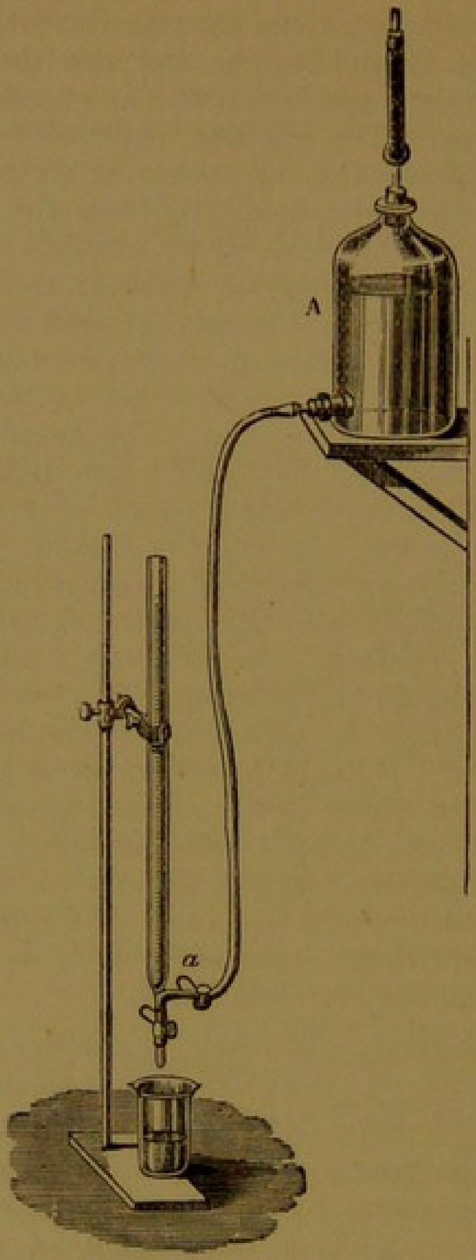


FIG. 79.—BURETTE, ARRANGED WITH RESERVOIR.

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 $2\frac{1}{2}$ 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 $4\frac{1}{2}$ 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 $4\frac{1}{2}$ lbs. of bread or $1\frac{1}{8}$ 4 lb. loaves: for every two quarts less substract the same amount.

The following is an example of such a table actually constructed by a baker for his own use. A baking test showed that a sack of a particular flour took 68 quarts of water and yielded 95 4 lb. loaves. The other figures are calculated. Of course, any loss during fermentation and general working affects the actual baking test and so is taken fully into account. The small percentage of loss on the variations in quantity of dough produced by stronger or weaker flours does not materially affect the yield, except in the case of flours which are either very far above or below the average. Every baker is strongly recommended to make a standard baking test for himself, but the following table agrees pretty well with the usual London practice.

| | | | | | |
|---|---|---|---|---|---|
| 56 | quarts per sack yield | 88¼ | 4 lb. loaves, or | 353 | lbs. of bread. |
| 58 | ” ” | 89⅜ | ” ” | 357½ | ” |
| 60 | ” ” | 90½ | ” ” | 362 | ” |
| 62 | ” ” | 91⅝ | ” ” | 366½ | ” |
| 64 | ” ” | 92¾ | ” ” | 371 | ” |
| 66 | ” ” | 93⅞ | ” ” | 375½ | ” |
| 68 | ” ” | 95 | ” ” | 380 | ” |
| 70 | ” ” | 96⅛ | ” ” | 384½ | ” |
| 72 | ” ” | 97¼ | ” ” | 389 | ” |
| 74 | ” ” | 98⅜ | ” ” | 393½ | ” |
| 76 | ” ” | 99½ | ” ” | 398 | ” |
| 78 | ” ” | 100⅝ | ” ” | 402½ | ” |

**467. Testing with Viscometer.**—As already explained, this instrument is of value as a means of obtaining an absolute measure of the stiffness or viscosity of any particular dough. Any judgment which depends on the faculty of touch must of necessity be uncertain; where great accuracy is required, an instrument of this kind gives a mode of measurement that is of considerable value. As a preliminary to directions for testing with the instrument a description of its various parts is given. Figure 80 is an illustration of the viscometer, together with a strength burette.

The figure is a sectional drawing 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

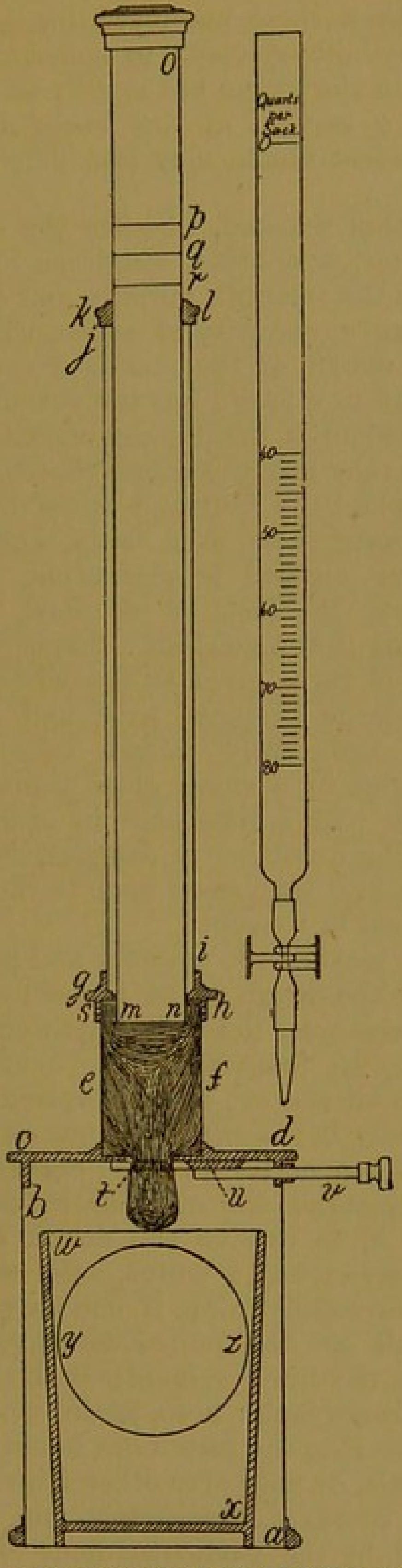


FIG. 80.—VISCOMETER AND STRENGTH BURETTE

give it the requisite weight. With the exception of the steel piston, *m n*, the instrument is throughout constructed of brass.

It has been already explained that the sixty-seconds' standard adopted for doughs is simply one chosen for convenience. 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 the 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: these have the great advantage that they mix the dough thoroughly, and with absolute uniformity. Either place the flour and water direct in the machine, or first roughly incorporate them in a basin, and then transfer to the machine. The former method is preferable, if one of Pfleiderer's absolutely water-tight machines be obtained. Give all doughs the same amount of mixing in the machine: this is readily accomplished by counting the number of turns given to the driving handle. The author drives his from the large pinioned axle, and gives each 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 bottom 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.

Having made one test on a sample of flour, and found whether too much or too little water has been added, try next another test with less or more water as the case may be, and again examine the dough viscometrically. Having obtained a pair of piston readings, one above and the other below the sixty seconds (or other pre-determined) standard, the actual quantity of water corresponding to the standard may be calculated as directed in paragraph 350, chapter XVI. For entering these tests it is recommended that a book be procured ruled both ways of the page: the strength results should then be entered as shown in Figure 52. 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 strength in quarts. Thus referring to Flour, No. 11, Figure 52, the 62 quart dough ran through in 82 seconds, and the 64 quart dough in 28 seconds: on these points being joined by a line, it cut the 60 seconds line at very nearly midway between the 62 and the 64 quart line, therefore the strength was taken as being 63 quarts. In this way, the strengths of various flours for intermediate points between two readings were arrived at. An inspection of Figure 52 shows that the upper portions of these lines graphically representing strength 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 strength may be deduced with sufficient corectness 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 52, representing the strengths 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 strength from the point where it cuts the 60 seconds line. Such a flour would probably have a strength of about 69·5 quarts. 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.

Among other uses to which this mode of testing may be put, the author suggests that millers should once or twice a-week examine their flours in this manner: they could thus see how nearly they approached to constancy in the character of their flour, so far as strength is concerned. When they were altering their mixture from time to time they would be able to trace the effects of the alterations in the mixture on the strength of the flour. A continuous record thus kept of the actual strength of a flour from week to week could not fail to possess great value and interest.

**468. 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 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 earlier stability tests, made by the author with the viscometer, were simply modifications of these. Samples of doughs were kept 12 or 24 hours 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 paragraph 351, chapter XVI., and are also represented in Figure 52. Some time ago the author had occasion to examine some similar flours, and found, to his surprise, that while the earlier samples fell off in twenty-four hours some ten or twelve quarts, those done later fell off little or nothing. There was some difficulty in accounting for this, until it was remembered that the former flours were tested during a hot July, while the latter tests were made in December, during a hard frost. This, then, evidently was the explanation: the higher temperature caused the gluten to soften and change with far greater rapidity. These experiments throw considerable light on one cause why a high temperature is so injurious during breadmaking. Apart from any action caused by fermentation, dough, composed of flour and water only, changes far more quickly in warm weather than in cold.

These experiments showed, that in order to obtain constant results in stability testing, it was necessary to always work at an uniform temperature. Comparatively few tests have as yet been made in this direction, but the following is the method now adopted by the author in determining stabilities. Knowing the strength of the flour, doughs are made with respectively 4, 8, and 12 quarts less water; these are placed in glass vessels with air-tight covers, and are then kept for six hours in a water-bath, maintained at a constant temperature of 25° C. by means of an automatic regulator. They are then tested by the viscometer. The stability tests quoted in paragraph 425, chapter XVII., were made in this manner.

**469. Gluten Testing.**—Having in the case of a wheat reduced it to a meal, or flour, the gluten estimation may be made. Crude gluten has already been defined as the insoluble albuminous matter of wheat or flour, together with a small quantity of fat. Its extraction is effected by enclosing a lump of dough in fine cloth, and then washing out the starch and soluble matters. In order that this operation shall indicate the quantity of gluten, it is necessary to conduct it with certain precautions to be now described.

**470. The Aleurometer.**—Not only should the quantity of gluten be determined, but also its character—whether firm and elastic, or soft and flabby. For investigating the character of gluten an instrument has been devised known as the "aleurometer." The essential part of this piece of apparatus consists of a brass cylinder about four inches long and one inch diameter; both the top and bottom can be easily removed. Through the top slides a piston rod half the length of the cylinder, viz., two inches, and graduated into 25 equal parts, each part evidently being the fiftieth of the length of the cylinder. At the bottom of this rod is fixed a piston, which is accurately fitted to the cylinder, up and down which it readily slides. A weighed quantity of the gluten to be tested is placed in the aleurometer, and this in its turn is arranged in an oil bath heated by a bunsen flame to a temperature of 150° C. (302° F.) Under the influence of the heat the water in the gluten volatilises, and causes the gluten to expand, thus raising the piston. The degree through which the piston is raised is taken as an indication of the quality of the gluten. According to the inventor, a gluten that does not raise the piston at all—that is, does not expand to one half the length of the cylinder—is unfit for bread making. The instrument, as made, has no means for keeping it at an exact temperature, and consequently its indications are thus rendered untrustworthy. The writer has fitted that used in his own laboratory with an automatic temperature regulator, such as previously described (chapter XI., paragraph 279), by which the temperature is prevented from varying; even then, however, the same gluten does not give constant results. The same weight from the same flour, in two successive experiments, in the one case may not raise the piston at all, and in another forces it to the top. The amount of rise depends on the way in which the gluten is manipulated. The best plan is to roll the required weight, namely, seven grams, into a ball, squeezing out as much of the water as possible.

After a little practice the results thus obtained agree fairly well, but must certainly be not trusted absolutely as a test of strength or weakness of flour. Some useful ideas may be obtained by inspecting the gluten after its removal from the instrument. On tearing open the little mass, the gluten from the best flours shows an uniform spongy texture, while that which is inferior has either not risen at all or is full of big bubbles. The heating for a short time in the aleurometer serves another good purpose: the gluten being rendered spongy is afterwards dried much more readily than when this treatment is dispensed with. The heating for a short time in the aleurometer does not, by decomposing the gluten, lessen its weight. Two samples of the same gluten, when wet, weighed each 2·25 grams; one was placed in the aleurometer for 15 minutes and then dried in the hot-water oven for 24 hours, this then weighed 0·922 grams. The second sample was placed in the hot-water oven direct, and weighed at the end of 24 hours, when its weight was 0·940 grams; it was again returned to the oven, and after a lapse of another 24 hours, weighed 0·917 grams.

When in gluten determinations it is wished to use the aleurometer, 30 grams of a flour, or 40 grams of a wheat meal, must be taken. In case this instrument is not employed, 10 grams of either flour or meal is a sufficient quantity to employ, but even when the aleurometer is not used as a measure of the strength of the gluten, it is convenient to employ it for the purpose of causing the gluten to expand as a preliminary to drying it in the hot-water oven. The method of procedure is, in each case, practically the same. The student should commence to practise on flours, because of their being simpler to work on than meals. In the following directions it is assumed that the aleurometer is to be used, but if not, the student can readily make the necessary alterations in his procedure.

On the pan of the coarser balance weigh out 30 grams of flour, transfer to a cup or small basin, and add about 25 c.c. of water by means of a pipette. Work into a dough by means of a spatula, allow the dough to stand for one hour, and then transfer to the washing cloth. For the purpose of washing the sample free from starch, &c., a piece of fine cloth is required. Various materials have been proposed for this purpose; muslin and fine calico have been used. The writer finds that fine silk, such as is used for dressing flours, answers the purpose admirably; a piece about twelve inches square is required. Wet, and if necessary, thoroughly clean the piece of silk. With the spatula take the dough from the basin in which it has been mixed, and place it in the centre of the silk. By the aid of the spatula thoroughly clean the basin, and having got the whole of the dough in the silk, gather the outer edges together round it, as though it were to be tied up like a pudding. It is necessary to do this carefully, as otherwise there is danger of losing some of the gluten during the subsequent operations. Next knead the mass between the fingers in a basin of clean water until most of the starch seems to have been washed out. Change the water in the basin and again go on with the kneading, taking fresh water from time to time. The washing should be continued until the water is no longer rendered milky. Next squeeze most of the water out of the silk, and then open it out. Remove the gluten from the interior, and roll the whole up together; look carefully over every part of the silk and pick off any little bits and add them to the rest of the mass. The gluten of some flours will be found to leave the silk readily and without trouble, that of others sticks to it most pertinaciously; in this latter case the reason is sometimes that the washing has not been sufficient. It is well to again carefully fold up the silk and wash once more, when often the gluten leaves the silk more readily. In case it still remains adherent there is nothing for it but to patiently remove every little bit, one at a time. One of the easiest methods of effecting this task is to spread out the silk on a piece of glass, and keeping it thoroughly wet, to rub the gluten with the wet finger; the gluten under this treatment becomes detached in little pellets, which must be added to the main lump. The silk must be gone over in this way until not the slightest bit remains on its surface. Another word of caution may be added here: when the gluten is soft and flabby, it is with rough treatment sometimes forced through the interstices of the silk, great care must therefore be taken not to be unduly rough in the kneading. The outside of the silk must be looked at in order to see that no such passage of the gluten through its meshes is occurring. If, with an unusually soft gluten, such should happen to be the case, the best plan is to wash the silk clean and begin again, working with even greater care than usual.

