THE ELEMENTARY PRINCIPLES OF BREADMAKING

JOHN GOODFELLOW, PHD., F.R.M.S.

Works by Dr. GOODFELLOW.

The Dietetic Value of Bread. MACMILLAN & CO., Bedford Street, London.

Practical Physiology (co-author, Dr. PILLEY). GEORGE GILL & SON, Warwick Lane, London, E.C.

Ventilation of Bakehouses. Bow and Bromley Institute, London, E.

The Treatment of Diabetes by Diet. Bow and Bromley Institute, London, E.

In Preparation:

The Baker's Encyclopaedia. THE BAKER AND CONFECTIONER, 13, Cursitor Street, London, E.C.

The Ventilation, Sanitation, and Construction of Bakeries. THE BAKER AND CONFECTIONER, 13, Cursitor Street, London, E.C.

THE

Elementary Principles

OF

Breadmaking,

BY

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PREFACE.

IN studying the rise and progress of our Arts and Manufactures one cannot help being impressed with the remarkable fact that it is only in comparatively recent times that the various processes and practices concerned in the great industries have been investigated and explained from the scientific standpoint. In no case is this better exemplified than in the ancient practice of Breadmaking. For centuries the baker set ferments, made doughs, and baked bread, and yet knew little or nothing of the great natural laws governing the processes which were the very foundation of his calling. He knew how to produce certain effects by rote and practice, but of the "why and wherefore" he was ignorant. During the last fifteen years a great change has been slowly taking place. The chemist, engineer, biologist, and physiologist have stepped in and explained the theory of the every-day operations of the bakehouse, with the result that improvements in the manufacture of bread are being constantly devised.

In the following pages I have endeavoured to place before the baker the elementary scientific principles which enter into the familiar processes included in the term "Breadmaking," and, at the same time, to put before him the more important facts of physiology, chemistry, and biology which bear upon his calling. It has been a work of no little difficulty to compress into the small compass of this book even an elementary review of the subject; but my object has been to produce a work as free as possible from technicalities, and one which, though laying no claim to an exhaustive treatment of the subject, will be in most cases sufficient for all practical purposes, and will also serve as a suitable introduction to a prolonged course of study.

The ventilation and sanitation of bakehouses are of such importance to the baker as to call for a more extended consideration than I could give them here, and I have therefore omitted them from the subjects treated. I do this all the more readily as I have in preparation a work dealing exclusively with the sanitary aspects of bakeries.

My thanks are due to Messrs. W. Jago, Brighton; F. E. Becker & Co., London; Watson & Son, London; W. F. Mason, Manchester; David Thomson, Edinburgh; J. Baker & Son, London; Werner, Pfleiderer & Perkins, London; T. Melvin, Glasgow; M. Geen & Son, Lewisham; and C. Merrit, London, for the loan of various blocks; and I have to acknowledge valuable assistance in the reading of the proof sheets from W. Thoms, F.R.M.S., Alyth, and Owen Simmons, F.C.S., Winchester.

I earnestly hope that this book may be of service to the trade in helping bakers to understand their business better and to work at it more intelligently. If it fulfils this anticipation, I shall be amply repaid for the time and work spent in its preparation.

THE AUTHOR.

September, 1895.

THE ELEMENTARY PRINCIPLES OF BREADMAKING.

PART I.

The Structure, Nature and Composition of the Raw Products used in Breadmaking.

CHAPTER I.

THE STRUCTURE OF THE WHEAT GRAIN.

THE wheat plant is an annual grass belonging to the natural order Graminaceæ, and is named *Triticum*.

The grain of the wheat plant is an oval body, with a deep furrow or crease running longitudinally on one side, and a small wrinkled depression near the base of the opposite side, indicating the position of the germ, below which is the scar marking the point of attachment to the stalk. If a longitudinal section be made along the line of the crease, the following parts may be seen with ease by the aid of a microscope:

(1) An outer protecting envelope named the bran.
(2) An internal white soft kernel—the endosperm.
(3) A yellowish body situated near the base of the grain—the germ, separated from the endosperm by an organ named the scutellum.

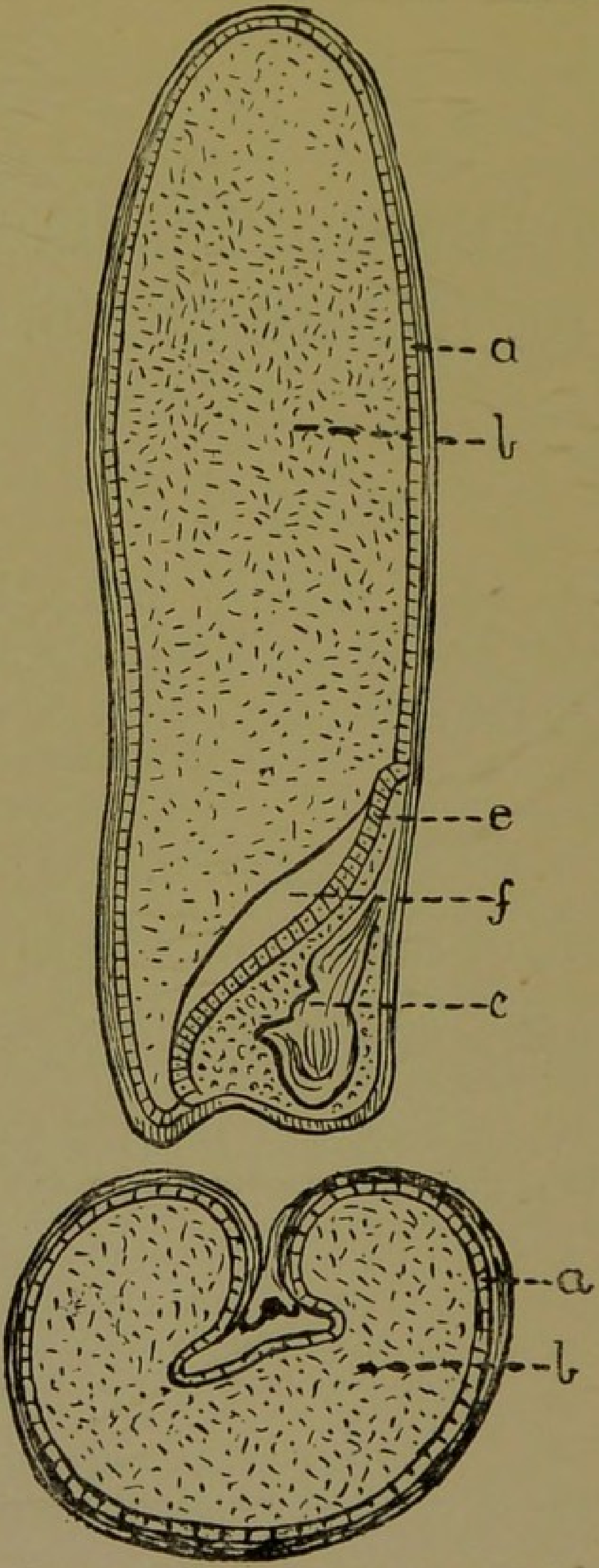


FIGURE I.—LONGITUDINAL AND TRANSVERSE SECTION OF THE WHEAT GRAIN.

(a) Bran. (b) Endosperm. (c) Germ. (e) Scutellum. (f) Space where germ has separated from endosperm in cutting.

Broadly speaking, the bran may be regarded as protective in function, the germ as the embryonic wheat plant, and the endosperm as a store of food for the germ during the various stages of germination.

The **Bran** may be divided into two coats :

(1) The outer coat representing the fruit or pistil, is made up of

(a) An external layer, consisting chiefly of oblong woody fibre and cellulose cells, arranged with their longest diameters parallel to the long axis of the grain.

(b) A second layer of cells with their longest diameters at right angles to the outer layer.

(2) An inner coat which may be regarded as the envelope of the *seed* proper.

These coats may be fairly well made out by soaking a few grains in warm glycerine and water, and then carefully peeling off the two coats with a fine pair of forceps with the aid of a hand lens. The first coat readily comes away in two layers, but the second coat is more difficult to remove. (See part 4.)

When an oblique section of the bran is treated with suitable stains and reagents, and examined under a high power of the microscope (one sixth), the inner coat of the bran is seen to be divided into two others.

The following table gives the names and relative position of the various layers :

COATS AND LAYERS OF BRAN.

(1) External coat (Pericarp)	a. Outer layer. b. Middle layer. c. Inner layer.
(2) Seed coat (Integument)	d. Outer layer. e. Inner layer. f. Cerealin cells belonging properly to the Endosperm.

The two outer layers of bran consist for the most part of cellulose and woody fibre arranged in oblong meshes, while in the third layer oblong cells are found transversely to the long axis of the grain. These cells are commonly known as the "girdle cells."

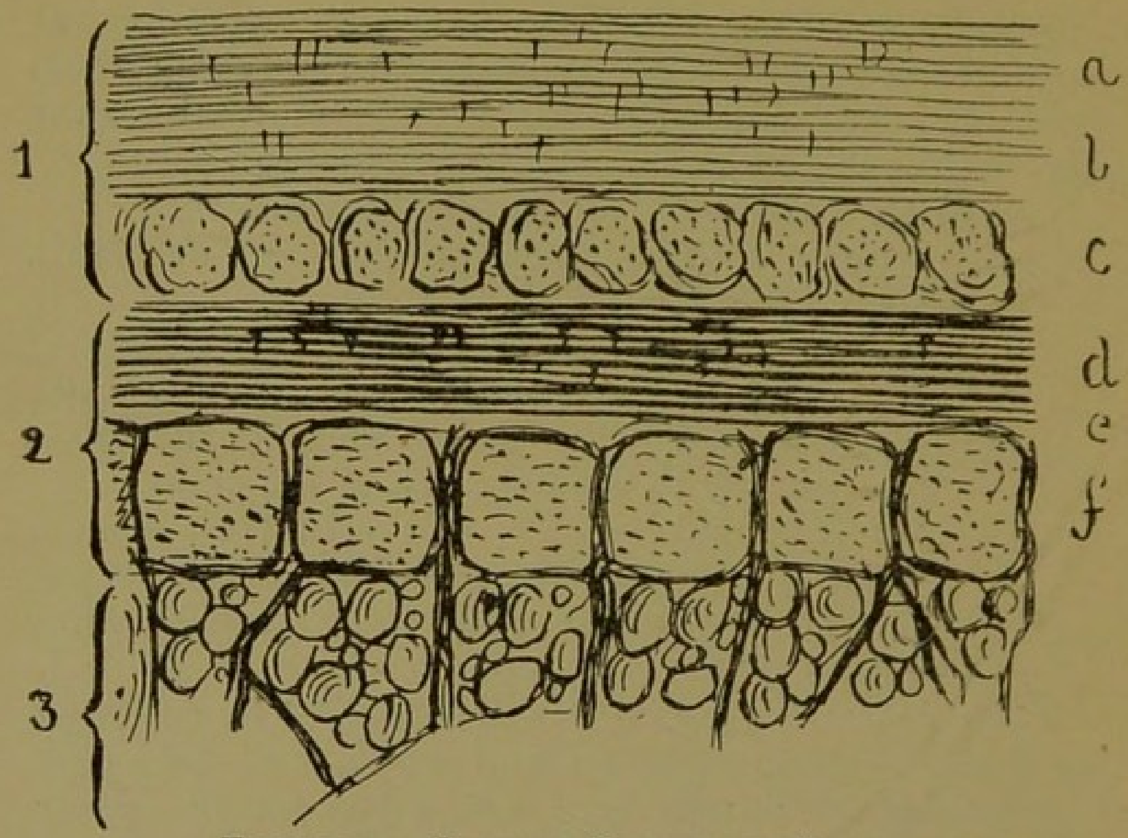


FIGURE 2.—OBLIQUE SECTION OF BRAN.

(1) EXTERNAL COAT or PERICARP: (a) Outer layer; (b) Middle layer; (c) Inner layer. (2) SEED COAT or INTEGUMENT: (d) Outer layer (e) Inner layer; (f) Cerealin cells. (3) ENDOSPERM.

The layer (d) may be regarded as the first of the coverings belonging properly to the seed, and usually contains pigment.

The cerealin cells are somewhat square shaped, and have walls of cellulose and woody fibre. Each cell is filled with a form of nitrogenous matter known as "aleurone grains."

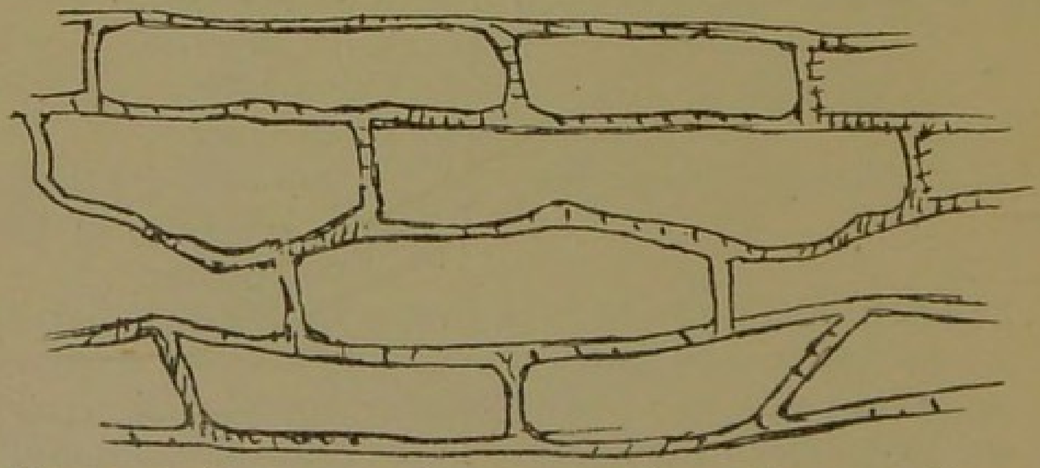


FIGURE 3.—CELLULOSE CELLS FROM OUTER LAYER OF BRAN.

The **Endosperm** is composed of irregularly-shaped cells of cellulose, containing starch grains lying on gluten. By washing the endosperm the starch grains may be separated, and are then seen to consist of lenticular granules.