Having got the whole of the gluten together in a single lump, none being left on the silk, another stage in the washing must be commenced. Prior to this, place a piece of silk or muslin over the top of a beaker or jug, so as to answer as a sieve. Fill a basin with clean water, and wash the naked gluten in it. This is best done by dipping the piece in and then rubbing it vigorously between the palms of the two hands, occasionally giving them a twisting motion. Every now and then again dip the gluten in the water. Watch carefully through all this in order to see that none is lost. After a little time pour the water away on the piece of silk or muslin arranged as directed, and look to see that no pieces remain; should any do so return them to the main piece. Change the water, and go on washing until, even after a vigorous rubbing between the palms, the gluten yields no turbidity to the water. Great care is requisite for the accurate performance of this operation; the gluten must be watched through every step. It is very easy to err on the one side by not washing out all the gluten, or on the other by losing some through careless treatment.

The mass of gluten from the flour may be here left for a moment, in order to point out the method of treating a meal up to this stage of gluten extraction. The meal is weighed, made into a dough, transferred to the silk, and washed until it no longer causes the water to become milky, exactly as before. But now there is a difference: the silk contains the bran as well as the gluten, 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 the 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 gluten, whether from flour or meal, being clean, wipe off any adherent water, and weigh on the pan of the coarser balance. From 30 grams of a flour the weight will probably be from 7 to 9·5 grams. Enter the weight in the note book. (At the end of this description there will be given an example of how the entering should be made). Weigh off exactly 7 grams of the gluten for the aleurometer, and put the remainder outside on a wet piece of glass. The fingers and knife used for cutting the gluten must be kept moist. After the gluten is weighed, wipe the scale pan quite dry.

Before arriving at this stage the aleurometer should have been got ready for use, by heating it with the help of an automatic regulator to a temperature of 150° C. In use, the oil bath of the aleurometer should be fixed at a convenient height in the ring of the retort stand, the temperature regulator may then also be fastened by means of a small clamp to the rod of the stand. The bulb of the regulator must be immersed in the oil bath, so that its stem passes through one of the holes in the top of the inner vessel of the bath. Instead of oil, paraffin may be used in the bath; this is a white, wax-like substance, melting readily on applying heat; it possesses the advantage of not corroding the copper so quickly as oil, and also evolves a less disagreeable smell when heated. If paraffin be used it must be warmed enough to melt it in the bath, and then the inner casing of the aleurometer fitted to its place; the regulator may then also be fixed. Through another hole in the top of the casing, a mercury thermometer, graduated to 200° C., should be passed in order to test the temperature of the bath. Working at this temperature the regulator must only contain air; the adjustment must be made exactly as before described. The instrument being finished with, always open the air vent before turning off the bunsen.

Having, by means of the regulator, succeeded in getting the oil bath of the aleurometer at a constant temperature of 150° C., the gluten may be inserted for the purpose of being tested. Take off the top and bottom of the aleurometer, and oil the interior by taking just a little oil on the tip of the finger and rubbing over every part of the inner surface: a small quantity only of oil is necessary for this operation, as merely the slighest film is needed. Mould the seven grams of wet gluten into a ball, and insert it in the aleurometer, put on both bottom and cover, see that the piston slides up and down readily, and then place the instrument in its casing in the bath. In about ten minutes the gluten will rise; as soon as it becomes stationary, note the height on the scale to which the piston has risen, and enter it in the note-book. Before reading the height of piston give it a gentle tap on the top with the finger, as sometimes it registers too great a height, owing to the formation of a cushion of steam between the upper surface of the gluten and the piston. The remaining piece of gluten must now be added. Take out the aleurometer and remove the top, drop in the wet gluten, again put on the cover, and replace in the bath, let it remain for another ten minutes, and then take out. In case the piston has been forced to its greatest height, the instrument should be allowed to cool somewhat before the top is taken off, as sometimes the pressure of steam within is so great as to violently eject some of the gluten, on the top being removed. Bearing in mind this caution, take off the top and bottom of the aleurometer and take out the gluten; if the instrument has been properly oiled it is removed with ease. Tear the little roll of gluten open, lengthways, and notice its texture; this should be fine and spongy. Also smell the gluten in order to see whether it shows any signs of mustiness in its odour. The gluten has now to be dried: place it on a dish, labelled with the name or number of the sample, and dry it in the hot-water oven for twenty-four hours. At the end of that time remove the gluten, allow it to cool in the desiccator for five minutes, and then weigh on the analytic balance. These dry rolls of gluten are among the very few things which may be weighed direct on the pan of the balance. Where time is an object the gluten may be weighed earlier, but in ordinary laboratory work it is as well to let the glutens remain in the oven over-night. It is a good plan to divide the weight of wet by that of the dry gluten, and thus obtain the ratio; this is a useful check against mistakes in weighing. The results should appear in the note-book like the following example:—

SAMPLE OF FLOUR, No. 17.

Gluten *ex* 30 grams.

| | |
|---|---|
| Wet ... ... ... | 8·45 = 28·16 per cent. |
| Aleurometer ... ... | 47° |
| Dry ... ... ... | 2·864 = 9·54 per cent. |
| Ratio ... ... ... | 2·9 |

Tough and elastic when wet, fine spongy texture after being heated; colour good.

The calculation of percentages in a case of this kind is very simple. As 30 grams have been taken we have :—

As 30 : 100 : : 8·45 : percentage of wet gluten.

When the quantity taken is 30 grams the first and second terms of the proportion will always be the same, therefore all that is needed is to multiply by 10 and divide by 3, an operation readily performed by first moving the decimal point one place to the right, and then dividing. When 40 grams have been used, employ 4 as the divisor instead of 3; if 10 be taken, the percentage is at once gained by multiplying by 10.

**471. 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 shewn in Figure 81.

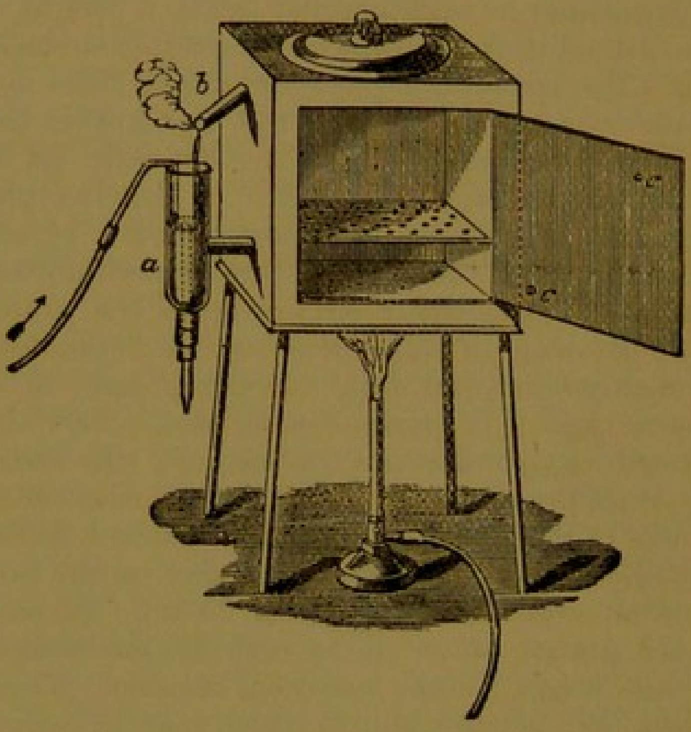


FIG. 81.—HOT-WATER OVEN.

The oven consists of an inner and outer casing, with a space between 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.

**472. 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.

**473. Interpretation of Gluten Results.**—As the first and one of the most important estimations made in the analysis of wheat or flour, the method of determining gluten has been described at full length. There are several suggested modifications of that that has been given, one of the most important being that the sample should be allowed to stand a longer time before being kneaded. Whatever method is employed, it is of the highest importance that absolute uniformity is observed in the method of testing; in this way results are obtained that may be fairly compared with each other. When giving methods for the determination of the soluble albuminoids, reference will again be made to the gluten, and a comparison instituted between the results obtained by its mechanical extraction, and the total albuminoids, soluble and insoluble, as estimated by purely chemical means. As has been frequently said, "It is comparatively easy to estimate the quantity of the gluten, but how about the *quality?*" The aleurometer is the result of one attempt to solve this problem; it, however, only does so in a somewhat rough fashion. With practice in its use, a division of the gluten of flours and wheats into strong and weak may be made, but no very fine lines of distinction can with certainty be drawn. As a result of experience, 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. It will often be found that a flour, which yields good baking results, contains only a moderately high quantity of gluten; the gluten would, however, be found on examination to possess those qualities to which favourable reference has just been made.

Generally speaking, a flour which is high in strength but comparatively low in gluten, will absorb a lot of water in doughing; but will fall off in fermentation and will lose considerably in weight in the oven. A flour of fairly high strength and with gluten high in both quantity and quality, will render a good account of all the water it absorbs, losing only the minimum quantity either in fermentation or in the oven.

**474. Estimation of 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, 2½ 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. (Orme & Co., of 65, Barbican, whose name has been already mentioned, have made a number of these counterpoises to order of the writer, for use with 2½ inch dishes. Other special apparatus for wheat and flour analyses, devised by the writer, may be obtained from this firm). 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 flours to do, weigh out exactly 5 grams of each 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 5 grams are employed, multiplied by 20 gives the percentage. An example should read thus in the note-book:—

MOISTURE DETERMINATION.
Sample No. 35, Dish No. VII.

| | |
|---|---|
| Weight of dish against counterpoise ... ... | —0·0015 |
| Flour taken 5 grams. | |
| Weight after drying 24 hours ... ... ... | 4·416 |
| Weight after another hour ... ... ... | 4·415 |
| Less weight of dish ... ... ... ... | —0·0015 |
| | 4·4165 |

$$\text{Moisture} = 5 - 4{\cdot}4165 = 0{\cdot}5835$$

$$0{\cdot}5835 \times 20 = 11{\cdot}67 = \text{percentage of moisture.}$$

It may be noted in passing that a difference of 5 milligrams in the actual weight amounts to just 0·1 per cent. difference in the estimated moisture.

**475. Baking Tests.**—The following are directions for making a baking test on a comparatively small quantity of flour: the quantity used, 3 lbs., produces from 4 lbs. to 4½ lbs. of bread. This may be baked either in one or two tin loaves.

First determine strength of the flour, either with the strength burette alone, or in conjunction with the viscometer. If the sixty-seconds standard is adopted, the dough had better be made with either 4 or 6 quarts less water, as if water be added to the full viscometric strength, the dough is much slacker than that used in many districts. This will present no difficulty to the practical baker, who can readily test for himself how stiff he requires his doughs to be, and can then either adopt his own viscometer standard or make a constant deduction from the strength 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.
51 ,, 21·8 ,,
52 ,, 22·3 ,,
53 ,, 22·7 ,,
54 ,, 23·1 ,,
55 ,, 23·5 ,,
56 ,, 24·0 ,,
57 ,, 24·4 ,,
58 ,, 24·8 ,,
59 ,, 25·3 ,,
60 ,, 25·7 ,,
61 ,, 26·1 ,,
62 ,, 26·6 ,,
63 ,, 27·0 ,,
64 ,, 27·4 ,,
65 ,, 27·8 ,,
66 quarts = 28·3 ounces.
67 ,, 28·7 ,,
68 ,, 29·1 ,,
69 ,, 29·6 ,,
70 ,, 30·0 ,,
71 ,, 30·4 ,,
72 ,, 30·8 ,,
73 ,, 31·3 ,,
74 ,, 31·7 ,,
75 ,, 32·1 ,,
76 ,, 32·6 ,,
77 ,, 33·0 ,,
78 ,, 33·4 ,,
79 ,, 33·8 ,,
80 ,, 34·3 ,,
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.

If wished, a determination of moisture may be made in the crumb of the loaf.

The above serves as a general method of making baking tests; the time of fermentation, temperature, quantities, &c., may be varied if wished; but if the object is to compare a series of flours, they should be treated as nearly as possible in the same manner.

The following are given as examples of how baking tests may be entered in the note-book:—

| | Hungarian Patent. | English Wheat Flour. |
|---|---|---|
| "Strength ... ... ... | 77 quarts. | 66 quarts. |
| Flour ... ... ... | 48 ounces. | 48 ounces. |
| Water ... ... ... | 33 ,, | 28¼ ,, |
| Salt ... ... ... | ½ ,, | ½ ,, |
| Yeast ... ... ... | ¾ ,, | ¾ ,, |
| | 82¼ ,, | 77½ ,, |
| Dough and Tin ... ... | 103½ ,, | 99¾ ,, |
| Less Tin ... ... ... | 22 ,, | 23¼ ,, |
| Dough ... ... ... | 81½ ,, | 76½ ,, |
| Loss during Fermentation ... | ¾ ,, | 1 ,, |
| Bread ... ... ... | 72½ ,, | 70¼ ,, |
| Loss in Baking ... ... | 9 ,, | 6¼ ,, |

Second dough when moulded and placed in tin was the slacker of the two."

It must be remembered that these 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 7 lb. baking test, and one on a sack of the same flour. Divide the yield of bread from the sack by that from the 7 lbs: then the quotient may be used as a multiplier in order to convert the 7 lb. yield into working yield per sack. Thus, suppose that this quotient is 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 XXI.

## DETERMINATION OF MINERAL AND FATTY MATTERS IN WHEATS AND FLOURS.

**476. 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.

**477. 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, one half must be taken for the phosphoric acid estimation, the other half must be used for the determination of potassium.

**478. Phosphoric Acid Estimation.**—For the purposes of this estimation two special reagents are required, known respectively as "Molybdic solution" and "Magnesia mixture."