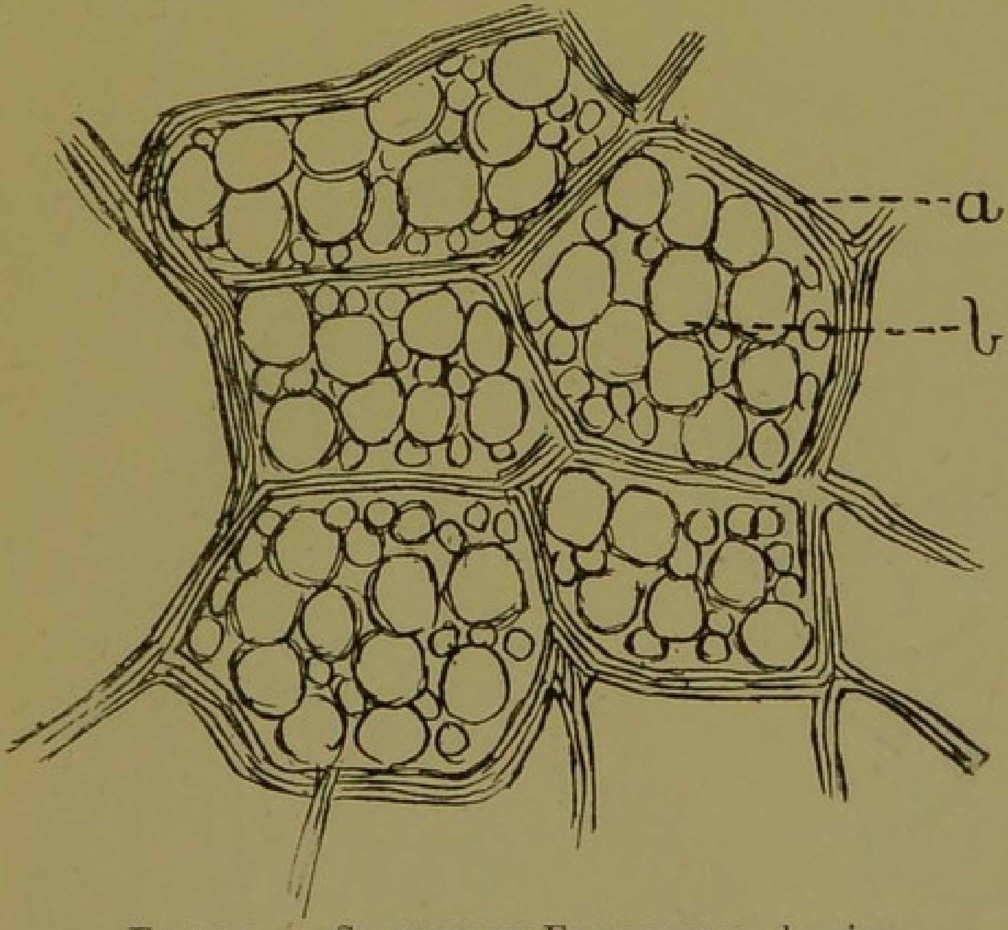


FIGURE 4.—SECTION OF ENDOSPERM, shewing (a) Walls of cellulose cells. (b) Starch grains lying on gluten.

The **Germ** is the embryonic wheat plant. It lies in a curious shield-like body named the scutellum, which separates it from the endosperm.

It is in form a double cone, ending below in the primary root (radicle), and above in the plumule, or first leaf.

When examined under a high power of the microscope it is seen to consist of a large number of protoplasmic cells, each capable, under certain conditions, of undergoing cell division.

The germ is separated from the endosperm by the scutellum, which acts as a medium of communication between the young growing plant and the store of food in the endosperm. The outer layer of the scutellum is modified into a layer of columnar cells termed "secretory epithelium." These cells, under certain conditions, to be discussed later, develop ferments, which gradually render diffusible the insoluble starch and gluten of the endosperm.

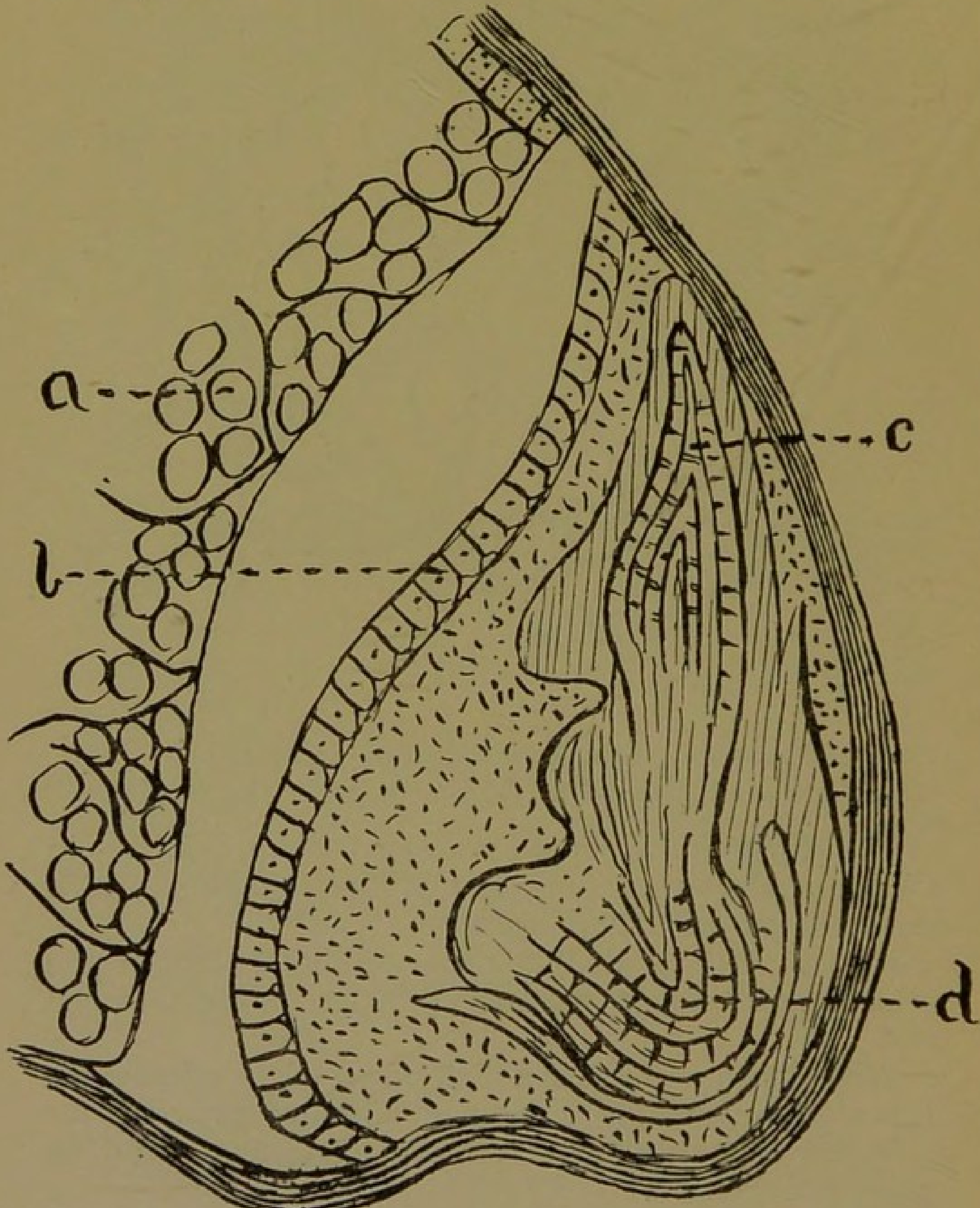


FIGURE 5.—SECTION OF GERM.
(a) Starch grains of Endosperm. (b) Secretory Epithelium. (c) Plumule (leaf). (d) Radicle (root).

CHAPTER II.

THE PROXIMATE PRINCIPLES OF THE WHEAT GRAIN AND THEIR FOOD VALUE.

HAVING learnt something of the physical structure of the wheat grain we may now pass conveniently to a study of the general properties of its more important constituents. When analysed the whole grain is found to consist of the following bodies in the proportions given :

COMPOSITION OF WHEAT GRAIN.

PROXIMATE PRINCIPLE.	FOOD STUFF.	PER-CENTAGE.
Water ...	Water	11·94
Proteids ...	Gluten (Insol.) and Soluble albumins.	14·23
Carbo-hydrates	Starch, Dextrin, Sugar	67·58
	Cellulose, Woody fibre ...	2·89
Fat ...	Palmitin, Olein	1·64
Ash ...	Alkaline Phosphates chiefly ...	1·72
		100·00

Proteids are compounds of carbon, hydrogen, oxygen, nitrogen and sulphur, and may be looked upon as the foods which renew the wasting nitrogenous tissues. They are absolutely essential to life, and animals deprived of them die of nitrogen starvation. The general composition of proteids may be stated as follows :

Carbon	52·8
Hydrogen	6·9
Nitrogen	16·8
Oxygen	21·7
Sulphur	1·8
	100·0

Some proteids are soluble and have the property of converting starch into sugar.

The more important proteids of the wheat grain are:

(1) Aleurone, found chiefly in the cerealin cells and germ.

(2) Gluten consisting of
 (a) Glutin.
 (b) Mucin.
 (c) Vegetable fibrin.

(3) Soluble albuminoids.
 (a) Vegetable albumin.
 (b) Legumin.

Carbo-Hydrates.—These bodies are compounds of carbon, hydrogen and oxygen in which the hydrogen and oxygen are in the exact proportions to form water. The following table gives a list of the more important carbo-hydrates and their simplest formulæ:

Animal	Lactose or Milk Sugar	$C_{12}H_{22}O_{11}$
	Glycogen or animal starch	$C_6H_{10}O_5$
Vegetable	Starch	$C_6H_{10}O_5$
	Dextrin	$C_6H_{10}O_5$
	Cellulose	$C_6H_{10}O_5$
	Woody fibre	$C_6H_{10}O_5$
	Dextrose, glucose or grape sugar	$C_6H_{12}O_6$
	Maltose or malt sugar ...	$C_{12}H_{22}O_{11}$
	Sucrose or cane sugar ...	$C_{12}H_{22}O_{11}$

The constitution of the carbo-hydrates will be readily understood by breaking up the formula of a carbo-hydrate into carbon and molecules of water. For example $C_{12}H_{22}O_{11}$ is the formula for cane sugar or sucrose; this may be written $C_{12}(H_2O)_{11}$. But H_2O i the formula for water, and it will be observed that there is just sufficient hydrogen to combine with the oxygen to form eleven molecules of water, so that cane sugar might be regarded as twelve atoms of carbon combined with eleven molecules of water. In a similar way any carbo-hydrate may be shown to contain the elements of hydrogen and oxygen in the exact proportions to form water. A very simple experiment will show that cane sugar contains carbon and water. Place a cube of loaf sugar in a tumbler, add sufficient pure strong sulphuric acid to cover the piece of sugar to the depth of half-an-inch and allow the whole to stand. After a time the cube will turn black, and on examination is found to consist of carbon, while the sulphuric acid may be shown to have gained water. Of the carbo-hydrates mentioned above, cellulose and woody fibre are indigestible, but perform mechanical functions in stimulating the natural movement of the small intestines, and giving bulk to a meal.

The carbo-hydrates are concerned in the production of animal heat, and contribute largely to muscular energy. They are incapable of taking part in the constitution of protoplasm, and thus cannot support life alone. Animals fed entirely on carbo-hydrates soon die of "nitrogen starvation."

Fats are also compounds of carbon, hydrogen and oxygen, but they differ greatly from the carbo-hydrates in the fact that they contain more hydrogen than is sufficient with the oxygen to form water. The following are the chief fats :

Stearin	$C_{57}H_{110}O_6$
Palmitin ...	$C_{51}H_{98}O_6$
Olein	$C_{57}H_{104}O_6 + 3H_2O$

Of these only the two latter are found in the wheat grain. The following example will help to make the difference between fats and carbo-hydrates clear :

890 grams of palmitin yield of

Carbon	684 grams.
Hydrogen	110 „
Oxygen	96 „
	890 grams

while 890 grams of starch yield of

Carbon	$395\frac{45}{81}$ grams
Hydrogen	$54\frac{76}{81}$ „
Oxygen	$439\frac{41}{81}$ „
	890 grams

These figures give a surplus of carbon and hydrogen in favour of fat to the extent of $288\frac{36}{81}$ grams and $61\frac{5}{81}$ grams respectively. In the example given there would be exactly 98 grams of hydrogen over that required to combine with the oxygen to form water. Fat is chiefly concerned in the production and maintenance of animal heat, primarily by the oxidation of the carbon and hydrogen which they contain. It follows therefore that fat, containing, weight for weight, far more of these elements than the carbo-hydrates, has greater caloric (heat) value. On this account, fat occupies a prominent position in the diets of people who live in cold countries. The other duties of fat in the body may be summarised as under:

(1) It is stored up in the cavities and depressions between muscles, giving a roundness and grace to the figure.

(2) It facilitates the movements of various organs by lining grooves and cavities.

(3) It minimises the effects of sudden jars by acting as elastic pads in various parts of the body.

(4) The layer of fat beneath the skin prevents the rapid loss of heat from the body.

(5) Its presence in the contents of the small intestine favours the peristaltic movement and thus tends to prevent constipation.

(6) Its presence in the small intestine facilitates the absorption of food by the villi.

Mineral Matter.—Little is positively known concerning the true functions of the various salts found in our foods. If mineral matter be withdrawn from the diet of an animal it soon falls into ill health, showing that salts are intimately connected with the nutrition of the tissues. The following table gives the various mineral bodies in the ash of wheat:

PERCENTAGE COMPOSITION OF ASH OF WHEAT.

Potash (K_2O) ...	... 31·86
Magnesia (MgO) ...	... 11·17
Lime (CaO) ...	... 2·61
Ironoxide (FeO) ...	... ·90
Soda (Na_2O) ...	... ·28
Phosphoric Acid (P_2O_5)	... 51·88
Sulphuric Acid (SO_3)	... ·75
Silica (SiO_2) ...	... ·49
Chlorine (Cl) ...	... ·06
	100·00

Broadly speaking, the ash consists chiefly of potassium phosphate.

The wheat grain contains all the necessary principles to support life, but they are not in the correct proportions required by the body. This will be readily understood by a study of the appended table, giving side by side the mean normal diet and the corresponding figures for the wheat grain :

NORMAL DIET.		WHEAT GRAIN.
Proteids ...	4·50 oz.	3·70 oz.
Carbo-hydrates	14·25	18·08 oz.
Fat	3·00	·48
Mineral ...	1·00	·49
Inert matter		Normal

Summing up, we may say that

(1) Wheat is deficient in proteid (N), fat and mineral matter.

(2) It contains a surplus of carbo-hydrates.

CHAPTER III.

THE FOOD STUFFS OF THE WHEAT GRAIN.

STARCH is very widely distributed through the vegetable kingdom, occurring in all green plants. It is found in the form of small granules technically termed "starch grains," stored up in various parts of the plant in cellulose cells.

Seeds, tubers and roots generally contain a considerable percentage of starch.

Starch usually appears in the chlorophyll corpuscle of a plant as a minute spherical body, technically termed an amyloplast, consisting of an hilum, and consecutive additions to the granule appear as more or less concentric layers. The formation of starch only goes on in the presence of sunlight. In the wheat grain, however, what is first formed in the chlorophyll corpuscle is an aldehyde.

The following diagram shows potato starch grains *in situ* (in their natural position).

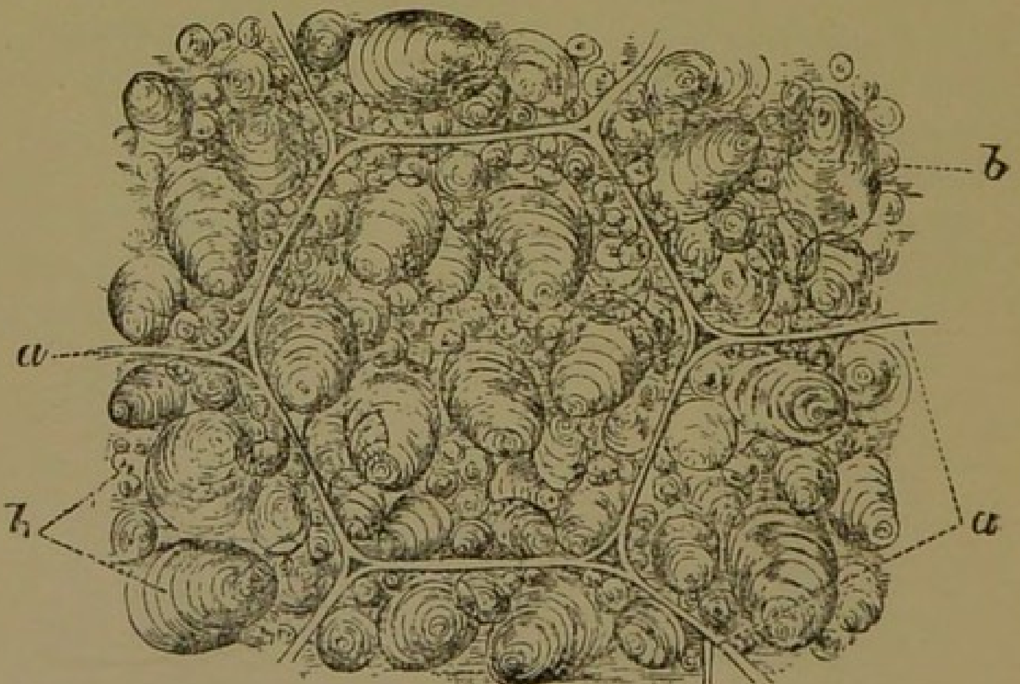


Figure 6.
Section of Potato Showing Starch Granules *in situ*.
(a) Wall of Cellulose Cell. (b) Starch Grains.

PROPERTIES OF STARCH.

Pure starch is a white powder, having a specific gravity of 1,600, water being taken at 1,000.

It is insoluble in cold water, and can only be dissolved by the disintegration of the organised structures of the granules.

On being boiled with water it forms a gelatinous looking mass, and partially dissolves. When examined after boiling the starch granules are seen to have been broken up, part remaining in the liquid as minute insoluble particles. In this condition starch is very susceptible to the action of the bodies known as ferments.

Starch from different plants gelatinises at different temperatures, but no exact figures can be given.

The following table should therefore be taken as approximate only:

NAME OF STARCH.	TEMPERATURE OF GELATINISATION.
Rye	125°F—135°F
Maize	130°F—145°F
Barley	135°F—145°F
Potato	135°F—145°F
Rice	135°F—145°F
Wheat	148°F—152°F

The filtered solution of starch is neutral, colourless, odourless and tasteless, but the starch may be precipitated by the addition of a sufficient quantity of absolute alcohol.

With iodine solution starch in the *presence* of water, and in the *absence* of alkalies, gives a beautiful indigo blue colouration, which disappears on boiling, but reappears on cooling. This may be regarded as the characteristic chemical test for starch. Starch, when boiled with dilute acids, is converted into sugar. Ferments like ptyalin of saliva and diastase of malt change starch into maltose and dextrin. When raised to 150°C starch is also converted into dextrin.

Appearance under microscope.

When starch grains are examined under a high power of the microscope they appear to consist of

(a) A central portion termed the hilum surrounded by (b) concentric layers.

In some starches, however—wheat starch for example—the concentric layers are only seen with difficulty.

When the light is "polarised" in many cases a beautiful cross appears in each granule. This is well seen in potato starch.

The starch granules from different plants vary considerably in shape and size, and it is comparatively easy to ascertain the plant from which the starch was derived by the microscopic appearance of the grains.

The following drawings have been taken directly from the microscope from specially prepared slides by the author, and for the purposes of comparison represent a multiplication of 375 diameters. The student is recommended to make a careful study of these drawings, and then proceed to practical work as directed in Part IV.

Potato Starch is found in the form of pear-shaped grains. Each grain shews a distinct hilum and eight or nine concentric layers. A distinct cross is seen under polarised light. The granules vary in size, the smallest being $\frac{1}{5000}$ of an inch in diameter, while the largest average $\frac{1}{400}$.

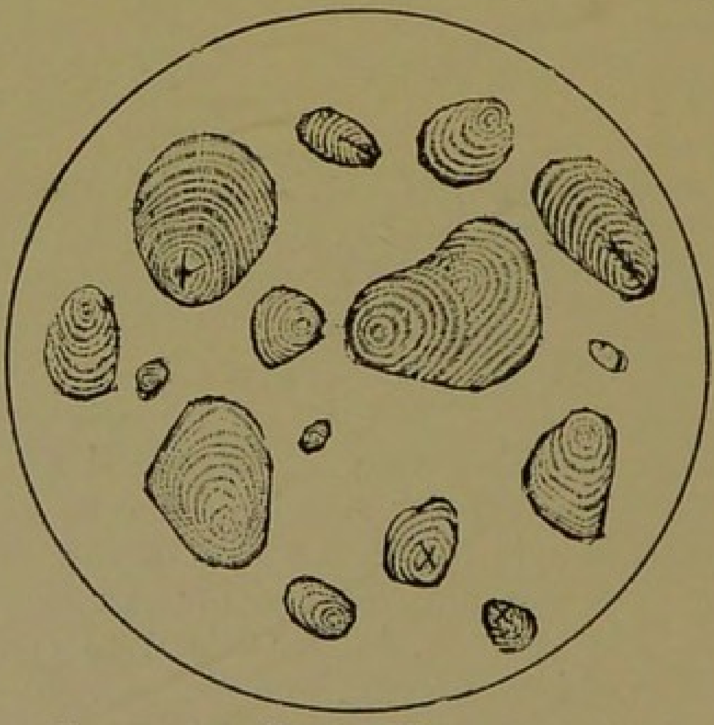


FIGURE 7.—POTATO STARCH × 375.

Barley Starch is composed of large and small grains averaging respectively $\frac{1}{6000}$ and $\frac{1}{8800}$ of an inch in diameter. Star-shaped nuclei are often seen, and no cross is observed under polarised light.

Rye Starch grains are larger than those of wheat and do not generally shew rings. The small grains average $\frac{1}{5700}$ of an inch, and the large granules $\frac{1}{730}$. A distinct cross is seen under polarised light.

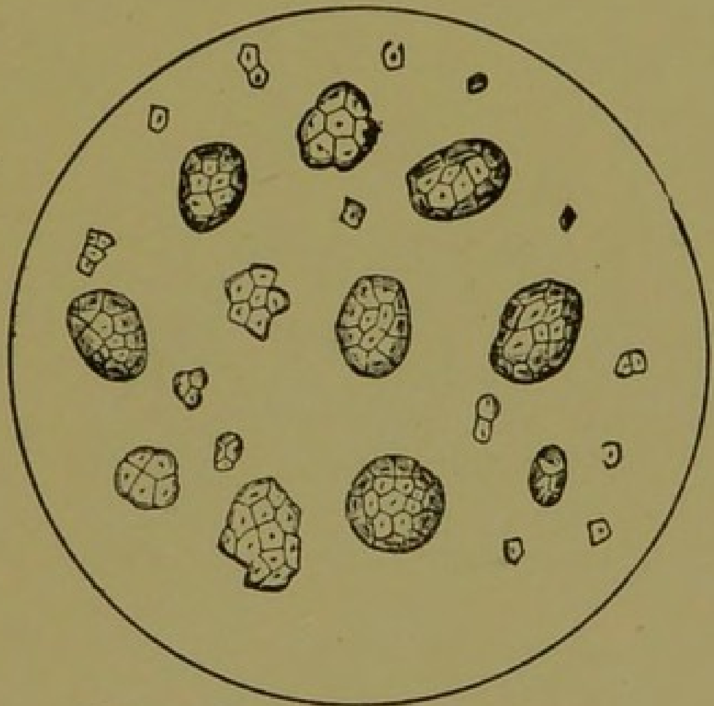


FIGURE 8.—RYE STARCH × 375.

Bean Starch differs greatly from the other starches excepting that of the pea. The grains are oval in shape

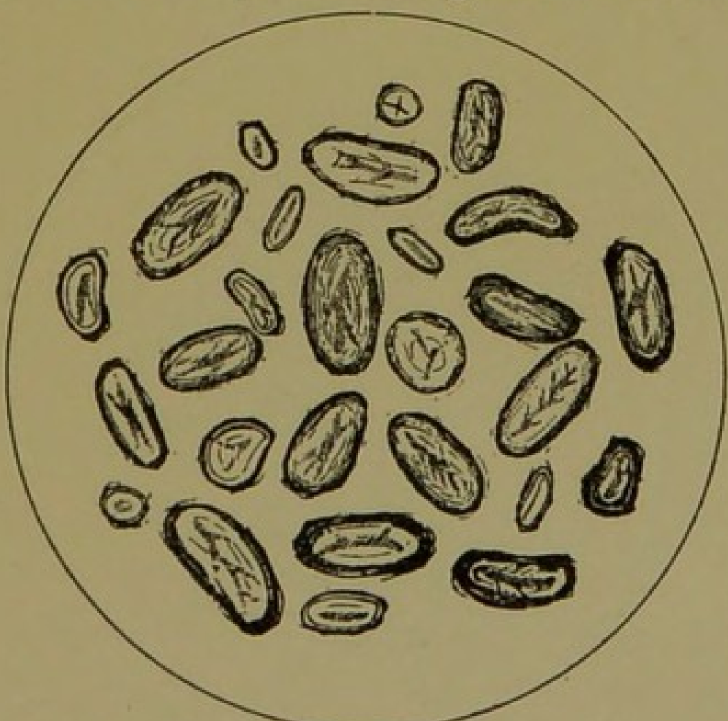


FIGURE 9.—BEAN STARCH × 375.

and uniform in size. The average grain measures about $\frac{1}{650}$ of an inch in length, and $\frac{1}{1000}$ of an inch in breadth.

Pea Starch is very like bean starch, but the grains are smaller.

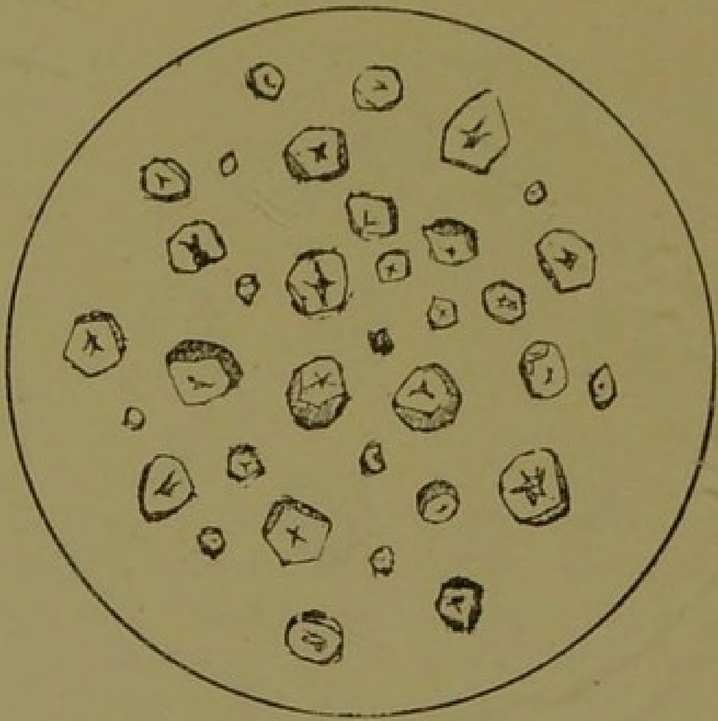


FIGURE 10.—MAIZE STARCH × 375.

Maize Starch grains are bounded by plane faces and angles. They have no rings, and usually present

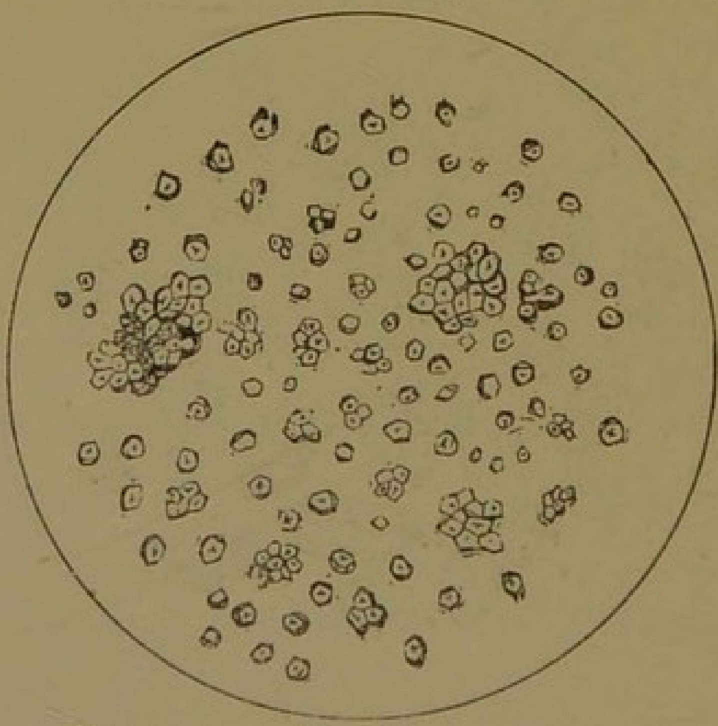


FIGURE 11.—RICE STARCH × 375.

a star-shaped nucleus. The average grain measures $\frac{1}{1000}$ of an inch in diameter.