**479. 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.

**480. 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.

**481. Mode of Analysis.**—Add to the solution of ash 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 their 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 phosphates, thus:—

$$\underset{\text{Ammonium phosphate.}}{Am_3PO_4} + \underset{\text{Magnesium chloride.}}{MgCl_2} = \underset{\text{Magnesium ammonium phosphate.}}{MgAmPO_4} + \underset{\text{Ammonium chloride.}}{2AmCl}$$

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

$$\overset{Mg_2}{48} + \overset{P_2}{62} \times \overset{O_7}{112} = 222. \qquad \overset{P_2}{62} + \overset{O_5}{80} = 142.$$

As 222 by weight of the pyrophosphate contains 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 half the total solution from 50 grams, the result, on being multiplied by 4, gives the percentage of phosphoric acid.

**482. 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 82, without disturbing the precipitate.

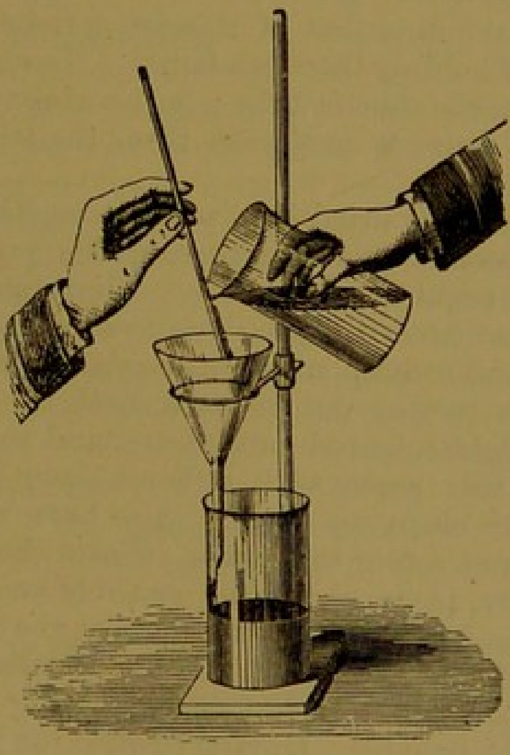


FIG. 82.

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 83.

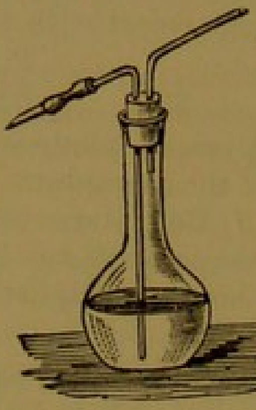


FIG. 83.—WASH-BOTTLE.

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.

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 disiccator, 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 precipiates, 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.

**483. 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, consequently 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.

**484. Potash Estimation.**—To the second portion 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).

**485. 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.

**486. Determination of Fat.**—The fat of meal and flour is estimated by treatment with either ether or rectified light petroleum spirit (*i.e.*, benzoline). 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. The petroleum spirit may be obtained by distilling benzoline, arresting the operation when the boiling liquid is at a temperature of 86° C. 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.

**487. Rectification of Petroleum Spirit.**—This distillation of benzoline is an operation that should only be performed by a person having considerable experience in chemical manipulation, and even then is fraught with danger unless every precaution is taken. The distillation should be performed in the open air. Take a large glass flask of about 120 ounces capacity, fit it with a good cork (indiarubber stoppers must not be used); bore two holes through the cork, one for the leading tube the other for a thermometer. Fit the leading tube by means of a good cork, to a condensing worm in metal vessel, such as is used for distilling water. Fit also by means of a cork the exit end of the tube of the condenser to a flask arranged as a receiver; this cork must have another hole bored in it and a two-bulbed thistle funnel, like *l* in Figure 84, inserted. Mercury must be poured into this funnel, so as to just fill the space between the two bulbs. The distilling flask must be arranged on a water-bath, having a tube by which steam may be led into it. Having put all the apparatus together, be sure that all the joints are tight; bring water to the condenser by means of tubing, and steam to the bath from a vessel within the building. The distillation is thus effected by means of the current of steam, and the steam pipe must pass through a small hole made specially for it. The apparatus is thus cut off entirely from any naked flames, and the operation can then be conducted without danger. Distillation must be stopped as soon as the thermometer registers 86° C. Rectified light petroleum spirit, distilling entirely below 80° C., and leaving no weighable residue, can be purchased from dealers in chemicals for analysis.

**488. 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 84, in which the complete apparatus is shown in section.

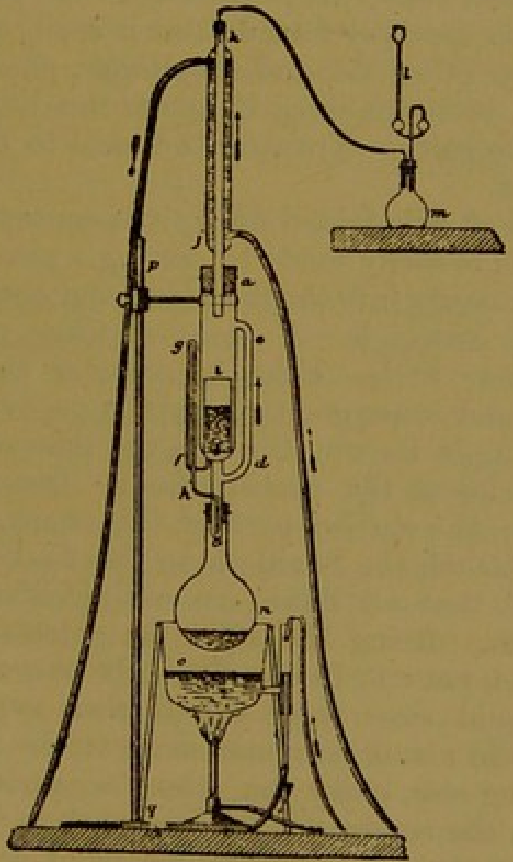


FIG. 84.—SOXHLETT'S EXTRACTION APPARATUS

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 small Liebig's condenser, *j k*. The body of this condenser should be about a foot 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 ⅜ 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. A small water bath, *o*, is also required.

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. (Some of the fat determinations, quoted in the earlier part of this work, are probably low from this cause). 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 air-tight. 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.

**489. 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; a special instrument for evaporations of this kind has been devised by Winter Blyth, and may be procured from the apparatus dealer. The apparatus consists essentially of a circular vessel of cast iron, having a support in the centre, on which is placed the dish, and around, a groove into which the edge of a bell-jar fits. This groove is partly filled with mercury, and so causes the bell-jar to make an air-tight joint with the cast-iron vessel. A hole in the top of the bell-jar is provided for a cork. When using the apparatus it should be placed on the top of a hot-water bath, with the dish containing the ether solution in its place. A leading tube is passed through the cork at the top of the bell-jar, and this in its turn is attached to a Liebig's condenser, with a receiver arranged for the ethereal distillate. The bath requires, under these circumstances, to be heated with a small bunsen flame; a rapid stream of water must, however, be sent through the condenser, and the operation should be conducted in a good current of air. It is still safer to fit the receiver to the condenser with a cork, and also add a mercury thistle funnel to serve as a valve, as in the Soxhlett described in the last paragraph. Where practicable it is advisable to reserve a small room for operations with ether, allowing no lights whatever to be used therein, and employing steam, generated in a boiler outside the room, for all heating purposes.

A simpler, and for this purpose, probably as efficient an arrangement as Blyth's, is made in the following manner:—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.

**490. Another Form of Extraction Apparatus.**—The author has recently used the form of extraction apparatus shown in figure 85. Directions follow for its construction and use.

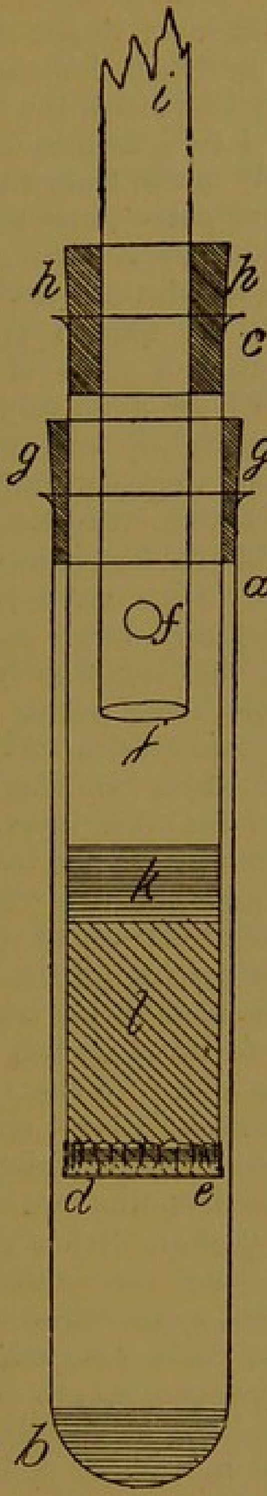


FIG. 85.—SIMPLE FORM OF EXTRACTION APPARATUS.

Take a large test tube (boiling tube) about 7 inches long and 1¼ inches diameter, procure a piece of vulcanised india-rubber tubing, of such an external diameter that it tightly fits the boiling tube on being pushed into it. The walls of this tubing should be an eighth or full eigthth of an inch in thickness. Next select a piece of glass tubing, of such a diameter that, when placed inside the tube *a b*, there shall be a space all round it of about from $\frac{1}{16}$ to $\frac{3}{32}$ of an inch. In other words, the external diameter of this tubing must be from $\frac{1}{8}$ to $\frac{3}{16}$ of an inch less than the internal diameter of the boiling tube. From this tubing, cut a piece 6 inches long, round off the ends in the blowpipe flame, and slightly flange the one end as at *c*, just as is done with a test tube. Two inches from the flanged end of this tube, with the blowpipe, fuse a hole through the side of the tube, from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. These tubes may, if wished, be obtained ready made from the apparatus dealer. In the next place, a piece of filtered paper must be tied on to the lower end of this tube. First of all cut out a piece of very fine muslin or flour dressing silk, stretch this over the end, and slip over it a tightly fitting india-rubber band, stretch the muslin tight, pulling all creases out round the edge. Next put on a piece of thick Swedish or Rhenish filter paper, again fixing with an india-rubber band, and very carefully smoothing out the creases or tightly folding them down. In the case of the paper, this must be done very carefully, so as not to break or tear it. Again, over the paper fasten on in the same manner a second piece of muslin or silk. The india-rubber bands should all be worked back about an inch from the end. Once more, look to see that the whole fit neatly and tightly, without any large puckers or creases. Next, as close to the end as possible, bind this tightly round and round with some very stong thread; tie neatly, so as not to allow a big knot to project; and lastly cut the paper and muslin off close to the thread, so as to leave no ragged or frayed ends. In this way a sort of drum-head is made of filter paper placed between layers of muslin or silk for the sake of protection. This constitutes the tube, marked in the figure *c d*; the filter is shown at *d e*; and the hole through the side at *f*. Next cut off a piece of the india-rubber about $\frac{3}{4}$ of an inch long. With a very sharp pen-knife take a cutting off the interior of this tubing, so as to make it about $\frac{1}{16}$ of an inch, or rather less in diameter at the one end, while the other is allowed to stand its full thickness; this then makes the cork, *g g*. To the open end, *c*, of the tube, *c d*, fit an india-rubber cork, *h h*; through this bore a hole large enough to take the end, *i j*, of the inverted condenser tube. This completes the apparatus. In order to remove all soluble sulphur from the two corks, *g g* and *h h*, soak them for twenty-four hours in a beaker, with a good quantity of light petroleum spirit. During this time the beaker should be kept under a desiccator, in order to prevent evaporation of the spirit. At the end of twenty-four hours take the corks out, wash them in spirit, and give them another soaking for the same length of time in a fresh quantity of the spirit. They will then have swollen considerably, through absorption of petroleum spirit, but in an hour or two will regain their original size.

To perform a fat extraction, weigh out a quantity of the meal or flour, sufficient to fill the tube *c d* up to about the height of the shaded part, *l*, in the figure. Close the hole *f* with the finger, and pour in the meal by means of a gutter of paper, taking care that none is lost, and that none finds its way out through *f*. Next, by means of the cork *g g*, fasten *c d* inside the tube *a b* in the position shown. The hole *f*, must be just below the cork *g g*. Pour into *c d* sufficient ether or petroleum spirit to saturate the flour or meal, and to form a layer about a half-inch deep on its surface. Next, cork in the end of the condenser *i j*, by means of the cork *h h*, so that its end is just below the hole *f*. This whole apparatus takes the place of the soxhlett and flask *n*, shown in the previous illustration. The water-bath should be so arranged that the end of the tube *a b* just dips into the water: the condenser may be arranged with either the separate flask or small U-tube, just as with the soxhlett. Turn on the water through the condenser, and heat the bath: by this time the petroleum spirit will have percolated through the flour, and collected in the bottom of *a b*. As soon as the spirit boils, its vapour passes through the hole *f*, in the tube *c d*, and up the condenser; the condensed spirit drops on to the top of the flour, through which it percolates, taking the fat with it down into the outer tube. This operation is allowed to proceed until all the fat is exhausted. At times, flours only permit the ether or spirit to percolate with extreme slowness: in such cases the apparatus has the advantage that it cannot overflow; for even when the whole of the ether is in *c d* it leaves a considerable space between its upper surface and the hole *f*. As drop after drop finds its way through, it is volatilised and returned to *c d*, leaving its modicum of fat in *a b*. At the close of the operation, pour the fat solution from *a b* into the counterpoised dish; rinse out the tube with successive small quantities of ether or petroleum spirit into the dish. Working with this apparatus, the total quantity of ether necessary is so small that no necessity arises for its distillation.

When one estimation is completed, the exhausted flour or meal must be poured out of the inner tube, which should be dusted out with a camel's hair brush; the next sample may then at once be inserted, without any further cleaning or washing of the tube being necessary.

The apparatus must be taken to pieces as soon as finished with; otherwise the india-rubber corks will swell through absorption of ether and burst the tubes.

## CHAPTER XXII.

### ACIDIMETRY AND ALKALIMETRY.

**491. Explanation of these Terms.**—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.

**492. 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.

**493. Indicators: Litmus and Phenolphthalien.**—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." 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. Another indicator, much more delicate than litmus, is phenolphthalien; this body, however, possesses the disadvantage of being unsuitable in the presence of carbon dioxide or ammonia. Phenolphthalien 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 phenolphthalien to an acid solution produces no colour, but with the slightest excess of alkali an intense magenta red is produced.