Rice Starch. The granules of rice are very small and angular, and present an appearance similar to the smallest grains of wheat starch. They average about $\frac{1}{5000}$ of an inch in diameter.

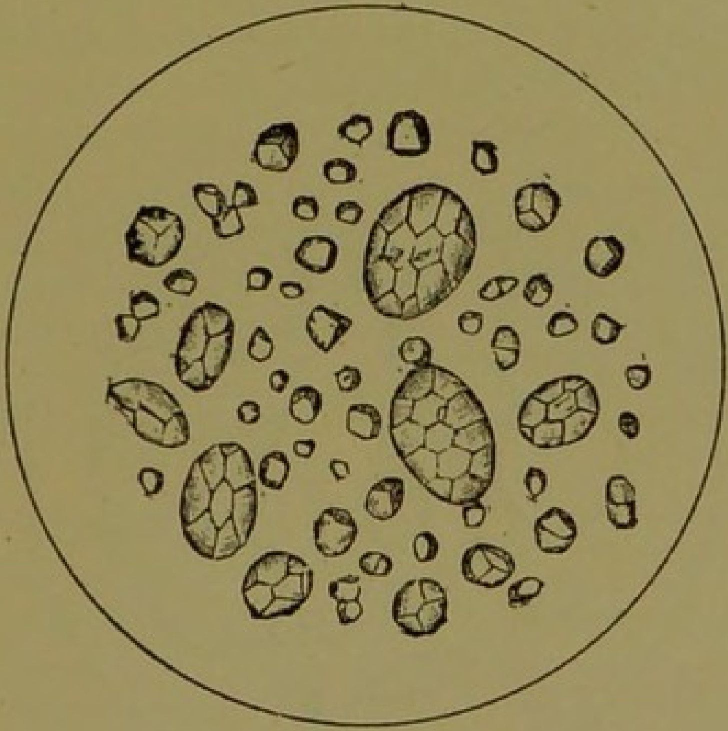


FIGURE 12.—OAT STARCH × 375.

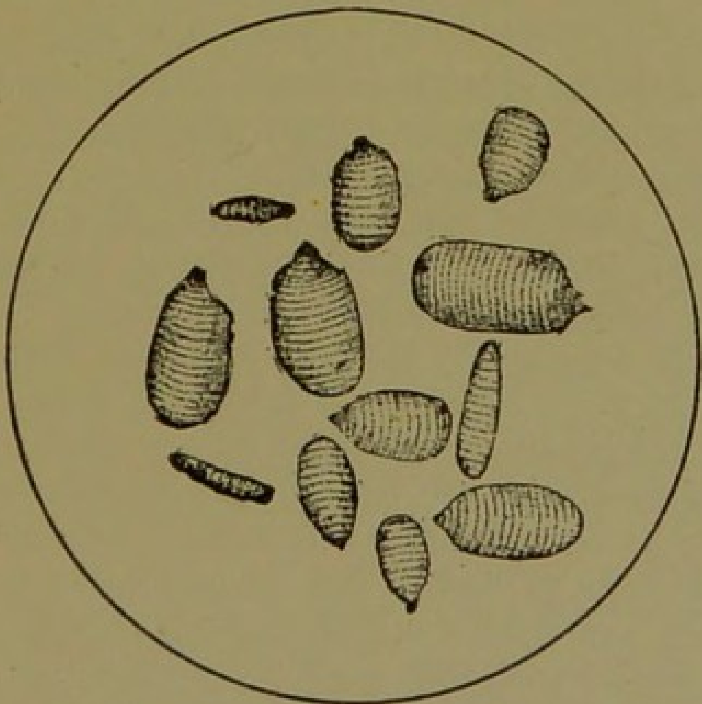


FIGURE 13.—TURMERIC STARCH × 375.

Oat Starch has a very similar appearance to rice under the microscope, and it is by no means easy to distinguish between them. The small granules are $\frac{1}{4080}$ of an inch in diameter and are usually bounded by curved faces.

Turmeric Starch is obtained from the *Curcuma Songa* and is used chiefly to colour other starches yellow. The nucleus is found at the extreme end of the granule which shows numerous rings.

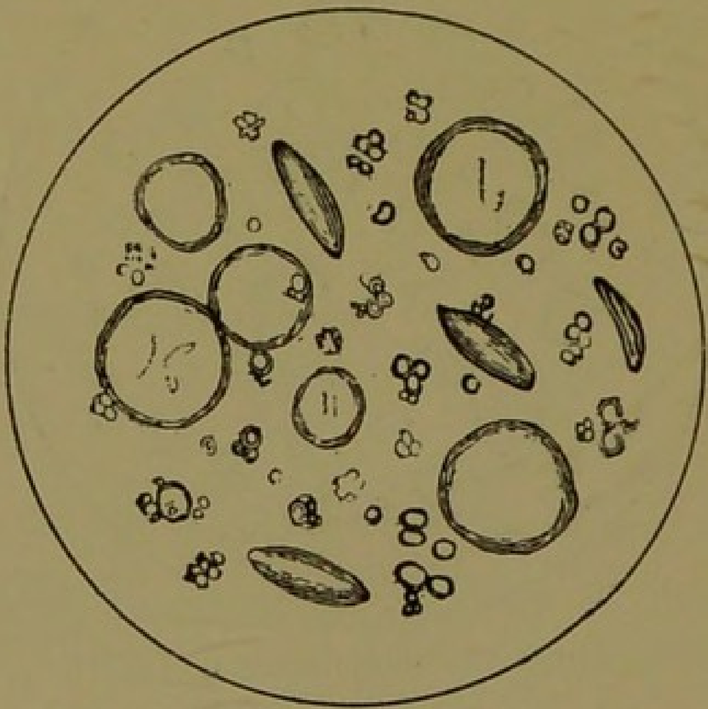


FIGURE 14.—WHEAT STARCH × 375.

Wheat Starch appears as two distinct kinds of grains.

(1) Small spherical or angular grains.

(2) Large lenticular grains.

The larger granular are from $\frac{1}{900}$ to $\frac{1}{1000}$ of an inch in diameter, while the smaller grains average $\frac{1}{5000}$. Intermediate sizes are comparatively absent.

The hilum is generally situated near the centre of the grain, but the concentric rings are only made out with difficulty. No definite cross is seen under polarised light.

Dextrin occurs in small quantities in wheat. When pure it is without colour and odourless. It readily dissolves in water, but is precipitated from its solutions by absolute alcohol. It possesses adhesive properties, and forms the main constituent of "British Gum." Ordinary commercial dextrin is slightly yellow on account of the presence of traces of caramel. Dextrin may be prepared by subjecting starch to a temperature of 150°C, and then treating with water. The water running away from the starch is a solution of impure dextrin. Dextrin is also produced by the action of certain ferments on starch. Ptyalin of saliva, and diastase of germinating seeds and malt extract, produce various forms of dextrin during the conversion of the starch into sugar. Dextrin is more digestible than starch, and hence has to a certain extent a higher food value.

Chemical Properties.—The actual constitution of the dextrin molecule has not yet been worked out satisfactorily. It probably consists of many groups, and the formula $C_6H_{10}O_5$ should only be taken as the simplest representation of the ratio of the various elements to each other. There are two great classes of dextrins :

(1) Erythro-dextrins.

(2) Achroo-dextrins.

The former are distinguished by the beautiful port wine colouration which they give with a solution of iodine. The colour disappears on boiling and does not return on cooling. The achroo-dextrins do not give a colouration with iodine solution. All the erythro-dextrins, and some of the achroo-dextrins are capable of being converted into maltose by the action of ferments or soluble albuminoids, and details of recent experiments by the author will be given in the chapter on "Fermentations and Malt Bread."

Dextrose is not found in the fresh wheat grain, but exists as a constituent of the juice of ripe fruits, and makes its appearance in wheat soon after storage. It is often spoken of as glucose or grape sugar. It is very soluble in water, and readily undergoes conversion into alcohol and carbon-dioxide under the action of yeast. It may be produced by the action of dilute acids on starch, and is manufactured in this way on a large scale to form commercial glucose. Glucose often forms a considerable part of "yeast foods." The chief chemical tests for glucose is Fehling's solution, which yields on heating a red precipitate of cuprous oxide. If Fehling's solution be not available Tronmer's test may be employed. (See Part IV.)

Lœvulose is similar to dextrose in many respects, but it rotates a ray of polarised light to the *left*, while dextrose moves it to the right. It gives a red precipitate with Fehling's solution.

Maltose is a most important constituent of germinating seeds, and is thus present in "malt extract." It does not appear to be present in the normal fresh grain of wheat, but is slowly formed in small quantities by the conversion of the starch. It is very soluble in water and sparingly so in alcohol. With Fehling's solution it gives a red precipitate.

Cane Sugar is present in the juices of certain plants, chiefly the sugar cane and beetroot. It is extremely soluble in water, sparingly soluble in dilute alcohol, but is precipitated by absolute alcohol or chloroform. On heating pure cane sugar, it first melts, and then begins to undergo decomposition at about 220°C. Volatile bodies are driven off, and a soluble solid brown mass is left behind to which the name caramel has been given. Cane sugar does not give a red precipitate with Fehling's solution, but will do so after heating with hydrochloric acid. Cane sugar so treated is named "invert sugar." The natural sugar of the wheat grain has many of the characteristics of cane sugar.

Invert Sugar may be produced by heating together a solution of sugar and hydrochloric acid at a temperature of 70°C. The cane sugar is converted into a mixture of dextrose and lœvulose, and is then capable of reducing Fehling's solution. The change is represented equationally below :

$$C_{12}H_{22}O_{11} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Lœvulose.}}{C_6H_{12}O_6}$$

Cellulose forms part of the skeleton of the wheat berry. It gives a brown colour with Schultz's solution (see part IV.), and is converted into dextrin by the action of sulphuric acid.

Woody Fibre is much tougher than cellulose, and is not found very largely in the wheat berry. It chiefly exists in the bran.

SUMMARY OF REACTIONS.

BODY.	WITH IODINE.	WITH FEHLING.
Starch ...	Blue colouration...	No precipitate.
Erythro-dextrin	Red " ...	" "
Achroo-dextrin	No " ...	" "
Dextrose ...	No " ...	Red "
Lœvulose ...	No " ...	Red "
Maltose ...	No " ...	Red "
Cane sugar	No " ...	No "

Proteids.—Before passing on to a consideration of gluten it will be well to enumerate the general properties of the class of bodies to which it belongs. Gluten is classified among the proteids or albuminoids. The proteids are very complex bodies, which do not diffuse through moist animal membranes. By the action of certain ferments, viz., pepsin of gastric juice, and trypsin of pancreatic juice, proteids are converted into highly diffusible bodies known as peptones, which are very soluble in water. Some soluble albuminoids possess this peptonising action. Solutions of native proteid material have the following properties:

(1) They are coagulated by raising to a temperature of 60°C—90°C.
(2) They are precipitated from their solutions by acids, particularly nitric acid and picric acid.
(3) They yield a yellowish green precipitate with acetic acid and ferrocyanide of potassium.
(4) They give a white precipitate with Millon's reagent.
(5) With sodium hydrate and copper sulphate they produce a violet colour which deepens on boiling.

When a native proteid is in combination with an acid or alkali it is said to be a "derived" albumin. The following are the two best known:

(1) Acid albumin or syntonin (albumin + hydrochloric acid).
(2) Alkali albumins or albuminates (albumin + soda or potash).

These are precipitated from their solutions by neutralisation.

Peptones differ from proteids in the following particulars :

(1) They are diffusible.
(2) They yield no precipitate with nitric acid, or acetic acid and ferrocyanide of potassium.
(3) They yield a pinkish colour with sodium hydrate and copper sulphate.
(4) They are not coagulated by the heat.

They resemble proteids in molecular constitution, and in giving a precipitate with Millon's reagent.

Gluten may be regarded as consisting of the insoluble protoplasm of the endosperm cells, which undergoes marked changes on the addition of water. When separated from flour by washing it is seen to be a soft, sticky, elastic, tenacious body. It is insoluble in water, but may be dissolved by ferments. Treatment with lime water materially increases its adhesive character and tenacity. It probably consists of three bodies—glutin, mucin, and vegetable fibrin.

Glutin, or Gliadin, is a yellowish soft body possessing great elasticity and cohesion. It is soluble in 50 per cent. solution of alcohol, but is precipitated by mercuric chloride. Glutin is the most important constituent of gluten, as it gives to that body the characteristic tough property which enables the dough to hold gas. Glutin is practically absent from the flour of the other cereals.

Mucin forms but a small proportion of gluten. It appears as flakes as it separates slowly from its solution in hot alcohol. It is insoluble in cold alcohol, but soluble in boiling alcohol and in cold acetic acid.

Vegetable Fibrin.—Makes up 75 per cent. of the crude gluten. It is soluble in acetic acid and caustic alkalies, and is precipitated from its solutions by neutralisation. It is insoluble in water and alcohol.

Soluble Albuminoids.—These are the albumins which can be washed out of gluten, but they are in largest proportion in the germ and bran, and are soluble in water. When extracted from wheat they are found to be coagulable by heat, and to be capable of converting starch into dextrin and sugar, and exerting a peptonising action on the gluten. The softening or falling off of dough is partly the result of this peptonising action of the soluble albuminoids.

(For practical work see Part IV.)

CHAPTER IV.

THE GERMINATION OF THE SEED.

THE wheat grain may be regarded as a link between the old plant and the new. A daughter of the one, it contains within itself the germ of the other, possessing latent vitality which only awaits favourable conditions to awake to activity. In the first chapter it was shewn that the grain consisted of three main parts :

(1) The bran—protecting in function.
(2) The germ or embryo, consisting of representatives of the stem, leaves and roots.
(3) The endosperm—a store of food for the young plant during the early stage of its growth.

At present we are concerned chiefly with the development of the germ and the changes which are brought about in the constituents of the endosperm. The essential properties of a seed are all summed up in the inactive rudimentary plant and the reserve food material which the latter will at some future time require. When the seed is subjected to suitable conditions—chiefly moisture and warmth—marked changes occur in the germ, which indicate a resumption of active life. The germ consists, for the most part, of cells of protoplasm, which have the power under suitable conditions of undergoing cell division. The growth of the young plant is thus due to a multiplication of the cells of which it consists, and this multiplication only occurs to any extent when suitable nourishment is provided for the developing cells. Part of the nutriment exists adjacent to the scutellum of the germ, but it is mainly found in the endosperm. The chief nutrients of the endosperm and germ are :

(1) Aleurone grains.
(2) Gluten.
(3) Soluble albuminoids.