**494. 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 a few drops of litmus. 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 solution becomes reddish-violet; next boil the solution gently over a sand-bath for two or three minutes, the liquid resumes its blue colour as the dissolved carbon dioxide is expelled. Continue adding the sulphuric acid solution, drop by drop at the last, boiling between each addition, until finally the colour becomes a permanent violet. 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.

**495. 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 phenolphthalien 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.

**496. Decinormal 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.

**497. 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 phenolphthalien to 100 c.c., but should strike a distinct and permanent pink on the addition of a drop of $\frac{N}{10}$ soda.

# CHAPTER XXIII.

## SOLUBLE EXTRACT, ACIDITY, AND ALBUMINOIDS.

**498. 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 albuminoids, sugar (maltose), 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 employed for the determination of the acidity and soluble albuminoids. 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 that 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.

**499. 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.

**500. 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 22 grams of flour in 253 c.c. of water. 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. A determination of soluble extract should read in the note-book—

“ Estimation of soluble extract in No. 29.

Made up 10 per cent. solution in usual manner, and evaporated 25 c.c. in dish No. 7.

| | |
|---|---|
| Weight of dish against counterpoise … … | − 0·004 |
| Weight of dish and extract … … … … | 0·139 |
| Less weight of dish … … … … | − 0·004 |
| Weight of extract … … … … … | 0·143 |

$0·143 \times 40 = 5·72$ per cent."

Graham suggests that in order to determine roughly the amount of soluble extract yielded by a flour that alcohol should be added to the aqueous infusion. This would cause the precipitation of the albuminoids, dextrin, and more or less of the maltose. After standing a certain time, the amount of precipitate is estimated by its depth. The less soluble extract, the less is the quantity of precipitated matter. The unfortunate part of this test is that it is difficult to judge accurately of the quantity in this way, as at times the precipitate may settle more closely than at others. It has been further proposed to filter off this precipitate and weigh it. There is, however, no advantage in such a course over the method of determining the whole soluble extract, especially as the precipitation methods entails an additional filtering. It must not be forgotten that this alcohol precipitate is a mixture of several of the soluble constituents of the flour, and that it does not consist of albuminoids alone.

**501. 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 phenolphthalien 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 indiarubber 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 $\times 0·009 \times 10 =$ 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.

**502. Estimation of Albuminoids by Combustion Process.**—The student is already aware that wheat contains a considerable percentage of organic nitrogenous bodies, and that these have been termed albuminoids from their chemical semblance to albumin. Certain of these bodies are soluble in water, others are insoluble. Directions have already been given for the estimation by mechanical means of the insoluble albuminoids, these being classed together for practical purposes under the one name of gluten. The determination of the soluble albuminoids is effected by strictly chemical operations. The most elementary of these is that depending on an estimation of the organic nitrogen contained in the body. When a nitrogenous organic compound is mixed with a large excess of caustic potash or soda, and then heated to a dull redness in a vessel out of contact with air, the nitrogen of the body combines with a portion of the hydrogen present, and is evolved as ammonia; the carbon comes over in part as carbon dioxide, in part as tarry matter consisting of volatile hydro-carbons, and when present in large excess may remain in part as free carbon. It is evident that, by measuring the quantity of ammonia produced during this operation, the percentage of nitrogen in a body may be determined, and thus indirectly that of the albuminoids. The evolved ammonia is collected and retained by causing the gases produced by decomposition to pass through either dilute hydrochloric or sulphuric acid, when it forms either ammonium chloride or sulphate. For very accurate analyses it is customary to employ hydrochloric acid, and then estimate the ammonium chloride in the usual way by precipitation with platinum chloride; for technical purposes, however, it is more usual to pass the evolved gases through an excess of standard acid, and then determine the amount of ammonia by afterwards titrating with standard alkali. In this case either normal or decinormal sulphuric acid may be employed. This particular analytic operation is usually spoken of as an estimation of nitrogen by combustion.

**503. Materials Required.**—A description of the apparatus and materials necessary follows.

**504. Soda-Lime.**—As caustic soda and potash are very deliquescent, and at the same time disagreeable substances to manipulate, "soda-lime" is employed in their stead; this body is simply lime slaked in strong solution of caustic soda, and then evaporated to dryness and ignited. Soda-lime may be purchased ready prepared, or may be made in the following manner:—Dissolve a pound of crude caustic soda in as little hot water as possible, and slake in the solution two pounds of recently burned quicklime; add the lime, a little at a time, and stir thoroughly with an iron road until all lumps have disappeared. The mixture should now be of a thick creamy consistency; pour into a clean cast-iron saucepan or pot, and evaporate to dryness. Raise the saucepan and its contents to a dull red heat, and then while warm reduce the soda-lime to a tolerably fine powder in an iron mortar. Keep in a clean, dry, well-stoppered bottle. The powder thus obtained is not deliquescent, and keeps for an indefinite length of time.

**505. Asbestos.**—Some asbestos is also required; in the matter of this substance the best is the cheapest (the United Asbestos Company, of 161, Queen Victoria Street, supply the best Italian carded fibre at three shillings a pound.)

**506. Combustion Furnace.**—The combustion is performed in a tube, which is heated in a special form of furnace, called a combustion furnace. These in their older form were adapted for use, with charcoal as a fuel, but those now employed are almost universally designed for employment with gas. The actual construction of the furnace may be readily gathered from an inspection of the apparatus; it will therefore suffice our present purpose to state that the furnace essentially consists of a frame, carrying a row of bunsen burners, by means of which the tube is heated; each individual burner is supplied with a separate stopcock, by which it may be turned on or off independently of the others. The part of the furnace designed for the reception of the combustion tube is enclosed with small fire-clay tiles, by means of which the heat is retained; these tiles are moveable at pleasure. Kerslake, of Bristol, has recently introduced a very cheap and simple form of combustion furnace. It has the additional advantage of being economical in the matter of gas consumed.

**507. Iron Combustion Tubes**—For making combustion tubes a difficultly fusible variety of glass tubing is commonly used, but when a number of analyses have to be made, iron combustion tubes are far more convenient, and are now frequently employed. Get an intelligent gas-fitter to make them as represented in Figure 86. He should select some of the tubing known as wrought-iron barrel, about seven-eighths of an inch external diameter, and cut off a piece rather over 20 inches long, one end is then to be welded up as shown, *a b*; for *b c* a piece of tubing nine inches long and a quarter-inch bore is required. In order to connect the two a hole must be bored at *b* and tapped; a thread is then to be cut on the smaller tube, and the one screwed into the other as tight as possible. A good joint, made in this way, should be perfectly air-tight after being heated to redness. The open ends at *a* and *c* must be carefully filed out, so as to present a smooth surface to corks. Before use each tube must be made redhot in the furnace throughout its whole length—branch as well as the main portion.

**508. U-Tube.**—The acid used for the purpose of collecting the evolved ammonia is most conveniently placed in a "U-tube" with three bulbs, *d e f*; the limbs of this tube should be eight inches in length. Fit a good cork to *a*, and pass through it a leading tube of glass, which is connected by means of a second cork to the U-tube; the further end of the U-tube should also be fitted with a cork and small piece of bent glass tubing, as shown; also cork up *c* with a good cork. All these joints must be made with great care, as it is essential that none of them shall show the least signs of leakage. This constitutes the apparatus necessary for the combustion.

**509. Description of the Analysis.**—The first step in making the analysis is to evaporate down a portion of the solution, the preparation of which has already been described, to dryness. Take a porcelain evaporating basin about five inches in diameter, and pour into it 50 c.c.

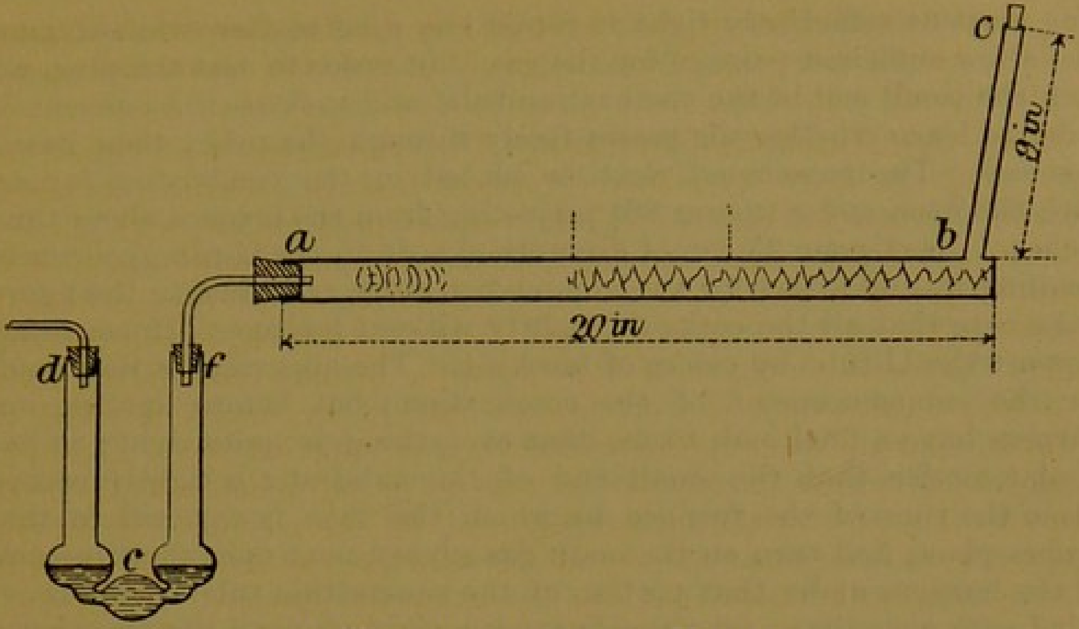


FIG. 86.—COMBUSTION AND U-TUBES.

of the solution. Next add about an ounce of recently ignited fine sand; this should be spread in as thin a layer as possible over the bottom. Evaporate over the water bath; it is well to stop just short of dryness, as the perfectly dry residue is only got out of the dish with difficulty. In case the residue has become quite dry and brittle, it again softens on being kept a few hours. Having cleaned the combustion tube and U-tube, and got all the apparatus required in readiness, heat over a bunsen burner in an iron dish sufficient soda-lime to about half fill the combustion tube; let this cool, and pour about half of it on the residue in the evaporating basin. By means of a thin steel spatula detach the residue from the basin and carefully mix with the soda-lime. Break down any lumps with a pestle, and when the whole is thoroughly mixed transfer to the combustion tube. This may be effected by putting the mixture on a piece of glazed paper and then pouring it down the combustion tube, the smaller end of which must be corked. Having cleaned out as much as possible of the residue from the dish, pour in two or three drops (not more) of water and just a pinch of soda-lime, give the dish a careful rinsing with the mixture, which dissolves off any residue still adhering to the dish. Mix this with some more of the soda-lime and transfer to the tube; finally rinse out the dish with the remainder of the soda-lime, and pour it into the tube. The soda-lime and residue will now rather more than half fill the tube. Holding the branch piece upright, tap the tube gently on the bench in order to make a passage along the top of the soda-lime mixture for the escape of the evolved gases.

In order to prevent any particles of soda-lime being mechanically carried over by the gases liberated during the act of combustion, a plug of asbestos is inserted in the open end of the tube. Take a sufficient quantity of this material to form a plug about two inches in length, and heat it in a crucible over a bunsen flame for about a minute in order to drive off any traces of ammonia. Then insert the asbestos far enough in the tube to allow about an inch clear between it and the cork. This plug must fit sufficiently tight to retain any solid matter, while it must also allow sufficient passage for the gas. In order to test the plug, uncork the small end of the combustion tube and suck at it a moment in order to learn whether air passes freely through the tube; then recork this end. The tube must next be placed in the combustion furnace with the open end *a* (figure 86) projecting from the furnace about three inches. Next pour 25 c.c. of decinormal soda in the U-tube, previously cleaning it, and attach to the combustion tube as shown in the figure. Take care that all the corks fit tightly without leakage. If necessary, support the U-tube by pieces of blocking. The apparatus is now ready for the commencement of the combustion; but before lighting any burners have a final look to see that everything is quite right; in particular, notice that the small end of the tube at *c* is tightly corked. Place the tiles of the furnace by which the tube is enclosed in their proper place, and turn on the main gas supply, next open the stop-cocks of the burners under that portion of the combustion tube which is not filled with soda-lime; let these burners remain on until the fore part of the tube is at a dull red heat. Should the outer end of the tube become so hot as to char the cork, pour a little water on it and turn out one or two of the end burners of the furnace. It is a good plan to wrap a little tow around the end of the tube outside the furnace and cause water to drop on it from a can with a tap at the bottom, suitably placed. A very little water allowed to drop in this way continuously will be sufficient to prevent any over-heating of the cork. During the time that the outer part of the tube is being heated the air should escape in bubbles through the acid in the U-tube: should it not do so there must be a leak; the most frequent reason is that the small end of the combustion tube is at times left uncorked. As soon as the outer part of the tube attains a dull red heat, turn on the burners under the mixture, two at a time, at intervals of two or three minutes. The rate at which these burners should be turned on depends on the rapidity with which gas is being evolved through the U-tube. The gas should escape in a gentle stream of bubbles with a distinct interval between each; should the gas escape very slowly more burners may be opened; in case the gas comes off too quickly turn one or two burners out. Very little practice will enable the student to so regulate his heat as to get the gas coming off at the proper rate. The aim is to make the combustion as rapidly as is consistent with the thorough absorption and retention of he whole of the ammonia by the acid in the U-tube. When the whole of the tube is at a full red heat, the combustion may be considered complete; at this stage the bubbling of the gas through the U-tube will also have ceased. Toward the end of the operation, discontinue the flow of water on the tow around the end of the tube in order that the cork may get sufficiently hot to drive over any moisture which may have condensed thereon. The combustion being over, turn off the gas from the furnace; as the tube cools, the liquid in the U-tube will recede toward the furnace; uncork the small end at *c* and draw a gentle current of air through the tube by an aspirator attached to the exit-tube at *d*. The air can be drawn through by sucking with the mouth, but as the gases contained within the tube have an unpleasant taste and odour, this method is seldom employed, especially as an aspirator is so easily constructed. Take a flask of twenty-four or thirty-two ounces capacity, fit to it a cork; through which bore two holes for glass tubing. Pass one piece of tubing down to the bottom of the flask and bend it over at right angles just outside the cork. The other piece of tubing should be about a foot long and must be just passed through the cork, so that all its length projects out of the flask. To use this aspirator, fill the flask with water, replace the cork and connect the end of the tube which reaches to the bottom of the flask by means of indiarubber tubing to the exit-tube, *d*. Pinch this tube between the finger and thumb and invert the flask over the drain. The water tends to run out through the long tube, and does so on the removal of the pressure on the rubber tube; at the same time it draws the air after it through the combustion tube. Air to the extent of three or four times the volume of the combustion tube should thus be drawn through in a gentle stream. The object of this is to sweep out any traces of ammonia the tube may contain and cause their absorption by the acid in the U-tube. When sufficient air has passed, turn over the flask and disconnect the indiarubber tubing. Carefully withdraw the cork from *a*, and by means of the wash-bottle, blow a small stream of water into the glass tube in order to wash its contents, if any, into the U-tube. It may be of interest to mention that of late the writer has used a bent tube connecting *a* with *f* of drawn brass instead of glass; it has the advantage of being unbreakable, but requires careful cleaning.