(4) Starch.
(5) Fat.
(6) Salts, chiefly phosphates.

Of these only the salts and part of the soluble albuminoids are immediately available as food. The other food stuffs, being indiffusible, are totally unsuited for the nourishment of the young plant. It follows then, that before the starch, etc., can be used by the growing germ, they must undergo some change, whereby they are rendered *diffusible*, that is to say, in a fit condition to pass through the walls of protoplasmic cells. The conversion of the indiffusible nutrients is effected by certain bodies known as unorganised ferments (enzymes) which develop in the germinating seed, more especially in the layer of cells termed the secretory epithelium. These ferments act on the starch, gluten and aleurone grains, converting them into highly diffusible bodies, capable of nourishing the living protoplasm of the growing cells. The following are the chief ferments of the grain:

(1) Cytase. Acts on cellulose.
(2) Diastase. } Act on starch.
(3) Cerealin. }
(4) Vegetable trypsin. } Acts on gluten and aleurone grains.
(5) A ferment which acts on fat, for which the author proposes the name Emulsitin. } Acts on fat.

In addition to these, some of the soluble albuminoids have fermentive properties. The ferments of the grain are nitrogenous, and belong to the class known as "unorganised." Their nature is little understood, and it is an undecided point as to how far their activity is connected with the albuminoids with which they are usually associated. They possess, however, the following common features:

(1) They are present in small quantities.
(2) Their activity is closely dependent on a limited range of temperature.
(3) They are not materially changed or destroyed by functional activity.

(4) They do enter themselves into the composition of the bodies which they produce.

(5) Their action is closely connected with the reaction of the medium, alkaline, or acid, in which they work.

Before passing on to the changes in the seed itself, a short account of the various ferments will be advisable.

(1) **Cytase.**—Little is known concerning the actual formation of this ferment, or the nature of its action. It makes its appearance in the secretory epithelium prior to diastase, and gradually dissolves the cellulose walls of the endosperm cells, thus setting free the gluten and starch granules. Under the action of the ferment the cellulose swells, and gradually disappears. Little is known concerning the products of its activity. The chief point to remember is that by its activity the starch and gluten are set free, so that the other ferments may act on them freely.

(2) **Diastase** is the most important of the vegetable ferments. It is elaborated by the cells of the secretory epithelium. The action of diastase has been exhaustively studied by various observers, and an account of the most recent researches will appear in the chapter on "Unorganised Ferments." It will be sufficient to say here that it acts on gelatinized starch at suitable temperatures with great energy, and that the final products of its action are maltose and a stable achroo-dextrin.

(3) **Cerealin** is found chiefly in the layer of square-shaped cells of the outer zone of the endosperm. It acts on starch converting it into maltose and dextrin. It has also, according to some authorities, an action on proteids. It is uncertain what part cerealin plays in the germination of the seed.

(4) **Vegetable Trypsin** is closely allied to a similar ferment found in pancreatic juice. It is elaborated by the secretory epithelium, and acts on aleurone grains and gluten. The action is very complex, and has not yet been worked out in detail. From experiments which the author has performed the following provisional statement may be made:—The first action of trypsin is to form two bodies named respectively anti-peptone and hemi-

peptone. The latter in large quantity. The former remains as peptone, and has certain functions to perform in the reconstruction of protoplasm, but the latter undergoes a further decomposition whereby two crystalline *amides* are formed, one belonging to the aromatic series and the other to the fatty series. These amides are specially adapted for diffusion through the walls of vegetable cells, and undoubtedly form the bulk of the products of the activity of vegetable trypsin.

(5) **Emulsitin** is not formed very extensively in the germinating wheat grain, but the author has studied its actions in the germinating seeds of the castor oil plant. It acts exclusively on neutral fats, splitting them up into fatty acids and glycerin. The former combine with alkaline bases of the grain to form soaps which are absorbed by the growing cells. There are indications also of an emulsion of neutral fats.

It will be observed that the whole of the ferments with the exception of cerealin are mainly elaborated by the secretory epithelium. But it is important to remember that the layer of secretory cells is *absorptive* as well as secretory, and acts as a medium, whereby the dissolved constituents of the endosperm pass to the growing cells of the germ.

We have seen then that the germinating grain of wheat develops ferments which produce chiefly :

(1) Maltose (carbo-hydrate).
(2) Peptones and amides (nitrogenous).
(3) Soap and emulsified fat.

all these being suitable nutrients for the developing plant.

In addition, diffusible salts—phosphates chiefly—already exist in the grain, and water is absorbed from the moist soil.

The germination of the seed then practically depends on the formation of the ferments, and the question now arises, "What is their origin?"

It is probable that the *antecedents* of these ferments already exist in the inactive grain, and that they only require the finishing touches to convert them into the actual ferments. The general name zymogen has been given to these antecedents of ferments, and the author has succeeded in tracing a zymogen of diastase and vegetable trypsin, to which the names Diataligen and Vegetable Trypsinogen may be provisionally given. On the exposure of the seed to moisture and warmth the alkaline reaction of the seed changes, owing to the formation of vegetable acids, and these acids effect the conversion of the zymogens into the ferments. Some observers say that the ferments are derived from the broken-down protoplasm of the cells in which they appear or in adjacent cells.

We are now in a position to briefly sum up the changes which occur in the seed during the various stages of germination.

There is first an absorption of water, and a slight increase in volume. Vegetable acids are formed which effect the conversion of the zymogens into the various ferments. The first ferments to act are probably cytase and trypsin, the former performing the preliminary work of setting free the contents of the endosperm, while the latter produces amides for immediate use, and which are necessary to give the initial start to the growth of the cells of the germ. Concurrently diastase and emulsitin are produced, and the slow work of solution goes on, the soluble products being absorbed by the embryo plant, and used as pabulum for the multiplying cells. As the cells develop, the germ rapidly increases in size, and so the plumule or leaf, and radicle or root, gradually increase in length—the former upwards, the latter downwards. By-and-bye, the leaves appear above the surface, where they are able to take in the CO_2 from the air, and the root has so far developed that it can now absorb soluble matter from the soil. The endosperm has by this time been depleted of its store of food, and the husk soon decomposes and drops off from the now vigorous plant. A new phase of life has now been entered upon. The plant no longer feeds on complex bodies like sugar, amides, and fat. It has ceased to be an analytical feeder. It no longer breaks down organic bodies into diffusible compounds. It is now a great builder. It is synthetical in its work, and from simple compounds like CO_2 ammonia and soluble salts it elaborates the very complex organic substances upon which it fed in its embryonic stage.

CHAPTER V.

THE MILLING PRODUCTS OF THE WHEAT BERRY.

THE more important bodies obtained by various modes of grinding the wheat berry may be enumerated as follows :

(1) Flour.

(2) Bran.

(3) Germ.

(4) Various other products unsuited for breadmaking included under the term offal.

(5) Decorticated meal.

(6) Whole-meal.

There are two systems of milling in vogue :

(1) Roller milling.

(2) Stone ,,

In the former system the grains are gradually reduced by being passed through a succession of steel rollers, while in the latter the grains are ground between mill-stones. The roller method produces a greater variety of products which differ widely in properties and composition, and more completely removes the germ from the grain than the stone-milling system. In the latter only two or three flours are produced, which do not differ very materially in composition. A short account of these different systems will be given in the next chapter.

Flours may be regarded as the products of the endosperm. They differ very widely in colour, percentage of gluten, &c., according to the part of the endosperm which predominates in the particular flour. Usually the central portions of the endosperm yield the lightest flours, while from the outer portions darker varieties are produced. The flours obtained from the centre of the grain contain less gluten and more starch than those produced from the more external parts, but the gluten, being older, is of better quality, and therefore more tenacious. The term "stable" is often applied to those flours which contain a high percentage of tenacious gluten.

Flour contains all the constituents which are found in the wheat berry, but is very poor in fat, cellulose, and ash. The physical properties of flour are of the utmost interest and importance to bakers. In order of merit they may be stated as follows:—(1) Colour, (2) Flavour, (3) Stability, (4) Strength.

Colour is often the only test which a baker applies to flour, for as a general rule the lightest flour produces the whitest loaf, and the baker usually regards colour in ordinary bread as of paramount importance. The colour may be examined dry and wet. In the former case the samples are placed adjacent to each other and smoothed on a small board by an ivory spatula, when the colours may be compared roughly by the unaided eye, while in the latter the smoothed flours are carefully dipped into clean water and allowed to dry, and the tints then examined. As a rule the colour of flour largely depends on the percentage of ash, fibre, fat and starch present. All other things being equal, the higher the percentage of the first three, and the lower the percentage of starch, the darker is the flour.

Often the darker flours are very rich in gluten, while conversely the lighter flours are comparatively poorer in that important constituent. It must not be concluded, however, that the *whitest* flour is the best. As a rule pure white is objectionable in a flour, as it indicates an undue proportion of *starch*. The best flours usually have a slight yellowish tinge.

Flavour is of the utmost importance to the baker, for bread of good flavour commands a ready sale and builds up a flourishing business. Flavour is, of course, not a matter for chemical examination, and is best judged by making the flour into bread.

Stability may be described as the length of time the dough will keep its tenacity and cohesion, after having absorbed a given quantity of water to form a dough of usual consistency, either with or without fermentation. After a dough has been made of a registered stiffness, a "falling off," or softening, will be observed. This softening is necessary, up to a certain point, for the production of good bread, and is due to the peptonising action of soluble albuminoids, in addition (during the fermentation) to the action of yeast, and, possibly, micro-ferments. The longer a flour withstands this softening, or peptonisation, the greater is its stability. Flours from the centre of the grain, though containing less gluten than the darker flours from the sides, are often the more stable, owing to the tenacious character of the gluten. (See flour blending and doughing.)

Strength.—The addition of water to a flour produces a tough, elastic mass termed dough. Evidently, the greater the quantity of water a flour is capable of taking up, the greater will be the weight of dough from a given weight of flour, and the larger will be the yield of bread. This capacity of absorption is usually spoken of as **strength**, and is generally expressed in quarts per sack. It is possible to estimate approximately the yield obtainable from a flour by ascertaining the number of quarts of water per sack which it will take up to produce a dough of the consistency required in the particular method of breadmaking followed, and Mr. Thoms, F.R.M.S., of Alyth, has devised a method whereby a rapid estimation on the above lines may be made, an account of which will be given in Part IV.

Bran is the outer covering of the wheat berry, and is rejected by millers in the production of flour. Usually, it carries the outer layer of aleurone grains belonging properly to the endosperm. It consists largely of woody fibre, and is rich in nitrogenous matter and alkaline phosphates.

The **Germ** is also rejected by millers in the production of white flour. It is exceedingly nutritious, and contains nearly the whole of the fat of the wheat berry. It is very rich in albuminoids and phosphates. The untreated germ is very liable to develop the ferments mentioned in the last chapter, and, if present in flour, fermentation is almost certain to set in. Various methods have, however, been invented whereby the ferments are destroyed, and the bitter principles neutralised or removed, and in this condition the germ may be mixed with flour (see germ bread).

Offal consists of the refuse from the various milling operations, and is usually sold as food for different animals and in the production of animal foods.

Decorticated Meal is produced from the whole wheat berry minus the outer layers of woody fibre found in the bran. It contains far more woody fibre and cellulose than ordinary flour, and is richer in albuminoids and phosphates.

Wholemeal is obtained by grinding the entire grain, and in composition is practically identical with the wheat from which it is ground.

The following table gives the average composition of the more important products mentioned:

	Water	Proteids.	Carbo hydts.	Fat.	Fibre.	Ash.
Flour (Fine)	11·89	9·33	76·53	0·81	0·72	0·72
Flour (Medium)	12·98	12·08	72·38	0·91	0·81	0·84
Bran	12·84	12·89	45·62	1·62	19·21	7·82
Germ	13·92	29·35	37·93	13·21	1·21	4·38
Wholemeal.....................	13·84	13·29	68·02	1·62	1·58	1·65

The practical work will be taken in Part IV.

CHAPTER VI

ROLLER MILLING.

THE system of manufacture, which in all mills of modern construction has almost entirely superseded the time-honoured system of grinding by mill-stones is commonly known as the "roller process," and essentially consists of a gradual reduction of the grain to the condition of flour. The broad distinction between the new method and the old lies in the fact that in the roller process the bulk of the flour is manufactured after the impurities have been got rid of, while, in stone-milling, the whole grains are ground down into a general mass, and a portion of the impurities removed subsequently. It would be impossible, within the limits of this book, to give anything like a complete account of the milling processes. Only the merest outline can be given, and the reader is referred to a manual on milling for further details. The process of roller milling may be conveniently divided into five stages :

1st. The preliminary cleansing and preparation of the wheat.
2nd. The break roller process.
3rd. Purification.
4th. The smooth roller process.
5th. Flour dressing.

PRELIMINARY OPERATIONS.

Rough Cleansing.—The wheat is first subjected to a rough cleansing process, by which various foreign impurities are removed. The wheat then passes to a sifter, in which foreign bodies like barley grains and small seeds are separated by the sieve. Aspirators are connected with these machines, which draw off the lighter impurities. The wheat from the sifter now passes to the cockle machines, which, by an ingenious arrangement, separate the cockle from the wheat. After this stage the various wheats used in the grist are roughly blended or treated separately, according to the taste of the miller.

Scouring.—The grain is now subjected to a scouring action, by which the hairs of the grains, clay, etc., are removed. In the machine are powerful fans to draw out dirt, and strong magnets which remove all iron particles from the mass.

The grain then passes through the **Brushing Process**, by which it is thoroughly cleaned and polished by rapidly-moving brushes, the impurities being drawn off by aspiration.

Washing.—It is the practice of some millers to wash certain wheats with currents of water, after which they are subjected to a **Preliminary Drying**, carried out by passing the washed wheat to rotatory machines, where, by centrifugal action, much of the water is drawn off. The partially dried wheat is thoroughly dried by gentle currents of warm air driven into the drying machines by fans, followed by currents of cold air.

THE BREAK ROLLS' REDUCTION.

The Break Rolls.—These rolls are fluted longitudinally with a slight spiral, and are mainly instrumental in producing semolina, though middlings, flour, and offal are also produced. There are usually four to seven sets of rolls, constituting the breaks. The products of each break are sifted by sieves of different sized meshes, the particles passing through the sieve being termed "**throughs**," while the portion which remains is termed "**tails**."

The "tail" from each break forms the feed of the next, and so on until the last break is reached. The "throughs" are reserved for further treatment.