The acid in the U-tube requires next to be titrated with decinormal soda. Pour the acid out into a porcelain evaporating basin, and rinse the U-tube thoroughly with distilled water, adding the rinsings to the main portion of the acid. Add two or three drops of litmus solution, and then run in the soda from the burette until the neutral point is reached. As the acid is usually somewhat coloured by the products of the combustion, it is sometimes rather difficult to determine with exactitude when the reaction is complete, as the litmus remains of a violet shade even after the addition of several drops of the soda. The colour can frequently be seen better in a thin layer of the solution, therefore pour most of the acid in a clean beaker and note the tint of the small quantity remaining in the basin, if too red add a little more soda, and pour back the acid solution from the beaker, stir up, and again pour off the most of the solution. By operating in this manner the point of neutrality can be determined with accuracy. This will have completed the analysis; it now remains to calculate the results. As 25 c.c. of $\frac{N}{10}$ acid were taken, it follows that that quantity, less the volume of $\frac{N}{10}$ soda required to neutralise the acid after the combustion, has been neutralised by the evolved ammonia. The easiest way to continue the explanation will be to give the results of an analysis, which will also serve the purpose of showing how such results should be entered in the note-book :—

"Estimation of soluble albuminoids in No. 30 by soda-lime combustion.
50 c.c. of 10 per cent. solution evaporated to dryness with sand.
Combustion performed as usual.

25 c.c. of $\frac{N}{10}$ sulphuric acid in U-tube.
21·45
4·30
---
$\frac{N}{10}$ soda required = 17·15
Acid neutralised by evolved ammonia =
25—17·15 = 7·85 c.c.
7·85 × 0·177 = 1·39 per cent. of soluble albuminoids."

The entry quoted will be plain, except the multiplying by 0·177 in order to obtain the percentage of soluble albuminoids; the student now requires to see the reason for this step. Decinormal sulphuric acid contains 0·0049 grams of $H_2SO_4$ to the c.c.; $\frac{N}{10}$ ammonia, by which $\frac{N}{10}$ acid would be exactly neutralised, contains 0·0017 grams of $NH_3$, or 0·0014 grams of N per c.c. Every c.c. of $\frac{N}{10}$ acid neutralised by the evolved ammonia represents, therefore, 0·0014 grams of nitrogen evolved from the contents of the tube; consequently the number of such c.c. multiplied by 0·0014 gives the weight of nitrogen yielded by the substance being analysed. Albuminoids contain $\frac{1}{6\cdot 33}$ of their weight of nitrogen, therefore the weight of nitrogen evolved multiplied by 6·33 gives the weight of albuminoids. It next remains to calculate from this the percentage. When 50 c.c. of a 10 per cent. solution have been taken, that quantity contains the soluble matter of 5 grams of the meal or flour, so that the percentage is obtained by multiplying by 20. The whole of this calculation is shown below:—

7·85 × (0·0014 × 6·33 × 20) = 1·39 per cent. As the figures within the brackets are constant (*i.e.*, never vary in different analyses) they may be multiplied together once for all, and the result used as a constant factor or multiplier:—

0·0014 × 6·33 × 20 = 0·177 = factor.

In this way the figure given above has been obtained. The student must remember that this factor is only applicable when the quantities directed have been used.

The iron tubes after each combustion should have the asbestos taken out and reserved for further use; they may then be cleaned by filling them with water, and allowing them to stand for a time; then, by means of an iron or steel rod, loosen the mass of soda-lime and wash it out.

**510. Estimation of Albuminoids by the Ammonia Process.**—In addition to the soda-lime or combustion process for the determination of albuminoids, there is another method of estimating these bodies known as the "Ammonia Process." Wanklyn and Chapman invented this process, and first applied it to the determination of nitrogenous organic bodies in potable waters. It was soon found that it was also applicable to the estimation of the albuminoids in such substances as wheat, flour, and similar bodies. In Wanklyn and Cooper's little work on bread analysis the authors describe the process, and even claim for it superiority, from the point of view of accuracy, over the soda-lime combustion method already explained. It is doubtful, however, whether this opinion would be endorsed by the majority of chemists; nevertheless the process, from its being so much more quickly performed, can often be advantageously substituted for the more tedious combustion method. With sufficient care, and the observing of certain precautions, results can be obtained that agree most closely with those yielded by nitrogen combustions. The student should practise the two methods against each other; he will then, in all probability, find that for most purposes the ammonia process is sufficiently accurate.

**511. Principle of Ammonia Process.**—The method depends on the fact that most nitrogenous organic bodies, on being boiled with a solution of caustic potash (KHO) and potassium permanganate ($K_2Mn_2O_8$), evolve a portion of their nitrogen as ammonia. If the steam be condensed in a Liebig's condenser, the quantity of ammonia may be determined in the distillate (*i.e.*, the distilled water which comes over). The actual quantity of ammonia in the distillate is extremely small, recourse is therefore had to "Nessler's Ammonia Test;" this test depends on the fact that "Nessler's solution," the composition of which is given below, produces a brown colouration in a water containing the merest trace of ammonia. The actual quantity of ammonia is judged by the depth of tint produced, compared with that caused by a solution of ammonia, or an ammonium salt of known strength. As the quantities of ammonia that have to be measured are small, and as ammonia is always present in both ordinary water and air, it becomes necessary to use special precautions to prevent error. The reagents necessary will be first described, then the apparatus used, and lastly, the method of making the analysis. There will be required Nessler solution, distilled water free from ammonia, standard solution of ammonium chloride, and alkaline permanganate solution.

**512. Nessler's Solution**—Dissolve 62·5 grams of potassium iodine (KI) in about 250 c.c. of distilled water; set aside a few c.c. of this solution. Prepare a cold saturated solution of mercury chloride ($HgCl_2$) by adding the finely powdered salt to water, and shaking up so long as any is dissolved, then adding a little more, and warming gently until this also is dissolved. Then cool the solution; the excess of mercury chloride will separate as crystals, and the solution is known to be saturated. Should no crystals be thus formed on cooling the solution, it is probable that not sufficient of the salt has been added, add therefore a little more, dissolve by gently heating, and again cool the solution. Having thus prepared a saturated solution of mercury chloride, add this to the potassium iodide solution until the precipitated mercury iodide ceases to be re-dissolved on stirring. When a permanent precipitate is thus produced, add the small portion of potassium iodide solution which was set aside, so as to dissolve this precipitate. Then continue adding the mercury chloride solution until a *very* slight permanent precipitate is obtained. (The object of setting aside a small portion of the potassium iodide is to enable the mixture to be made rapidly, without danger of over-shooting the quantity of mercury chloride necessary.) In the next place dissolve 150 grams of solid potassium hydrate, fused stick or cake, in 150 c.c. of distilled water;

cool the solution, and add it gradually to that previously prepared. Make up the whole with distilled water to one litre. This solution throws down a slight brown precipitate; allow it to stand until it becomes clear, and then decant it, without disturbing the sediment, into a clean bottle. The solution will now be of a pale greenish-yellow colour, and is ready for use. As strongly alkaline solutions have a tendency to set glass stoppers, it is a good plan to store this reagent in a bottle having an india-rubber stopper. A smaller bottle should be filled from the store bottle, and kept for use.

**513. Distilled Water Free from Ammonia.**—A still and condenser should be reserved specially for the preparation of this reagent. A four to six gallon still of copper is most convenient. Thoroughly rinse both the still and condenser, then fill the still with water, and render it distinctly alkaline by the addition of sodium carbonate. Commence to distil, and collect the water in Winchester quarts. The first bottle or two are almost certain to contain ammonia, they must therefore be rejected for this purpose, but may be used for ordinary analysis. After one or two bottles have been thus distilled, proceed to test the distillate for ammonia. To do this a "Nessler glass" is required: these are little cylindrical jars of colourless glass about six inches high, and holding about 170—180 c.c.; they should have a graduation mark on the side of 50 c.c., and a second at 100 c.c. (These may be ordered from the apparatus dealers as "graduated Nessler glasses.") Wash a Nessler glass and place it under the condenser, and thus collect in it about 100 c.c. of the distilled water. Place the glass on a clean white porcelain tile, and add to the water, by means of a small pipette, 1 c.c. of Nessler solution; stir the two together by taking the glass in the hand and giving it a rotary motion. Cover the top of the glass with a watch glass, and allow it to stand for five minutes. If the water be free from ammonia it will remain perfectly colourless on looking down through it on to the tile, but if any be present the water will have assumed a yellow tint. Should it be thus shown to be impure, the distillation must be proceeded with and the water again tested after about another half a Winchester has come over. As soon as the water is thus found to be pure, proceed to collect in Winchesters which have been most carefully cleaned and finally rinsed with some of the pure water itself. Fill each bottle to the neck, stopper tightly, and tie down with paper. Continue to distil until the still contains only about half a gallon. Using a clean still and having fairly pure water at disposal to start on, five or six Winchester quarts of pure water may be obtained from four gallons placed in the still.

**514. Standard Solution of Ammonium Chloride.**—Dissolve 1·5735 grams of pure ammonium chloride ($NH_4Cl$) in a litre of distilled water free from ammonia, of this take 200 c.c., and make up to two litres with ammonia-free water. This latter solution will contain ammonium chloride corresponding exactly to 0·00005 grams of ammonia ($NH_3$) per c.c. Store the solution in a stoppered Winchester, and fill a small bottle from it as required for use. Keep the store bottle carefully tied down with paper.

**515. Alkaline Permanganate Solution.**—Dissolve in a large glass flask 400 grams of fused potassium hydrate and 16 grams of potassium permanganate in 2500 c.c. of ordinary distilled water. Set the flask over a sand bath and boil rapidly until the volume is reduced to two litres. Let it cool and store in a stoppered Winchester.

The operation of boiling a liquid in a large glass flask is fraught with considerable risk of cracking the flask. The boiling may instead be conducted in a perfectly clean cast-iron saucepan or pot; in this case, however, a portion of the permanganate is decomposed by the iron; this, however, may be remedied by using an excess of the permanganate.

**516. Apparatus Required in Ammonia Process.**—Having given directions how to prepare the special reagents required in this estimation, it is now necessary to describe the apparatus required. The solution of the meal requires to be boiled in a retort or flask with the alkaline permanganate solution, and the steam condensed and collected. For the boiling, a glass flask may be employed; but when boiled in glass such solutions are apt to "bump" violently, and a number of retorts are likely to be broken unless great care is taken. In case a glass retort is used, carefully bend the stem of a 24 or 30-ounce retort in about its middle, so that when the retort is fixed in the retort stand the first portion of the stem may be ascending, and that part which is connected to the condenser inclined downwards. In this way any portions of the liquid that may be mechanically carried over with the steam, on impinging on the sides of the retort stem, flow back into the retort. Bohemian flasks with rounded bottoms seem, on the whole, to stand the violent bumping better than retorts. The writer strongly recommends the use of a flask of sheet copper, which may be obtained to order from the apparatus dealer. The flask should be three inches in diameter and six inches high to the place where the side is tapered off to the neck; the neck must be three-quarters of seven-eighths of an inch diameter, and must be slightly flanged outwards at the top, in order to take a cork. The joints must all be brazed. Such a flask would have a capacity of about 700 c.c., and is shown in Figure 88, which represents the whole apparatus as fixed for working. Select an indiarubber cork, having one hole, that tightly fits the flask. Take a piece of glass tubing three-eighths of an inch external diameter, bend this to an angle of about 80°, so as to form a leading tube, as shown in the figure; slightly draw out in the blow-pipe flame the one end, so that it easily enters the glass tube of the condenser. Round off the ends of this tube, and pass the one through the indiarubber cork.

The condenser is an ordinary Liebig's condenser, about 18 inches long in body, and needs no further remark.

Select two graduated Nessler glasses, in which the actual distance from the bottom of the jar to the 100 c.c. mark is the same. Measure this distance, and divide it into 20 equal parts on a piece of paper or thin card. Use this as a scale, and thus graduate each jar. The marks should be cut on the side of the jars with a writing diamond. The jars will thus be graduated at intervals of 5 c.c.; draw the 10 c.c. marks a little longer than those intermediate. Orme & Co. supply Nessler jars graduated at every 5 c.c.

Procure a globular pipette, ungraduated, but of about 100 c.c. capacity, and with the lower part of the tube sufficiently long to reach to the bottom of a Nessler glass when bent, as shown in Figure 87; bend this tube as there indicated. Cut the tube above the body of the pipette to about a length of one inch, and round of the edge. From an indiarubber dealer procure a pear-shaped indiarubber ball, such as is used for an injection syringe, and attach it to the top of the pipette.

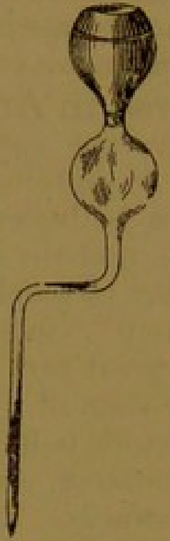


FIG. 87.—NESSLERISING PIPETTE.