The first break reduces the grains to the condition of large particles technically termed "**schrot**."

As the "tail" passes down to the lower breaks it becomes more and more branny, until at the last break very little of the endosperm remains.

The germ separates chiefly at the first and second breaks.

From the break rolls then the miller obtains :

(1) "Throughs" from the breaks.
(2) The "tail" from the last break.

The "throughs" from the breaks after purification go to the reduction rollers; those from the last one or two breaks being sometimes treated separately. The "tail" from the last break is sent through a slowly rotating reel (offal reel) which separates it into :

(a) Fine middlings.
(b) Coarse middlings.
(c) Pollard (small bran chiefly).
(d) Bran.

Besides the "tail" from the last break, the lowest products from various purifiers are sent to the offal reel.

The "throughs" consist chiefly of

(a) Semolina large and small, being really small pieces of the endosperm, frequently with portions of the bran adhering.
(b) Germ.
(c) Middlings.
(d) Branny particles.

These bodies being intimately mixed.

The "throughs" from the earlier breaks are mixed together and sifted, producing :

(a) Semolina.
H { (b) Middlings.
H { (c) Flour.

The semolina is carefully sized and passed to the purifiers.

THE PURIFICATION PROCESS.

Purifiers.—These are machines fitted with horizontal rapidly reciprocating sieves of Swiss silk, through which currents of air are caused to ascend by aspiration. By the motion of the sieve, together with the action of the air passing upwards through it, the light and impure particles are lifted to the top; the lightest are carried clear away and the medium floated to the tail to be re-purified. The heaviest and best semolina, only, passes through the sieve if the operation is properly performed. The result is:

1 { (a) Coarse semolina.
(b) Fine ,, }

(c) Semolina to be further purified.

(d) Offal.

The purified semolinas (1 above) are then passed to

THE SMOOTH ROLLS REDUCTION.

Smooth Rolls.—These rolls are quite smooth, run at a slightly differential speed, and treat the "throughs" from the various breaks, while the waste from the purifiers is sent to the offal reel.

The middlings and flour obtained from the sifting of earlier breaks (H above) and also the products from the smooth rolls are subjected to the action of centrifugal machines from which flours are obtained and fine middlings. The latter are purified, producing a small proportion of patent flour, bakers' flour, and offal. From the earlier reductions patent flours are produced chiefly, while low grade flour comes from the last. Bakers' grade may be taken off any of the reductions. The germ chiefly appears in the first and second reductions, and may be removed by sifting. The "throughs" from the last break are treated separately, and produce:

Dark flours.
Offal.

FLOUR DRESSING.

This is done in the centrifugal machines above referred to. They are light cages, or cylinders, covered with fine Swiss silk, with from about 80 to 140 threads per inch. Within the cylinders are rapidly-revolving beaters, which continually distribute the material to be treated, with gentle impact, against the silk surface, those particles only which are fine enough and of sufficient specific gravity to reach and pass through the silk going to make the flour.

Break Flours.—A certain quantity of flour is produced from the break rolls, but it is not of the highest class.

The final products of roller milling then may be enumerated as follows:

(1) Patent flours characterised by extreme lightness of colour and stability.
(2) Bakers' grades, not so light.
(3) Low grade flours of dark colour.
(4) Germ from first and second smooth rolls.
(5) Offal consisting of middlings, pollard and bran.
(6) Waste.

In some mills the germ is not separated, but goes into the offal. The yield of flour varies from 67 to 73 per cent. of the cleaned wheat, according to the kind of wheat used and the process followed.

A study of the various products of the roller process cannot fail to be of the utmost interest and importance to bakers, and the results of a series of analyses will be found in the appendix. The flours were taken directly from the machines in use at Messrs. Marriage, Neave & Co.'s Flour Mills, Albert Bridge, London, S.W., and I have to acknowledge their courtesy in placing the entire mill at my disposal for the purpose of obtaining a representative series of roller mill products, and my indebtedness to them for many details.

Stone-Milling.

The preliminary process in stone-milling is much the same as in the roller process. The method pursued by Mr. Moore, of Farningham, consists of blending, purification, cleansing, washing and drying. The grains are elevated over the mill-stones and fed in. The meal then passes over the "scalper" which removes the bran, and subsequently over silk reels to separate the flour from semolina. The semolina is purified and then passed on to rolls. The products are purified and passed through a centrifugal, which separates out the finished flour. The following are the chief products of the mill:

(1) Best flours or firsts.
(2) Households.
(3) Seconds.
(4) Middlings.
(5) Offal, consisting of bran, pollard, and sharps.

The average yield is:

Flour ...	... 72·5	per cent.
Middlings	... 9·5	„ „
Offal ...	... 14·0	„ „
Waste ...	... 4·0	„ „
	100·0	

It is important to note that **wholemeal** is largely produced by the stone-milling process, but wholemeal of a more granular character, and often preferred by bakers to the finer varieties, can be produced from rollers.

CHAPTER VII.

WATER, SALT, BAKING POWDERS, MILK, POTATOES AND CONES.

WATER is a most important compound from our standpoint, seeing that next to flour it is the most abundant body used by the baker. Pure water is a compound of hydrogen and oxygen in the proportions by weight of one to eight. Pure water is perfectly tasteless, inodorous, boils under normal pressure at 100°C (212°F) and solidifies or freezes at 0°C (32°F). Water is a very slow absorber of heat, but radiates that which it possesses very slowly. The boiling point of water may be raised by pressure to almost any temperature, and also lowered by the removal of atmospheric pressure from the surface. Water is one of nature's greatest solvents. It dissolves a large number of salts, and absorbs gases with considerable avidity. Ordinary tap waters usually contain bodies like lime, magnesia, and potash, in solution, besides air and carbon-dioxide.

Some waters, notably those containing lime and magnesia, have the property of "curdling soap." This quality is due to the breaking up of the soluble soda soap by the lime and magnesia, with the consequent formation of insoluble lime and magnesia soaps in the water. Such water is known as "hard" water. Waters which contain less than seven grains of hardening salts per gallon are usually considered to come under the category of soft waters. The hardness due to *bi-carbonate of lime* is of a temporary character, and may be got rid of by boiling, or adding a softening reagent, like soda, to the water. The hardness due to other salts is spoken of as "permanent." Generally speaking, soft water is more favourable to fermentation than hard water, the latter rather retarding the fermentive changes going on in the dough. It is of the utmost importance that the water supplied to a bakery should be pure and wholesome. It should not contain organic matter or deleterious gases. Water for use in the bake-house, on account of its absorbent power, should be cut off from all possible contamination from drains or water closets. The supply should be separate from that of the water closets; and waste and overflow pipes should discharge in the open air. The water direct from the main is best. Cisterns, butts, &c., are apt to get foul and dirty. If the water be stored in a bakery, the cistern or butt should be very frequently cleaned, and *all* communications cut off from drains, urinals, and water closets.

Salt (common) is a compound of sodium and chlorine having the formula NaCl. It is added to the dough in varying quantities to give sapidity to the bread, the proportions used per sack of 280 lbs. varying from 2½ to 6½ lbs. Soft water and close-packed loaves need more. Bread made without salt is insipid and cannot be eaten with relish or enjoyment. Besides having a definite effect on the flavour, salt retards fermentation, keeping in check especially the lactic and butyric ferments. The activity of yeast is also reduced by salt.

Sugar is sometimes employed by the baker to quicken fermentation, but the more important characters of the sugars have already been described in a previous chapter.

Baking Powders are bodies used by the baker to produce the gas known as carbon-dioxide or carbonic acid gas.

Carbon-dioxide is a compound of carbon and oxygen having the formula CO_2. It is a colourless, tasteless, inodorous gas, turning moist blue litmus red. Carbon-dioxide is extremely heavy, and easily poured from one jar to another like water. Its characteristic reaction is on lime water, turning the latter milky. The milkiness is due to the formation of insoluble calcium carbonate. The following equation gives the changes:

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O$$

Lime water.	Carbon-dioxide.	Carbonate of lime.	Water.

Carbon-dioxide is given off during the alcohol fermentation of sugar, and from carbonates on the addition of stronger acids. Some baking powders contain a carbonate and an acid body to liberate the gas on the addition of water. Others contain a bi-carbonate which is decomposed by heat. A certain quantity of an inert body like starch is added to keep the active constituents of the powder fairly dry.

The following are the more common bodies used in baking powders and similar substances :

Tartaric Acid is an organic acid largely present in grapes. It has the formula $H_2C_4H_4O_6$.

Bicarbonate of Soda is a compound of sodium with carbonic acid, possessing considerable acid properties. Its formula is $NaHCO_3$.

Cream of Tartar is a body in which part of the acid (tartaric) has been neutralized by potassium. It is usually written $KHC_4H_4O_6$.

Ammonium Bi-carbonate is a compound of ammonium and carbonic acid, in which only part of the acid has been neutralized. It has the formula $(NH_4)HCO_3$. This body keeps badly, slowly giving off ammonia (NH_3) gas.

Hydrochloric Acid is a combination of hydrogen and chlorine (HCl). The commercial acid is usually employed in the bakehouse, but as it contains impurities the higher qualities should be used.

The following are the more important baking powders, and the reactions which take place during the liberation of the gas on the addition of water :

Tartaric Acid and Sodium Bi-carbonate.

$$H_2C_4H_4O_6 + 2NaHCO_3 = Na_2C_4H_4O_6 + 2H_2O + 2\mathbf{CO_2}$$

$H_2C_4H_4O_6$	$2NaHCO_3$	$Na_2C_4H_4O_6$	$2H_2O$	$2CO_2$
Tartaric acid.	Sodium bi-carbonate.	Sodium Tartrate.	Water.	Carbon dioxide.

Cream of Tartar and Sodium Bi-carbonate.

$$KHC_4H_4O_6 + NaHCO_3 = KNaC_4H_4O_6 + H_2O + \mathbf{CO_2}$$

$KHC_4H_4O_6$	$NaHCO_3$	$KNaC_4H_4O_6$	H_2O	CO_2
Cream of Tartar.		Rochelle salt.	Water.	Carbon dioxide.

This mixture does not act well in the cold, but chemical action goes on vigorously when the goods are in the oven.

The following are decomposed by heat :

Sodium Bi-carbonate.

$2NaHCO_3$ + heat =	Na_2CO_3 +	H_2O +	$\mathbf{CO_2}$
Sodium bi-carbonate.	Sodium carbonate.	Water.	Carbon dioxide.

Ammonium Bi-carbonate.

$2(NH_4)HCO_3$ + heat =	$(NH_4)_2CO_3$ +	H_2O +	$\mathbf{CO_2}$
Ammonium bi-carbonate.	Ammonium carbonate.	Water.	Carbon dioxide.

Bi-carbonate and Hydrochloric Acid.

$NaHCO_3$ +	HCl =	$NaCl$ +	H_2O +	$\mathbf{CO_2}$
Sodium bi-carbonate.	Hydro-chloric acid.	Common salt.	Water.	Carbon dioxide.

Many substitutes for cream of tartar and tartaric acid are in the market. In some the acid ingredient is potassium hydric sulphate ($KHSO_4$) and in others the acid salts of phosphoric acid. The "cream powders" of the Manchester Chemical Company are a good example of phosphate baking powders. They consist of various hydric phosphates possessing acid properties, mixed with sodium bi-carbonate and dried rice or maize. Experiments on the powders by the author in the bakehouse proved that they keep well and give off a regular evolution of mixed gas, producing light goods of even texture. As an example of the changes which occur the action of potassium di-hydric phosphate on sodium bi-carbonate may be mentioned :

KH_2PO_4 +	$2NaHCO_3$ =	KNa_2PO_4 +	$2H_2O$ +	$2CO_2$
Potassium di-hydric phosphate.	Sodium bi-carbonate.	Potassium di-sodium phosphate.	Water.	Carbon dioxide.

These powders, besides having a greater gas producing power, are cheaper than the mixtures in which tartaric acid liberates the gas.

In all the above reactions, the compounds formed remain in the bread.

Self-raising Flour is simply flour mixed with a baking powder, which evolves gas on the addition of water.

The following table gives the relative gas-producing power of the various bodies quoted in order of merit:

	Weight.		Vol. of CO_2
(1)	84 grams	of Sodium bi-carbonate	produce 22 litres
	36·5 "	" Hydrochloric acid	
(2)	68 "	" Potassium di-hydric phosphate	" 22 "
	84 "	" Bi-carbonate of Sodium	
(3)	158 "	" Ammonium bi-carbonate	" 22 "
(4)	75 "	" Tartaric Acid	" 22 "
	84 "	" Sodium bi-carbonate	
(5)	168 "	" Bi-carbonate of Sodium	" 22 "
(6)	188 "	" Cream of Tartar	" 22 "
	84 "	" Sodium bi-carbonate	

In this table the quantities give the exact neutralizing proportions, and it will be observed that the phosphate powder is the most economical with regard to gas-producing power. In practice, however, variations are found to be necessary.

Many inferior baking powders contain alum, and as the presence of alum in bread is a contravention of the Adulteration Act, bakers should be careful to use baking powders guaranteed free from alum. A test for alum will be given in Part IV.

In some factories the bread is aerated mechanically (see Aerated Bread) the gas being produced by the action of sulphuric acid on limestone:

$$\underset{\text{Sulphuric acid.}}{H_2SO_4} + \underset{\text{Calcium carbonate (limestone.)}}{CaCO_3} = \underset{\text{Calcium sulphate.}}{CaSO_4} + \underset{\text{Water.}}{H_2O} + \underset{\text{Carbon dioxide.}}{\mathbf{CO_2}}$$

Lately **liquid** carbonic acid gas has been supplied in strong iron cylinders. The CO_2 is under enormous pressure, and on being allowed to escape vaporises, and may thus be used to aerate dough.

Physiological action of Baking Powders.—It is a most important point to ascertain whether the compounds which remain in bread after the reactions of baking powders are injurious to the body. Among the bodies which are distinctly injurious are sulphate of potash, formed when the potassium hydric sulphate is used as the acid agent. This body is strongly aperient.

The use of any powder therefore containing the acid potassium sulphate is to be avoided. Most tartrates are laxative, especially Rochelle salt, so that the tartaric powders are not to be recommended unconditionally. Sodium carbonate is not injurious in small quantities, but it may act as a neutralising agent to the free hydrochloric of the gastric juice, delaying digestion. The same may be said of ammonium carbonates which remain in goods after the action is over. Where common salt remains in the bread there are, of course, no injurious effects. The phosphatic powders produce various alkaline phosphates which are harmless, and have a distinct food value.

Milk is often used in breadmaking to give a distinct flavour and increase the nourishing properties of the bread. Usually skim milk is employed. Milk has the following composition :

Water	86·12
Proteids (Casein)	4·28
Fat	3·61
Sugar	5·27
Ash	·72
	100·00

Skim milk contains only about ½ per cent. of fat, but is richer in proteids and sugar than whole milk.

Sour milk is sometimes added, instead of tartaric acid, to sodium bi-carbonate to liberate CO_2 the lactic acid of the milk being sufficient to set free the gas.

Potatoes are largely used by bakers for "fruit"—that is to say, as yeast food, in "ferments." The following is an analysis of a potato :

Water	74·35
Starch	14·89
Proteids	3·21
Sol. carbo-hydrates (sugar and dextrin)	2·58
Fat	0·42
Amides and extractives	2·32
Cellulose and fibre	1·21
Ash	1·02
	100·00

The potatoes are boiled before use, so that they contain gelatinised starch, sugar, dextrin, amides and mineral matter, all these bodies being yeast nutrients, the first named being converted into sugar by a ferment in the yeast.

Cones.—This term is applied to the flour used in moulding the dough up into loaves. It is usually prepared from fine rice, but is sometimes manufactured from maize. It consists chiefly of pure starch, as the following analysis by the author shows :

CONES.

Water	10·89
Starch	86·24
Proteid	2·14
Fat	·13
Cellulose	·22
Ash	·38
	100·00

CHAPTER VIII.

MALT EXTRACT, DIASTASE EXTRACT, YEAST FOODS.

MALT EXTRACT is prepared from the grains of a cereal in which partial germination has been allowed to proceed. Barley is usually employed for this purpose. The process is briefly summarised as follows in the author's work on the "Dietetics of Bread":

"The barley is placed in a cistern of water for about four hours, after which the water is drained off and the grains exposed to the air for twenty-four hours. During this period germination begins, and diastase and other ferments are formed in the grain. The barley is then made up into heaps and frequently turned for three weeks. During these malting operations the ferments act on:

"(1) The albuminoids.

"(2) The starch.

"The action on the albuminoids is to soften and render them more soluble, during which process they acquire limited diastasic powers.

"The starch is mainly converted into maltose and dextrin by the action of the diastase.

"The object of malting is to obtain the maximum quantity of sugar from the barley. It is necessary therefore, to arrest the germination at an early stage, otherwise the growing plant would use the sugar for food.

"This is accomplished by removing the partially developed plants to a kiln, where they are spread out on perforated brick floors, and subjected to a temperature of 145°–150° F. The heat destroys the embryo and further germination is thus prevented.

"The *diastase* is not destroyed at this temperature, and therefore continues to act on the starch of the endosperm. Malt extract is prepared from such malted barley."

A pure malt extract, like Boehme's, when analysed, when analysed, is found to have the following composition:

Water	21·89
Maltose and other sugars ...	61·58
Dextrin	1·18
Diastasic bodies and albuminoids	7 14
Ash and inert bodies	8·21
	100·00

The nature of most of these bodies has already been discussed, and it only remains to point out that malt extract contains bodies which act as direct yeast foods and stimulants, and, in addition, a body named diastase which converts starch into maltose and dextrin.

The complex action of diastase on starch will be fully dealt with in Part II., and therefore it need only be stated here that the baker, in using malt extract, has the following objects in view:

(1) The predigestion of some of the starch of the dough.

(2) The quickening of fermentation.

In securing these objects the bread is rendered more digestible, moister, and generally possesses a sweet and nutty flavour. The acceleration of fermentation lessens the danger of sour bread, and allows the bakehouse operations to be completed in less time.

Some authorities conclude that malt extract has a peptonising action on gluten, and the author agrees with the conclusion from the result of experiments carried on in the early part of 1893 with Montgomerie's extract on very stable flours.

The yeast foods contained in malt extract are principally the various sugars, but the phosphates and soluble albuminoids present, also act as powerful stimulants to yeast reproduction.

Diastase Extract is not manufactured in exactly the same way as malt extract. The malt is specially prepared and extracted in the cold by a new process. It has the fo'lowing composition:

Water	21.89
Maltose and other sugars ...	47 16
Dextrin	8·93
Diastasic bodies and albuminoids	11·81
Ash and inert bodies	10·21
	100·00

Diastase extract has the same general action on dough as malt extract. There are indications that the diastase present in malt diastase extracts is not exactly identical with that of the actual germinating seed. For instance, the latter acts on raw starch vigorously, while the former has only a very slight action on ungelatinised starch.

Yeast Foods are "extracts" manufactured by mixing substances like glucose, phosphates, proteids and similar bodies together, either with or without the addition of pure malt extract or diastase.

Those which contain no diastase simply act as quickeners of fermentation, and increase to varying extent the percentage of soluble carbo-hydrates in the bread, by protecting them from fermentation. All the advantages of quick fermentation are obtained by the use of such yeast foods, but there is no predigestion of starch owing to the absence of diastase. Bakers use such mixtures solely for the purpose of supplying the yeast with available material to accelerate the fermentation. At the same time the bread is rendered somewhat moister and sweeter.

Those yeast foods which contain diastase act much in the same way as malt extract, converting varying proportions of starch into maltose and dextrin. The author has made some careful experiments with diastase yeast food, taking as a standard and type the well known Supermalt Extract of the Manchester Chemical Company. This extract is very concentrated, and possesses many unique characters.

It consists of a judicious blend of fermentable sugars, albuminoids, diastase, suitable mineral matter, and other pure ingredients. The "supermalt" was used in the proportions advised, the sponge and dough method of bread-making being followed. Careful examination showed that the use of supermalt accelerated the fermentation, and increased the percentage of sugar in the bread by diastasis of part of the starch. The resulting bread also kept moist longer than ordinary bread. In some of these extracts a peptonising ferment like "pepsin" is added, which acts in the direction of softening the gluten of the dough.

The diastasic power of a malt extract is measured by ascertaining how much starch a given weight of the extract will convert into maltose, in a given time, and Lintner gives a value in degrees to a certain standard, thus affording a means of comparison. The author, however, has ascertained by direct experiment that results on Lintner's scale do not always afford a safe criterion of the actual value of a malt extract in bread-making. In an experiment two extracts were taken, one giving 200 on Lintner, the other 30. These were worked on the same flours under the same conditions. The first produced 9·41 per cent. of maltose as the result of diastases, and the latter 6·21., a difference only of 3·21 per cent., and yet on Lintner's scale one was six times as powerful as the other.

Commercial Glucose is sometimes used by bakers as a yeast food, or quickener of fermentation. It is prepared from starch (rice, maize, or potato starch) by the action of sulphuric acid. During the "digestion" with sulphuric acid, dextrose is chiefly formed according to the following equation:

$$\underset{\text{Starch.}}{C_6H_{10}O_5} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6}$$

The acid is neutralized subsequently by calcium carbonate.

Commercial glucose may be obtained in two varieties —the syrup form, and the hard crystalline form. The former contains, in addition to dextrose, a certain quantity of maltose and dextrin, while the hard variety contains only traces. The following are analyses of two samples of commercial glucose:

	Syrup.	Hard.
Water	14·98	10·89
Dextrose and other sugars (excepting maltose) ...	59·63	82·89
Maltose	12·82	Trace
Dextrin	1·93	1·28
Ash	1·48	1·42
Inert and other bodies ...	9·16	3·62
	100·00	100·00

CHAPTER IX.

YEAST.

YEAST is an organism belonging to the vegetable kingdom, of the class fungi and the order saccharomyces.

There are many varieties of yeast, but the genus saccharomyces cerivesiæ, the common baker's yeast, may be taken as a type to study the morphology and physiology of the organism.

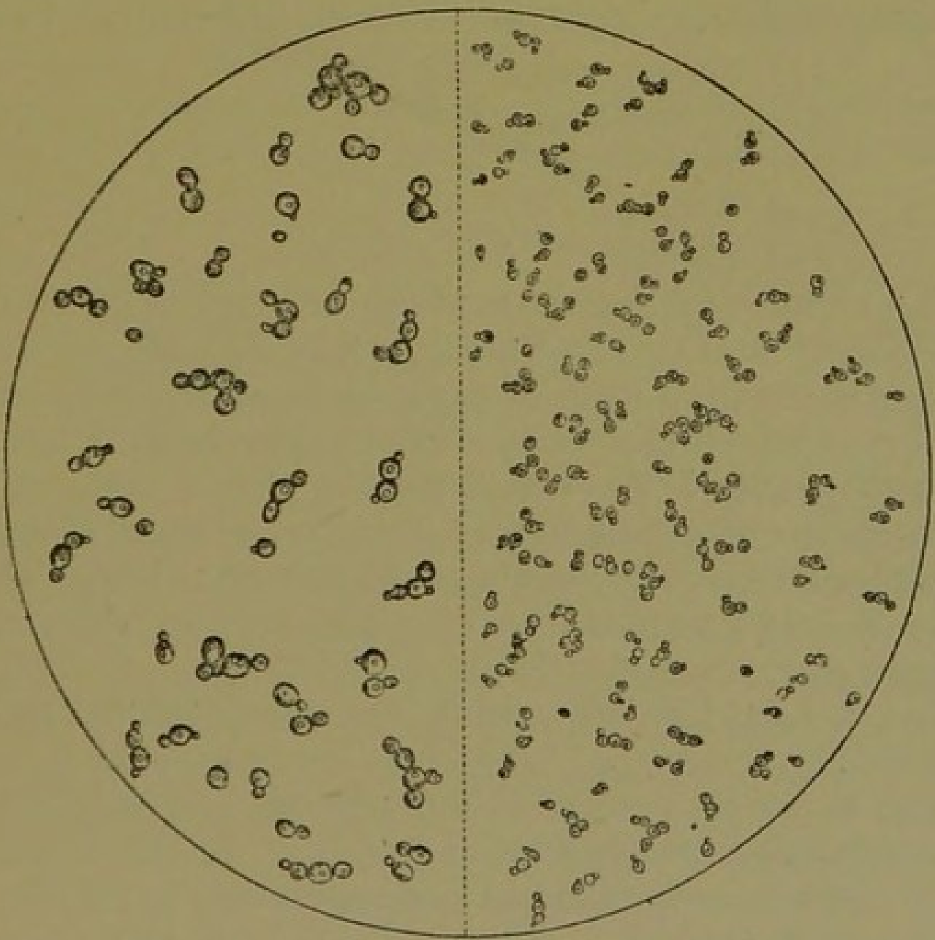


FIGURE 15.—SACCHAROMYCES CERIVESIÆ.

Structure.—A yeast cell is a spherical or ovoid body, and consists of the following parts :

(1) A cell wall of cellulose enclosing a semi-fluid living matter termed
(2) Protoplasm.
(3) Vacuoles or clear spaces in the interior of the protoplasm, containing cell sap.

Some observers maintain that a **nucleus** is present.

The cell wall consists of a substance known as fungus cellulose, while the protoplasm is composed of proteid bodies and fat. Iodine and magenta stain the protoplasm, usually leaving the cell wall unaffected. The protoplasm may be dissolved out by caustic potash leaving the cell as an empty sac.

The cells vary in size and shape, but the average may be stated at ·0003 inch or ·006 mm in diameter. The structure is best brought out by using Schultz's solution as a staining reagent. (See Part IV.)

Composition.—Yeast may be regarded as consisting of

(1) Fungus cellulose.
(2) Protoplasm.
(3) Fat.
(4) Ash.
(5) Water.

The cellulose is found mainly in the cell wall, and is a carbohydrate in constitution. It is capable of being transformed into a form of sugar by the action of certain acids, and sometimes gives a blue reaction with iodine.

Protoplasm is the living portion of the cell, which performs the vital functions. It consists largely of living proteid material, and possesses the general properties of proteids. It contains the elements carbon, hydrogen, oxygen, nitrogen and sulphur.

Fat is found chiefly within the protoplasmic matter of the cell.

Ash is mainly present in the cell wall. The following is an analysis of yeast (dry):

Proteids Extractives and Peptones	69·73
Cellulose	22·37
Fat	2·10
Ash...	5·80
	100·00

The ash of yeast is said by Mitscherlich to consist of the following bodies:

Phosphoric acid	53·2
Potash	39·8
Magnesia	6·0
Lime...	1·0
Silica and other bodies	Traces
	100·0

so that it may be considered to be composed chiefly of potassium, magnesium, and calcium phosphates, the first greatly preponderating.

Food and Digestion.—Yeast is mainly regarded as a plant on the grounds that it can assimilate nitrogen from inorganic compounds, and it thrives well in fluids which contain certain mineral bodies and nitrogenous matter capable of assimilation. Ordinary albuminous bodies are incapable of acting as foods for yeast, but peptones and amides are excellent nutrients.

Pasteur's solution is well adapted for the cultivation of yeast for experimental purposes, and is made up as follows:

PASTEUR'S SOLUTION.

Water	83·76 grams.
Cane sugar	15·00 "
Ammonium tartrate ...	1·00 "
Potassium phosphate ...	·20 "
Calcium phosphate ...	·02 "
Magnesium phosphate ...	·02 "

But yeast thrives well in any fluid containing fermentable sugars, with diffusible proteids and phosphates. Meyer's solution is practically the same as Pasteur's, except that *pepsin* takes the place of the ammonium tartrate.

Malt extracts and potato "fruit" are excellent yeast foods on account of the sugar, peptones, amides, and phosphates they contain.

The diffusible bodies pass through the cell wall to the protoplasm, and are there, by the action of the living matter, gradually converted into the cell protoplasm. Closely connected with the assimilation of food is

Respiration.—Metabolic changes are going on in the cell which require a supply of oxygen and lead to a production of carbon-dioxide. As long as a plentiful supply of oxygen is forthcoming the yeast cells can live and thrive in a fluid devoid of fermentable substance. But when the supply of oxygen is limited or cut off, the yeast in a sugary solution becomes more a *ferment* than a fungus, and profound changes are effected in the constitution of the sugar, bringing about the dissociation and rearrangement of the atoms, resulting in the formation of other compounds, and a supply of oxygen to the yeast cells. These actions are collectively spoken of as "fermentation," and will be fully studied in the next chapter. Fermentation essentially consists of the breaking up of sugar into alcohol, carbon-dioxide and other bodies. All sugars are not equally fermentable. Lactose or milk sugar does not undergo the alcoholic fermentation, and cane-sugar and maltose are first converted into dextrose and lœvulose before undergoing the change.

Reproduction.—The yeast cells multiply in two ways:

(1) By budding.
(2) Free cell formation.