**517. Method of Making the Analysis.**—In making these estimations it is convenient to make several at a time rather than one only. The same solution as that made up for the soluble extracts serves for these analyses; a beginner will find four solutions sufficient for him, but after a time he may make up six. The object is to get a sufficient number for a day's work, and no more than can be done during daylight, as the solutions must not stand over night. A little judgment is required in order to so arrange the several operations so as to avoid loss of time: this is, however, soon obtained by experience. The following will probably be the best way to arrange the work:—

Supposing that four wheats or flours are to be analysed, commence work early in the morning by taking 125 c.c. of alkaline permanganate solution, putting them into a large flask or retort, and adding thereto about a litre of tap water. Put this on a tripod and boil briskly, applying the flame direct to the bottom of the retort, until the volume is reduced to 750 c.c. Toward the end of this boiling operation attach the flask or retort to the Liebig's condenser, collect 50 c.c. of the distillate in a Nessler glass, and test as before described for ammonia. If the tap water is good, the distillate should be free from ammonia, if traces are still present, add 250.c.c. of ammonia free water, and continue distilling and again test. In case the original solution does not give off the whole of its ammonia in being reduced from 1125 to 750 c.c. a larger quantity of tap water must be taken to commence with; this will speedily be learned by experiment. This operation being complete, there remains in the retort 750 c.c. of dilute alkaline permanganate, containing 25 c.c. of the concentrated solution to 150 c.c., and free from ammonia. Pour this solution into a clean flask, rinsed immediately before use with tap water, and cork it up. This boiling is best conducted in a large brazed copper flask. Before boiling, the flask with its contents should be weighed; then as 375 c.c. have to be evaporated, the boiling must be continued until the flask and contents shall have lost, in weight, 375 grams.

The reason for this boiling operation is that all water, unless specially purified, contains ammonia; further, except the greatest care is taken, ammonia-free water again absorbs ammonia from the atmosphere, therefore, as a large quantity is required, it is more convenient, and also safer, to thus prepare it immediately before use. This treatment also expels any traces of ammonia that may have remained in the alkaline permanganate solution. When good drinking water is obtainable the quantity of ammonia it contains is usually evolved considerably before the volume is actually reduced to 750 c.c. It is a good plan to first collect each 50 c.c., and test it separately, noting how much has to be distilled over before the last trace is expelled. Should this point be reached much before the volume is reduced to 750 c.c. the liquid may afterwards be boiled down to the required volume, and the testing dispensed with. It should even then, however, be occasionally repeated, and must never be omitted whenever a fresh lot of the alkaline permanganate solution is made up. Having set this solution to boil, proceed to make up the 10 per cent. flour or meal solutions as has been directed. Label all the flasks, funnels, beakers, &c., used, with a numbered label, so that no confusion may arise.

While the solutions are filtering, proceed to fit up the flask and condenser. In the case of the new flask, boil it out most thoroughly with some caustic potash and permanganate, rinse it well with tap water, and set aside completely filled with water. Whenever the flask is finished with, for the time being, it should always be filled with water and put away corked. The indiarubber cork and leading tube, when new, should be soaked for a time in dilute soda solution, and then washed thoroughly. Supposing that the flask and leading tube are not being used for the first time, pour away the water which was put aside in them, rinse them out with tap water, about a quarter fill the flask with water, insert the cork, and set the flask to boil. Meanwhile send a stream of water through the tube of the condenser, and then connect it up in the usual way with the water tap, so that the stream of the condensing water enters the jacket at the lower end, arrange a second piece of tubing to convey the overflow water to the drain. Having scalded out the flask and leading tube, disconnect them, pour out the water, and put 150 c.c. of the ammonia-free dilute alkaline permanganate solution in the flask, replace the cork, and connect up to the condenser, as shown in Figure 88. In order to make a tight joint between the leading tube and the condenser, cut a piece of red vulcanised rubber tubing about an inch long, slide this over the end of the leading tube, and then insert it into the condenser tube, so that the outside of the rubber tubing just fits into the condenser. Wash a Nessler glass and place it under the far end of the condenser tube, so as to receive the distillate. The general arrangement may be gathered from the figure. (The engraver has made the lower end of the condenser tube terminate in a point: it should, of course, be open with just a slight constriction).

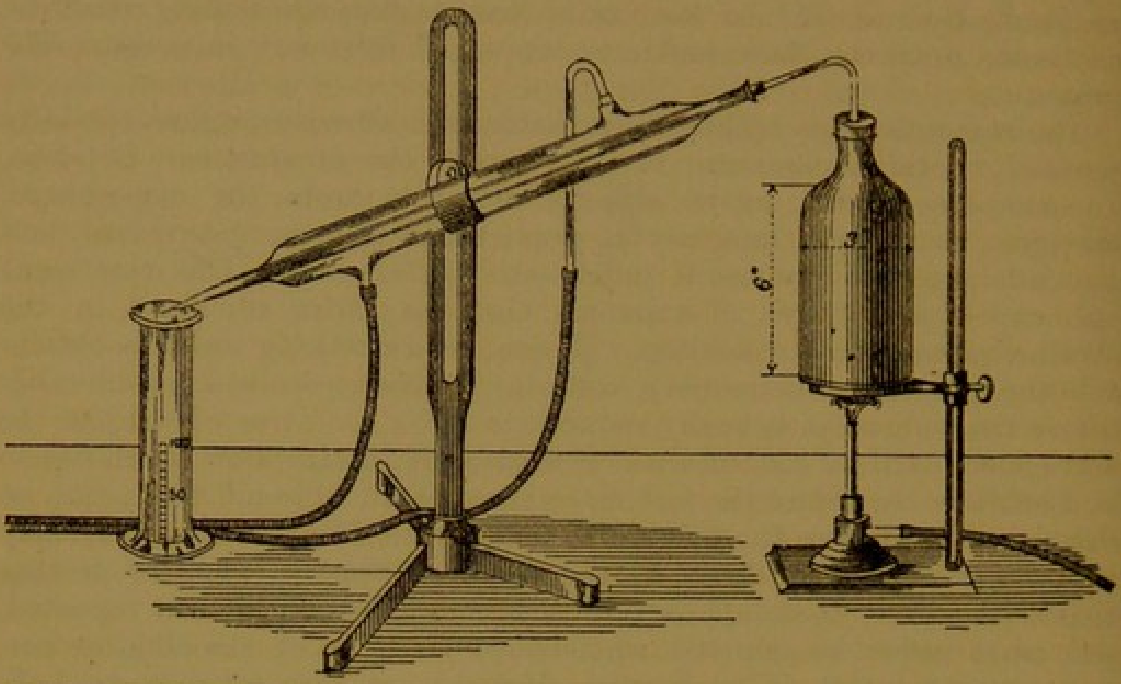


FIG. 88.—APPARATUS ARRANGED FOR DISTILLATION IN AMMONIA.

Turn on a gentle stream of water through the condenser, and light up the bunsen underneath the flask; collect 50 c.c. of the distillate, remove the Nessler glass and put another in its place. Test the distillate for ammonia; there should be none present—at most only a trace. In the latter case distil over a second 50 c.c. and test it. This must contain no ammonia; should it do so the flask could not have been clean, and must be again boiled out with alkaline permanganate. Having succeeded in freeing the whole apparatus from ammonia the analyses may now be proceeded with.

Take 10 c.c. of the ten per cent. solution, pour them into a 100 c.c. flask, and make up to 100 c.c. with distilled water; this produces a one per cent. solution. Pour away the residue of permanganate left in the flask from the blank experiment, add another 150 c.c. of the ammonia-free dilute alkaline permanganate solution, and then 5 c.c. of the one per cent. solution of the flour or meal. Re-cork and again connect up the whole apparatus. Place one of the clean specially graduated Nessler glasses to receive the distillate. Light the bunsen and place it under the flask. Unless care is taken, the solution is liable to boil right over into the condenser; to avoid this, place the bunsen, not in the middle, but to one edge of the bottom of the flask, and use only a small flame. Distil over exactly 100 c.c.; remove the Nessler glass, cover over with a watch-glass, and turn out the bunsen. A number of experiments have shown that the whole of the ammonia comes over in the first 100 c.c. Time is saved by having two pairs of graduated Nessler glasses; in case there are these, put one of them to receive the distillate, pour out the contents of the flask, and put in the same quantity of permanganate and 5 c.c. of the one per cent. solution of another sample, and set it distilling.

While the second sample is distilling proceed to estimate the ammonia in the first distillate. In the second Nessler glass of the pair put 2 c.c. of standard ammonium chloride, and make up to 100 c.c. with ammonia-free water. To each of the two add, by means of a pipette, 1 c.c. of Nesslers' solution, cover them over with watch-glasses, and allow them to stand for about three minutes. Place the glasses on a tile, look down through the liquids and observe which is the darker in colour; with the quantities taken the glass to which the standard solution has been added is usually of the darker hue. Take the bent pipette with india-rubber ball, squeeze out the air, and put the end in the darker of the two solutions; allow the ball to expand, it thus sucks up some of the solution. In this way remove some of the darker solution until, looking down vertically through the two solutions, they are exactly of the same depth of tint. Then read off the height of the liquid in the glass and enter in the note-book. This comparison should be made in a good light. When apparent equality of tint is obtained, lift both glasses up from the tile some three or four inches and again look down. The two liquids will then appear lighter in colour, but should be equal to each other in depth of tint. This double test assists in forming a correct judgment. The glasses may now be washed out and got ready for the next analysis. While the one sample is distilling, nesslerise the other (*i.e.*, determine the ammonia with Nessler's solution).

The next step is to calculate the percentage of albuminoids from the results obtained. When the Nessler glasses show the same vertical depth of tint they contain similar quantities of ammonia; that in the one glass is known, and thus the other may be calculated. Suppose that the test glass (*i.e.*, the one to which the standard ammonium chloride solution has been added) has been the darker, and that when the two are of the same vertical depth of tint the test glass then contains 75 c.c. of liquid. As at first there were 2 c.c. of the standard solution in 100 c.c., there must now be $\frac{75}{100}$ of 2 c.c. $= 2 \times 0{\cdot}75 = 1{\cdot}5$ c.c. of standard solution.

Suppose next that the distillate were the darker, and that it had to be drawn off until there only remained 85 c.c., then, as 85 c.c. contains ammonia equal to 2 c.c. of the standard solution, 100 c.c. of the distillate must have contained ammonia equal to $\frac{100}{85} \times 2 = 2{\cdot}35$ c.c. of standard ammonia.

Having thus found the quantity of ammonia yielded by 5 c.c. of a one per cent. solution, as expressed in c.c. of the standard solution, it now remains to calculate the percentage. To find the absolute weight of ammonia yielded, multiply the number of c.c. of standard solution by 0·00005, which is the weight of ammonia per c.c. Wanklyn has shown that egg albumin, and presumably also the albuminoids of the cereals, yield, when distilled in this manner, about 10 per cent. of their weight of ammonia; therefore the weight of albuminoids contained in a sample is ten times the weight of ammonia evolved, consequently the next step is to multiply by 10. This gives the weight of soluble albuminoids in 5 c.c. of the one per cent. solution, which equals 0·05 grams of the meal or flour. To obtain the percentage, the result must further be multiplied by 2000, or, writing all the factors together, No. of c c. × (0·00005 × 10 × 2000) = percentage. But the figures included within the brackets, when multiplied together, produce unity, so that with the quantities taken the number of c.c. of standard solution of ammonia, required to produce the same depth of tint when nesslerising, represents the percentage of soluble albuminoids.

These estimations should appear thus in the note-book:—

"Estimation of soluble albuminoids by 'ammonia process' in No. 31.
Usual quantities taken.
Distillate contained less ammonia than standard.
With tint equal, standard = 80 c.c.
2 × 0·80 = 1·6 per cent."

**518. Comparison between Combustion and Ammonia Processes.**—When worked in the manner described, and with due care, the combustion and ammonia processes give fairly concordant results. The writer appends the percentages obtained in some experiments specially made for the purpose of comparing the processes. The combustions were made by him personally, the ammonia estimations by his assistant, so that not only were the methods different, but each was worked by a different person.

| | Ammonia Process. | Combustion Process. |
|---|---|---|
| Wheat ... ... ... ... | 1·79 | 1·63 |
| " ... ... ... ... | 1·81 | 1·81 |
| " ... ... ... ... | 1·88 | 1·89 |
| " ... ... ... ... | 2·17 | 1·94 |
| Flour ... ... ... ... | 1·21 | 1·23 |
| " ... ... ... ... | 1·30 | 1·28 |
| " ... ... ... ... | 1·40 | 1·28 |

**519. Estimation of Total Albuminoids.**—The total albuminoids may also be determined by either method. To make a soda-lime combustion, mix 1 gram of the flour with sufficient soda-lime to about one-third fill the combustion tube. Collect the evolved gas in 25 c.c. of decinormal sulphuric acid. Every other part of the operation is conducted in the manner already described. The number of c.c. of acid neutralised by the evolved ammonia, multiplied by 0·0014 × 6·33 × 100 = the percentage of total albuminoids.

The ammonia process may also be employed for this determination. Carefully weigh out 0·2 grams of the flour, transfer to a 200 c.c. flask, and make up to 200 c.c. with a solution containing 5 grams of caustic potash to the litre. Shake up thoroughly two or three times during half-an-hour; in this way a 0·1 per cent. solution is obtained. Take 5 c.c. of this for the estimation, and proceed exactly as before. The number of c.c. of standard ammonia solution found multiplied by 10 gives the percentage.

A sample of wheat analysed by the two methods gave 11·37 per cent. by the ammonia process, and 10·63 per cent. by the combustion process, of total albuminoids.

**520. Modification of Combustion Process for estimation of true Albuminoids only.**—The determination of albuminoids by the nitrogen combustion process is open to the objection that that portion of the nitrogen which existed in the grain or flour as nitrates, &c., is also reckoned as nitrogen from albuminoids. It is at times of service to estimate the percentage of nitrogen existing as albuminoids or flesh formers, as distinguished from other compounds of nitrogen.

Carbolic acid possesses the property of coagulating the soluble albuminoids, and thus rendering their separation from nitrates, &c., comparatively easy. Take two grams 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 soda-lime combustion of both the residue and filter, cutting the latter up into shreds and intimately admixing these with the soda-lime. The percentage of nitrogen thus obtained, multiplied by 6 33, gives the quantity of true albuminoids.

## CHAPTER XXIV.

### ESTIMATION OF CARBOHYDRATES.

**521. 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.

**522. 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.

**523. 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.

**524. Action of Sugars on Fehling's Solution.**—A careful investigation has of late 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 lœvulose in equal quantities, viz, :—

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Lœvulose.}}{C_6H_{12}O_6}$$

Dextrose and lœvulose both act on Fehling's solution, precipitating copper sub-oxide, $Cu_2O$, in definite quantity.

**525. 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 hydrocloric 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 add dry sodium carbonate in small quantities until the solution is neutral, the approach of this point is known by the addition of the sodium carbonate causing only a very slight effervescence. Test finally 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. neutral solution of cane sugar converted into dextrose and lœvulose. 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. Arrange a filter-stand with two funnel holders, one above the other, so that the filtrate from the upper funnel drops into the lower one; place a beaker underneath for the filtrate. Fold one of the pair of counterpoised filters and place it in the upper funnel, and filter the copper oxide rapidly from the solution; the filtrate should still be of a deep blue colour. Examine the filtrate carefully in order to see if any traces of the precipitate have found their way through the paper; if so, re-filter. Being assured that the precipitate is being entirely retained by the upper filter, place the other one of the counterpoised pair in the funnel underneath, so that the filtrate passes through it. Wash both the filters rapidly with boiling water and dry both in the hot water oven. The reason for allowing the filtrate to also pass through the second paper is to cause each to be in as nearly as possible the same condition, so that it 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 lœvulose, 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—

Cane sugar has no reducing action.

| | | | |
|---|---|---|---|
| Glucose - - - | 1 gram produces | 1·983 | grams of $Cu_2O$. |
| Cane sugar after inversion | ,, ,, | 2·087 | ,, ,, |
| Maltose - - - | ,, ,, | 1·289 | ,, ,, |

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, $\frac{1}{1\cdot983}=0\cdot5042$.

Cane sugar after inversion, $\frac{1}{2\cdot087}=0\cdot4791$.

Maltose, $\frac{1}{1\cdot289}=0\cdot7758$.

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

$$0\cdot1972 \times 0\cdot5042 - 0\cdot0794 \text{ of cane sugar.}$$

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 doubtlessly 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.

**526. Volumetric Method of 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 indiarubber 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. = 0·0741 „ „ maltose.

The difference between the cane sugar and glucose is here again explained by the fact than 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 $\frac{93}{95}=$ 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 grams of sugar, so that 11·4 c.c. contains 0.0570 grams 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.
$\frac{0·0465 \times 100}{11·4 \times 0·005}$ = 81·58 per cent. of pure sugar."

**527. 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 albuminoids 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 ten 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 albuminoids by passing the liquid through a dry filter; the filtrate is a 10 per cent. solution, *minus* the albuminoids coagulated by boiling.

If maltose is to be determined volumetrically the solution should always be first freed from coagulable albuminoids, as described at the close of the previous article. 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 270, page 152, in which an additional precipitate is obtained as a result of treatment with hydrochloric acid.

**528. 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

**529. 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 hydrolising 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.

**530. 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.

$$S_D = \frac{100 \times 21{\cdot}73}{2 \times 16{\cdot}350} = 66{\cdot}45^\circ$$

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 lœvo-rotation are applied to the right-handed and left-handed rotation respectively. Also the symbol + is used to represent dextro- and − to represent lœvo-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 |
| Lœvulose | $C_6H_{12}O_6$ | − 98° at 15° C. |
| Invert sugar | $2C_6H_{12}O_6$ | − 23·05° at 15° C. |
| Dextrin | $C_6H_{10}O_6$ | + 193° |

**531. 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.

Figure 89 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.

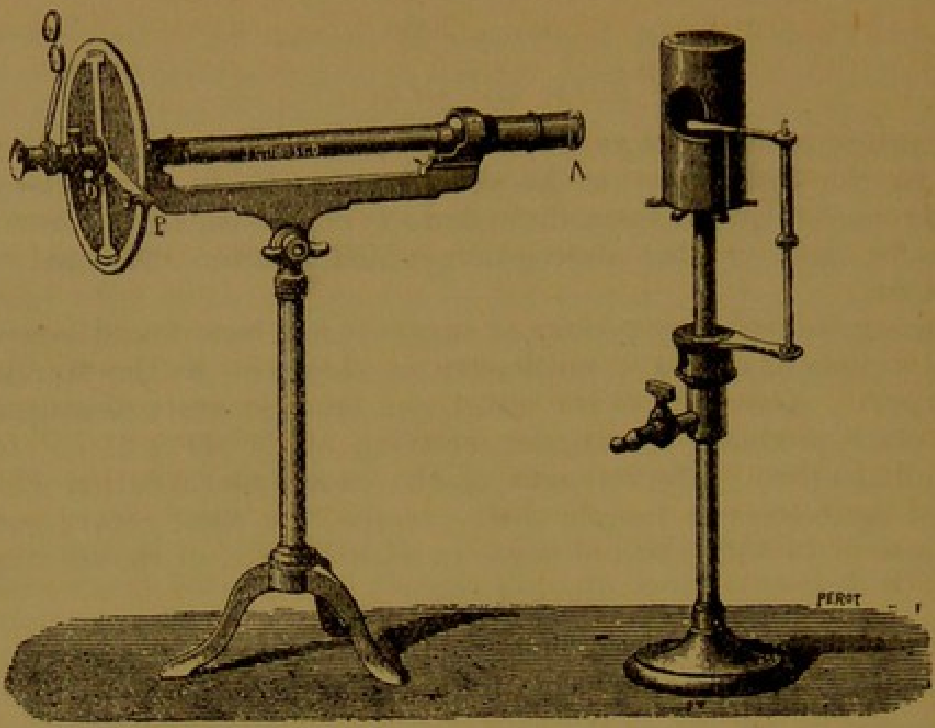


FIG. 89.—JELLET-CORNU POLARIMETER.

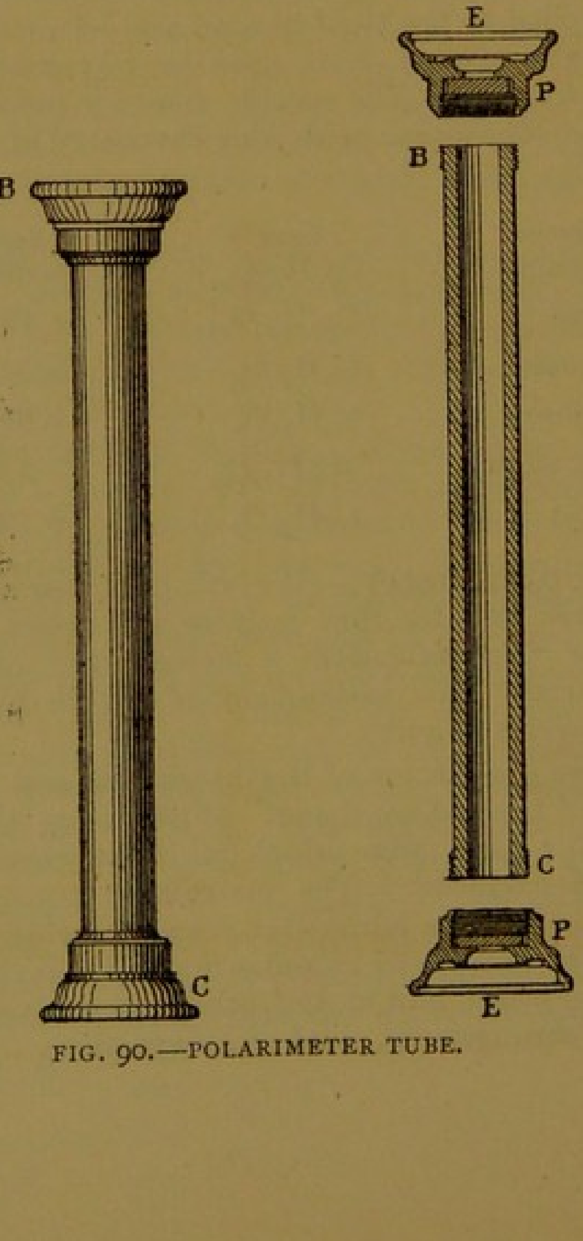


FIG. 90.—POLARIMETER TUBE.

**532. Polarimeter Tubes.**—These tubes are made of brass, lined with tin, and are exactly 20 centimetres in length from end to end inside the caps. The left-hand illustration, Figure 90, 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.

**533. Polarimeter Tube, with Thermometer.**—Figure 91 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.

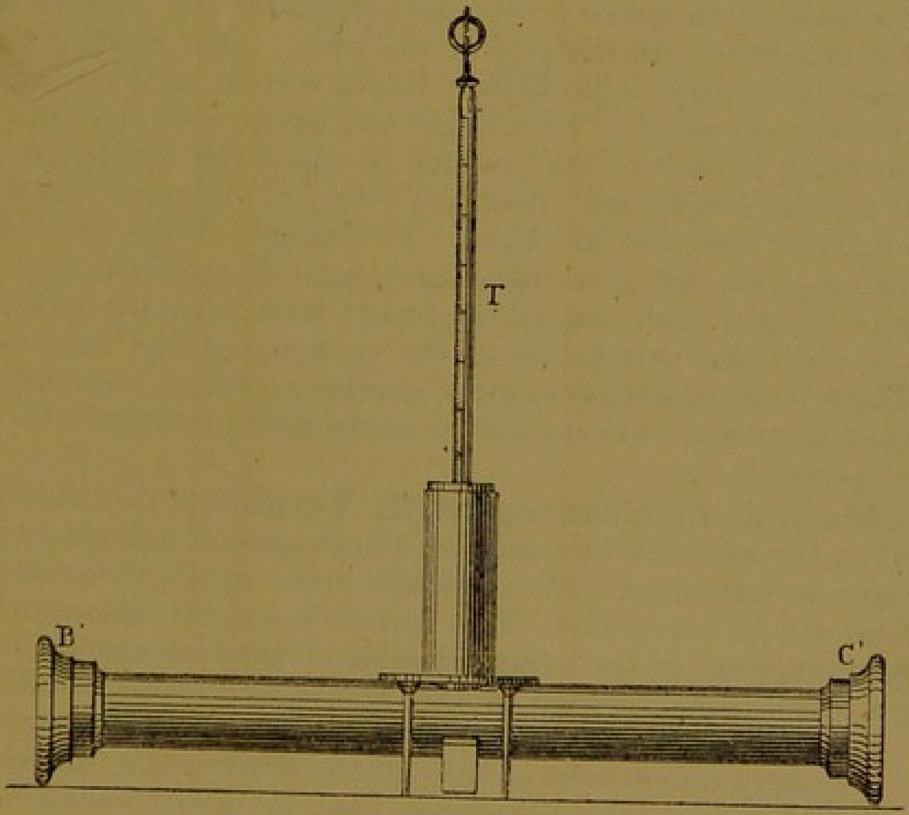


FIG. 91.—POLARIMETER TUBE, WITH THERMOMETER.

**534. 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 instrument. 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 in a vertical direction 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 an intense yellow light is produced. Arrange the axis of the instrument in the direction of the flame, so that on looking through the eye-piece 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.

**535. 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."

**536. 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.

**537. 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 threfore, 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 the 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.

**538. 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. It may happen that the liquid is not sufficiently clear to be transparent in a layer of so much as 20 centimetres; it must 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. Should the liquid contain any coagulable albuminoids they should next 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. 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.

**539. 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.

**540. 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:

**541. 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 time 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.

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, o/o | Specific gravity, at 15·5° C. | Absolute Alcohol, by volume, o/o |
|---|---|---|---|
| 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

$$Q = \frac{A \times w}{\times a} - W.$$

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.

**542. 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.

**543. 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 just 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 and 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 transfered 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 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 of boiling water at a time. 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 S<sub>D</sub>, and contained 2·195 grams of maltose.

$2{\cdot}196 \times 2{\cdot}78 = 6{\cdot}10°$, angular rotation due to maltose. $8{\cdot}52° - 6{\cdot}10° = 2{\cdot}42°$, angular rotation due to dextrin. $\frac{2{\cdot}42}{4{\cdot}008} = 0{\cdot}605$ gram of dextrin in 100 c.c.

Maltose, 2·196 = starch, 2·196 × 0·95 = 2·086
Dextrin, 0·605 = starch, 0·605

Total starch = 2·691

$$\frac{2{\cdot}691 \times 100}{4{\cdot}94} = 54{\cdot}47 \text{ per cent. of starch present.}$$

A duplicate analysis on 6·009 grams differed only by 0·03 per cent.

**544. 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.

**545. 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.

**546. 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, and also a portion of the cellulose, 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 the 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 weight of indigestible fibre in the sample.

## CHAPTER XXV.

### BREAD ANALYSIS.

**547.** 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.

**548. 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.

**549. 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.

**550. Piling.**—In the south of England, by a well-piled loaf is understood one that has risen well, both in the dough stage and after being placed in the oven. The "well-proved loaf" is another phrase having there substantially the same meaning. 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-piled loaf is a heavy one; hence this matter of the piling of a loaf is of importance. The loaf which in this particular looks the best is that which is most digestible and wholesome.

The trade terms, Pile and Proof, are used in very different senses in different localities; thus, a number of bakers use this term to refer to the size of a loaf: with them a well proved loaf is a well risen one. On the other hand, it has been explained to the author, that two loaves may have risen equally well, and yet the one be far 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 albuminoids during fermentation. Mr. W. A. Thoms has been kind enough to inform the author as to the exact sense in which these terms are used in Scotland, and as no man can speak with more authority on this subject, his letter is quoted at length:—"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-skinned 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 by-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."

**551. 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.

**552. 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.

**553. 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:

| | Minimum. | Minimum. | 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 |

**554. Quantity of Water in Bread.**—Much has been written on this question of the quantity of water in bread. Thus, in "Bread-Analysis, a practical treatise," Wanklyn and Cooper quote as an improved method of making good white bread, that 6 lbs. of fine flour should be taken to 2½ lbs. (=1 quart) of water. This means that 46·6 quarts of water are to be taken to each sack of flour! Taking these as the standard proportions, they calculate and assert that "well-made bread should contain some 34 per cent. of water, and the bread-solids in well-made bread will thus amount to 66 per cent." They then point out that "the bread to be met with in the market contains sometimes 40 per cent. of water, and even much more than 40 per cent." In the subsequent paragraph this is styled "the profitable commercial operation of making 60 lbs. of bread-solids do duty for 66 lbs. of bread-solids." Further on they state that they "have already called attention to the fraud on the public which is involved in the supply of bread surcharged with water." These are serious accusations which are thus preferred by Wanklyn and Cooper against the baking community: charges of this kind should never be made without the amplest and most trustworthy evidence being forthcoming in their support.

Let us examine a moment the nature and value of the evidence adduced. The recipe on which Wanklyn and Cooper's calculation is based is quoted from an old book, date 1813. Now at that time the Corn Laws were in full operation, and, as is well known, bread had to be made from flour which now would scarcely be deemed fit for cattle food. Thanks to the magnificent wheats and flours at this time to be obtained in the British markets, a baker would find himself puzzled to discover a flour that could be worked with 46 quarts of water to the sack. Doubtless the surcharging of bread with water is an offence against the community, but it is fortunately an offence that immediately brings with it its own punishment, inasmuch as the injury done to the appearance of the bread, by excess of water, diminishes its saleable value. Wanklyn and Cooper, in laying down their hard and fast line that no more than 46 quarts of water to the sack should be used, take no cognizance of the fact that different flours vary most widely in the quantity of water they require to make a dough of the same stiffness. Thus among the number of flours examined by the author, he finds that to make a dough of standard consistency, some flours, principally those milled from weak English wheats, take 60 quarts of water to the sack; others take 70 and even 80, while one sample he has examined required 98 quarts of water to produce a standard dough. With such wide divergencies among flours, how can a baker possibly adhere to the rigid rule of 46 quarts to the sack? Wanklyn and Cooper proceed to quote analyses made by them of samples of bread obtained from Peterborough: they find that 17 samples contained, on the average, 40 per cent. of water, that 11 contained 34 per cent., and that 14 were intermediate. Wanklyn and Cooper state that these Peterborough samples "exhibited an astonishing tendency to become mouldy," but say—"unfortunately we did not take the requisite precautions to ascertain by direct observation whether or not the degree of mouldiness ran parallel with the degree of hydration." There is ample evidence that a high percentage of water does not necessarily produce a bread that rapidly develops mouldiness. It is well known that Vienna bread, and fancy bread generally, made from high class patent flours, contain much more than the average percentage of water: yet these are of all breads the least susceptible to mould. It is no uncommon thing to see a sample of such bread which has been preserved for years, and which nevertheless exhibited not the slightest trace of fungoid growth.

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, after having cooled 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 slighest 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 permissible 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. But even in districts where very strong flours are habitually employed, the buying public suffers no injustice in the matter of the price paid for solid bread stuffs; for if the flours used are such that the bread contains a high percentage of water, and its production is thereby cheapened, natural economic laws force down the price. It is well known that in those districts where strong flour is used, the price of the bread per quartern loaf is low.

**555. Analytic Estimations.**—In an ordinary analysis of bread, where the object is not to test for adulteration, the following estimations may be made: water, ash, and acidity. 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.

**556. Moisture.**—Weigh out 5 grams in a counterpoised dish and dry until the weight is constant. The dish may conveniently be left in the hot-water oven over night.

**557. Ash.**—Weigh out 5 grams in a tared platinum dish; ignite gently until only a white ash remains, and weigh. A properly burned ash should not exceed 5 per cent. Should there happen to be more than this quantity adulteration may be suspected.

**558. Acidity.**—Add 200 c.c. of distilled water to 10 grams of the bread; after a quarter of an hour, shake up, allow to subside, and filter through a dry filter. Titrate 100 c.c. of the filtrate with decinormal soda, using phenophthalien as an indicator. The acidity may be calculated as lactic acid.

**559. Fat.**—This may be estimated, if wished, in from 10 to 25 grams of the bread. Weigh, dry in the hot-water oven, and extract the fat by means of ether or light petroleum spirit in either of the fat extraction apparatus previously described. The method is precisely the same as for flours.

# CHAPTER XXVI.

## ADULTERATION.

**560. 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.

**561. 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.

**562. 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 :—

**563. 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 event of the flour containing darnel the alcholic 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.

**564 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.

**565. 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

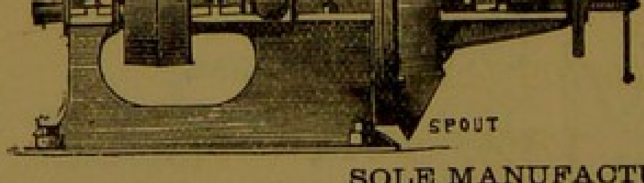
**566. Chloroform Test.**—This test depends on the fact that chloroform has a density higher than that of the normal constituents of flour, but lower than that of minerals generally ; consequently, on agitating a mixture of flour and chloroform, and then allowing it to rest, the flour rises to the surface, 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.

**567. 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.

**568. 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.

THE END.

# INDEX.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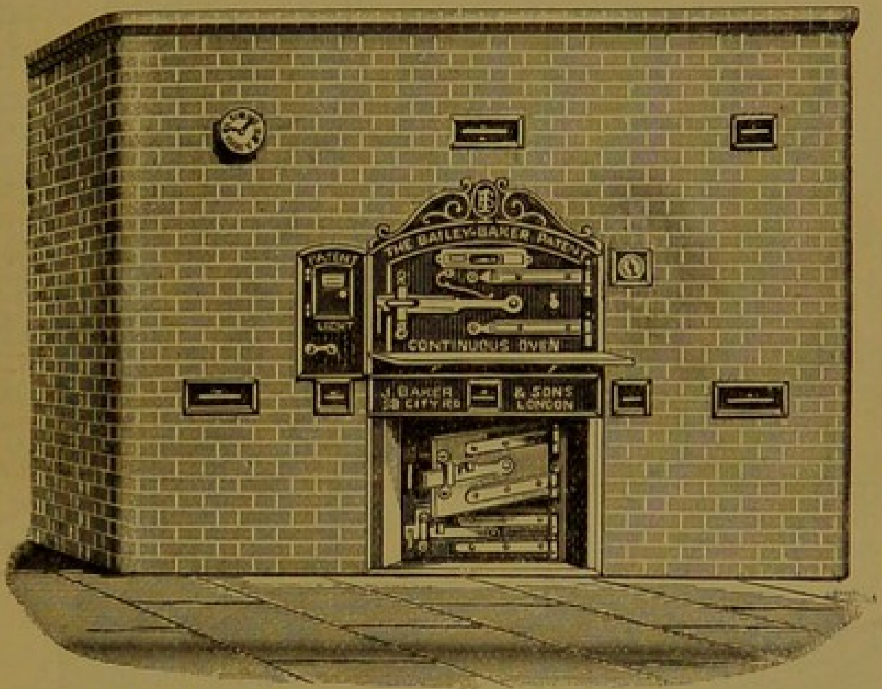

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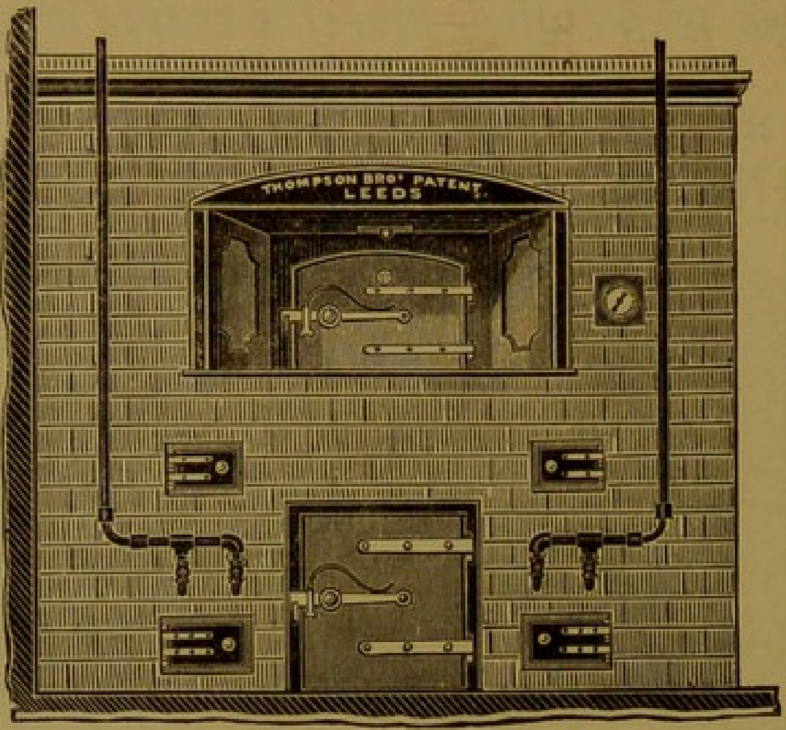
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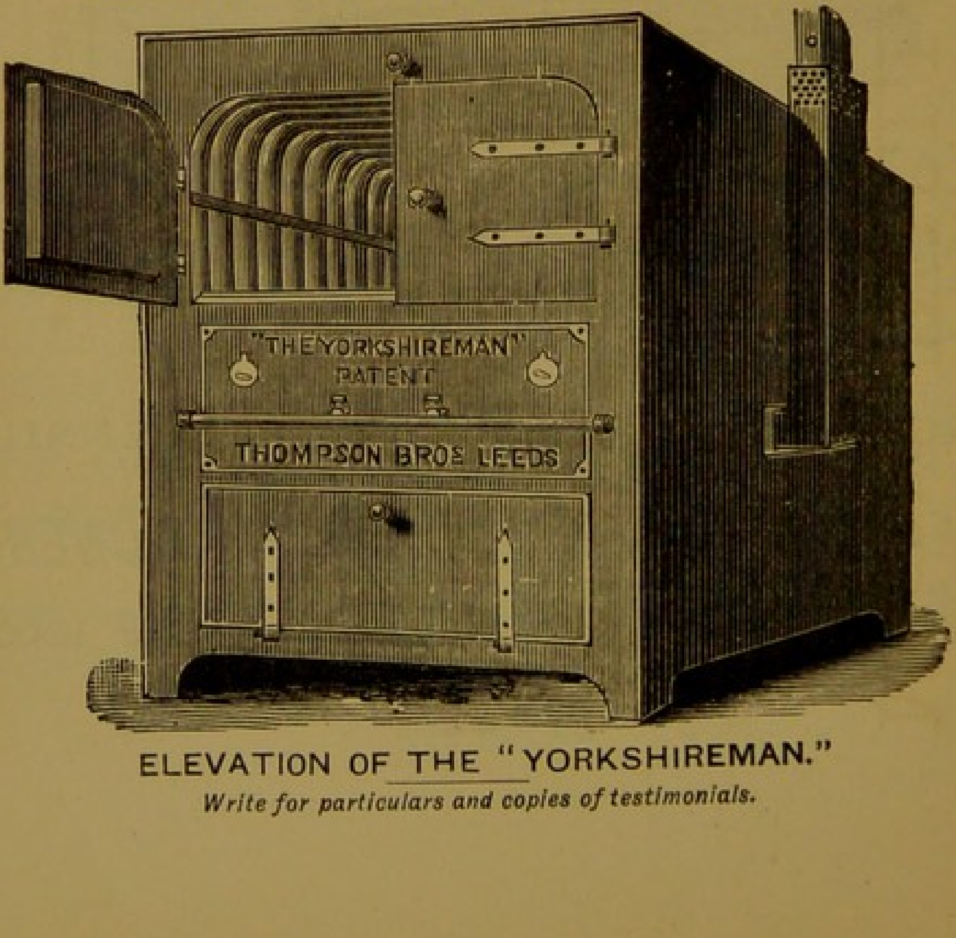
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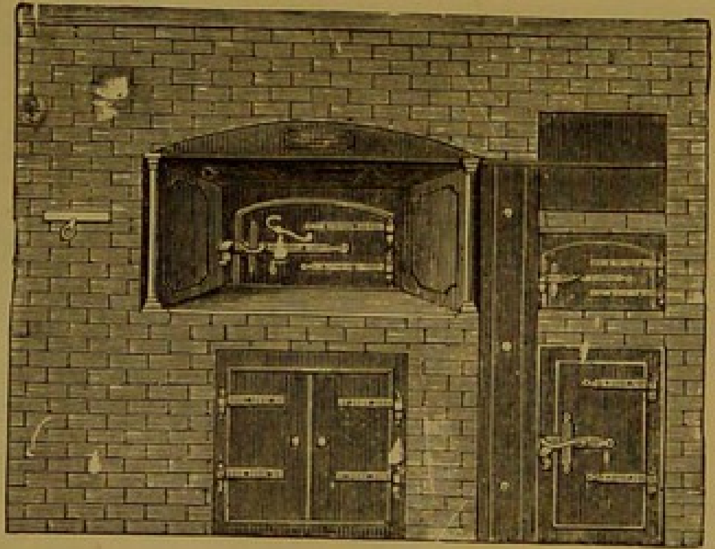

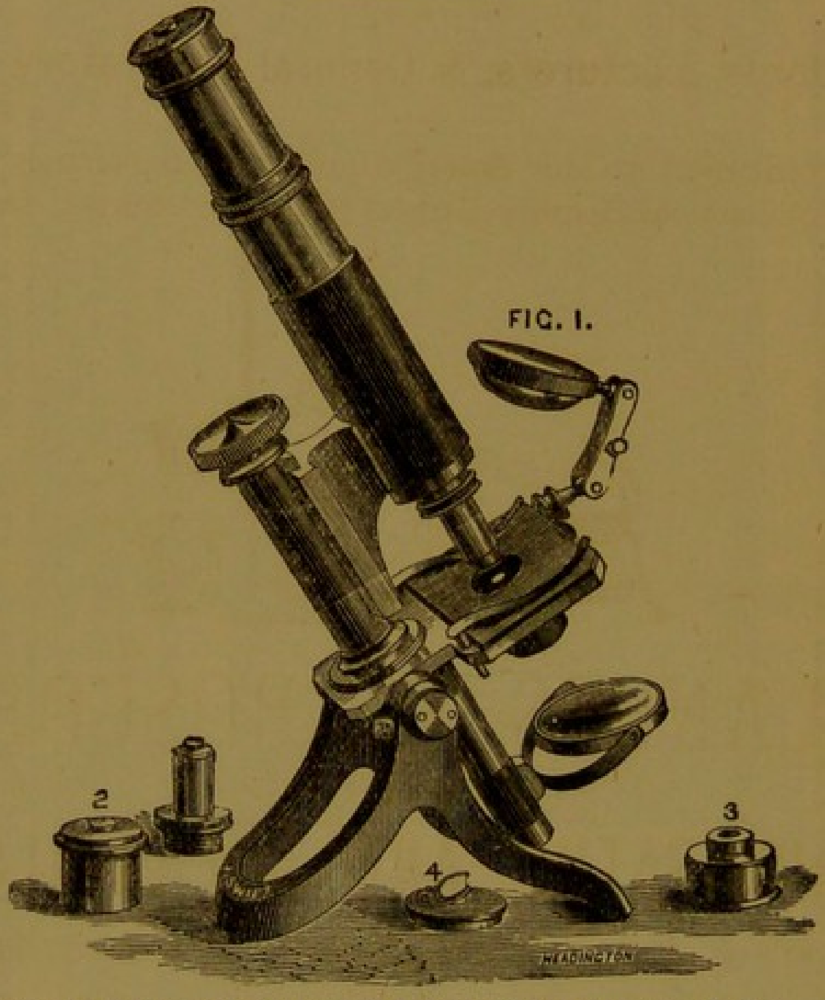
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