In budding a single cell gives rise to one or more minute projections which grow rapidly. The original cell is termed the "**mother cell,**" while the newly-formed ones are known as "**daughter cells.**" The daughter cells soon reach the full size, and are then seen to be separated from the mother cell by a septum of cellulose. In some cases the cells drop off and form independent organisms, but often, where the growth is vigorous, the cells remain attached end to end, forming long chains. The presence of diffusible albuminoids and phosphates is very favourable to the development of new cells.

In **free cell formation** the protoplasm within the cell wall breaks up into two, four, or more rounded bodies. The cell wall of the parent cell bursts, and the interior bodies are set free, each developing into a perfect cell. This mode of propagation is not very common according to most authorities.

Mr. Thoms, F.R.M.S., of Alyth, believes that immediately after budding normal spore formation commences.

The parent and daughter cells come to a state of rest, and cease fermentation. The nucleus undergoes subdivision into spores, which are set free by the bursting of the cell wall.

The activity and growth of yeast is closely dependent on temperature. The most favourable temperature is from 30°C to 35°C (86°F to 95°F). At temperature below 25°C or above 35°C fermentation and development go on slowly. Yeast is destroyed at about 150°F, but if dried the cells are not destroyed at even the boiling point of water 212°F. Freezing does not kill yeast cells if the cells can withstand the expansion without rupture.

Kinds of Yeast.—There are other kinds of yeast besides the cerivesiæ. The chief are the following:

Saccharomyces Minor is the ferment of leaven or old dough, consisting of spheroidal cells.

Saccharomyces Ellipsoideus is the yeast of wine fermentation, and naturally forms in grape juice. The cells are somewhat oval.

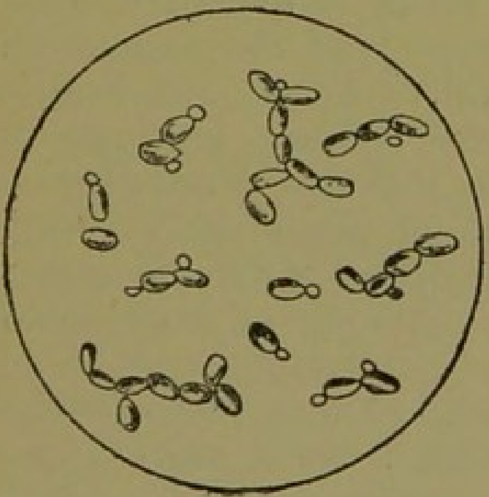


FIGURE 16.—UPPER YEAST.

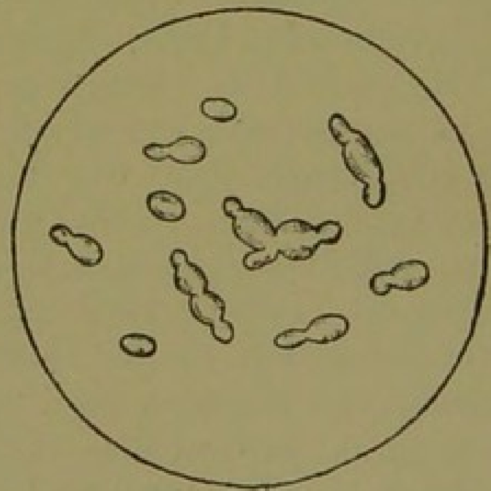


FIGURE 17.—LOWER YEAST.

Saccharomyces Pastorianus consists of irregularly sized cells, and forms a part of the later fermentations of wines, and occurs sometimes in "patent yeast."

The saccharomyces cerivesiæ is known under two forms:

(1) Upper yeast.
(2) Under yeast.

Upper Yeast rises to the surface of the fermenting liquor, while

Under Yeast or low yeast is found as a sediment at the bottom. The latter is not used for breadmaking purposes.

Brewers' Yeast is obtained from the fermenting vats of the brewer in which malt liquors are being prepared.

It is somewhat slow in its action, and produces bread with a characteristic flavour.

Distillers' Yeast is prepared from fermenting liquors destined to produce spirits, and is much more active than brewers' yeast.

Compressed Yeasts are simply yeasts (either brewers' or distillers') carefully prepared and pressed with or without the addition of starch.

The manufacture of compressed yeasts has been brought to a very high state of perfection, and they are rapidly replacing liquid yeast, patent yeasts, and flour barms. As an example of the extreme care bestowed on the preparation of compressed yeast, may be quoted the mode of manufacture adopted at the Netherlands Yeast Manufactory, Delft, Holland, makers of the well-known "N. G. & S. F." brand of distiller's yeast. Not only is the utmost care exercised in the ordinary processes of manufacture, but the highest scientific knowledge is brought to bear on the problem of producing a steady and reliable yeast, free from an excess of foreign organisms, and from added starch. Samples of each batch are submitted to an eminent bacteriologist and to an analytical chemist, and "sowing" yeast is very carefully examined before use. The result is that a yeast is produced of great purity and uniformity in action. Compressed yeast, provided it be a good brand, may usually be relied on to produce good results. Compressed brewers' yeast is much slower in its action than, and cannot be depended on to the same extent as, compressed distillers' yeast.

Pure Compressed Yeast may be regarded as consisting simply of yeast cells, dried and pressed, without admixture with starch or other substance, and free from an excess of foreign ferments, and is certainly to be preferred to those which contain starch.

Patent Yeasts are yeasts developed by bakers in the bakehouse from their own formula, in which hops, malt, potatoes, and other bodies are used.

Barms are similar preparations in which flour is added to the other ingredients, but, like patent yeasts, they are rapidly giving place to the use of compressed yeast.

For the practical testing of yeast see Part IV.

Part II.

The Principles Involved in the Manipulation of the Raw Products.

CHAPTER X.

ORGANISED FERMENTS AND FERMENTATION.

A FERMENT may be defined as a body which has the power of producing a rearrangement of atoms in certain substances brought into contact with it, resulting in the production of new compounds, differing in chemical and physical properties from the original substances, subjected to the action of the ferment.

There are two great classes of ferments:

(1) Organised.

(2) Unorganised.

The former are classified among living organisms (fungi), while the latter are simply complex compounds, usually associated with some form of albumin or proteid, and are inanimate.

The following table gives the more important of these ferments :

I.—Organised.

(a) Yeast.
(b) Bacterium Lactis.
(c) Bacillus Subtilus.
(d) Bacterium Termo.
(e) Ropy Ferments.
(f) Mycoderma Aceti (not regarded as a ferment by many authorities).

II.—Unorganised.

(a) Diastase.
(b) Cytase.
(c) Cerealin.
(d) Soluble Albumins.
(e) Ptyalin.
(f) Pancreatic diastase.

Act only on proteids. { (g) Pepsin.
(h) Trypsin. }

Yeast Fermentation only takes place in sugary solutions, and essentially consists of a splitting up of sugar into alcohol, carbon-dioxide, and other bodies. The action, as previously explained, may be regarded as the effort of the yeast organisms to obtain certain constituents for the nourishment and maintenance of their own bodies, the alcohol and carbon-dioxide being bye-products in the breaking down process, as far as the yeast itself is concerned.

All sugars are not *directly* fermentable, and one or two are not acted on at all by yeast.

The following tables give at a glance the relation of the various carbo-hydrates to fermentation :

1	Dextrose (glucose) Lœvulose	Directly fermentable.
2	Maltose (sugar of malt) Sucrose (cane sugar)	Indirectly fermentable.
3	Starch Dextrin	Not fermentable.

In the case of the first group the change may be equationally represented as follows :

$$\underset{\text{Dextrose or Lœvulose.}}{C_6H_{12}O_6} = \underset{\text{Alcohol.}}{2C_2H_5HO} + \underset{\text{Carbon-dioxide.}}{2CO_2}$$

but it must be distinctly remembered that other bodies are formed.

When maltose and sucrose are subjected to the action of yeast, before the alcoholic fermentation begins, the maltose and cane sugar are converted into dextrose and lœvulose, and the equation reads as follows :

$$C_{12}H_{22}O_{11} + H_2O = 2C_6H_{12}O_6$$
Cane Sugar. Water. Dextrose or Lœvulose. } 1st stage.

$$2C_6H_{12}O_6 = 4C_2H_5HO + 4CO_2$$
Dextrose. Alcohol. Carbon-dioxide. } 2nd stage.

In the case of starch, or dextrin, they must first be converted into sugar, by some hydrolytic ferment, and then fermentation goes on as described above.

The whole of the sugar does not reappear, however, as alcohol and carbon-dioxide. There is a considerable production of the higher alcohols, accompanied with various organic acids.

The following table gives some recent estimations by the author of the bodies produced during slow and vigorous fermentation :

100 parts of sugar yielded by

	Slow Fermentation by Brewers' yeast.	Quick Fermentation by NG and SF yeast.
Alcohol	46·48	48·05
Carbon-dioxide ...	44·41	45·99
Glycerin	5·71	3·18
Succinic acid	1·92	1·21
Acetic acid	·61	·48
Butyric acid ... Propyl alcohol Butyl " ... Amyl " ...	·52	·62
Unaccounted for ...	·35	·47
	100·00	100·00

It will be seen that the main products of yeast fermentation are alcohol and carbon-dioxide, and that slightly more of these bodies are produced during vigorous fermentation than when the process goes on more slowly.

Flour mixtures are fermentable on account of the sugar which they contain. Potato mashes, or water in which potatoes have been boiled, are great aids to fermentation. The same may be said of malt extracts and yeast foods.

Some kinds of yeast work very slowly, others work rapidly. As a rule, brewer's yeast is very slow in its action, as compared with compressed distiller's, and unless a baker has special considerations and reasons for its use, much valuable time may be saved by its abandonment. Successful fermentation is closely dependent on temperature, which should be kept as even as possible. A sudden chill will suspend vigorous fermentation for considerable periods.

As an example of the difference in rapidity of fermentation between brewer's and distiller's yeast, the following experiment may be quoted. A ¼ oz. of compressed brewer's and the NG and SF brand distiller's yeast were sown in 6 ozs. of sugar solution at 30°C. The following gives the number of cubic inches of gas evolved each hour up to the ninth:

	Brewer's.	NG & SF.
End of 1st hour......	6·2 cubic in.	12·8 cubic in.
" 2nd hour......	21·6 "	32·6 "
" 3rd hour......	37·2 "	54·8 "
" 4th hour......	48·8 "	68·9 "
" 5th hour......	59·6 "	82·6 "
" 6th hour......	70·1 "	98·8 "
" 7th hour	82·4 "	112·6 "
" 8th hour......	92·6 "	124·8 "
" 9th hour......	98·8 "	136·2 "

The table shews that during nine hours' fermentation, a ¼ oz of the NG and SF distiller's yeast produced 37·4 cubic inches more gas than the same weight of brewer's compressed, both yeasts working in similar solutions and under the same conditions, and this may be taken as indicating general results, being only one of many experiments.

A baker usually judges the value of yeast by

1st. Its purity,

2nd. Its gas producing power,

3rd. Its freedom from excess of foreign ferments,

and all things being considered, in these modern days, when time is of so much moment, it seems likely that the more rapidly acting distiller's yeast will ultimately drive its competitors out of the market, and of the successful kind only pure brands, carefully manufactured, may expect to hold the field.

On albuminoids yeast has no fermenting action, but they are partially peptonised, and they then acquire slight diastasic properties, having the power to convert starch into sugar. This action of yeast has a most important bearing on changes which go on during "panification" in the doughing stage.

In "ferments" not only does alcoholic fermentation go on, but there is a vigorous development of *new* cells. But in doughs the growth of the cells is usually in abeyance, fermentation being carried on by the living cells originally introduced.

Bacterium Lactis.—This ferment belongs to the great order Schizomycetes, usually classed among the fungi, and which includes all bacteria, bacilli, and similar micro-organisms. They derive their generic name from their power of "splitting."

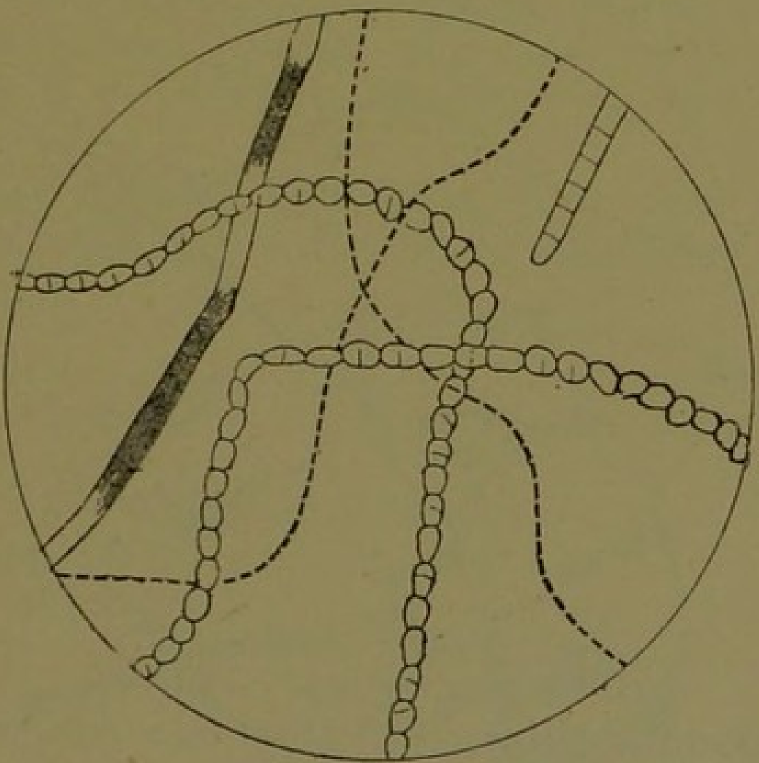


FIGURE 18.—BACTERIUM LACTIS.

The members of this order (Schizomycetes) have gelatinous membranes or cell walls which often adhere, forming a slimy mass in which lie the microbes. Such a coherent colony is termed Zooglœa.

The Bacterium Lactis acts on sugars, converting them into lactic acid. The action goes on best at from 35° to

40°C, and may be well studied in souring milk. The following equation shows the change:

$$C_6H_{12}O_6 = 2C_3H_6O_3$$

Dextrose. Lactic acid.

Such sugars as lactose, maltose, and sucrose are first converted into dextrose, and then into lactic acid. The presence of the lactic ferment in excess in yeast is detrimental, as it may lead to the souring fermentation developing in the dough or bread. It is present in considerable quantity in barms and patent yeasts, but Scotch bakers rather strive for a slight acid flavour in their bread, and as hard flours are used, the ferment may be of some service in toning down the harsh gluten.

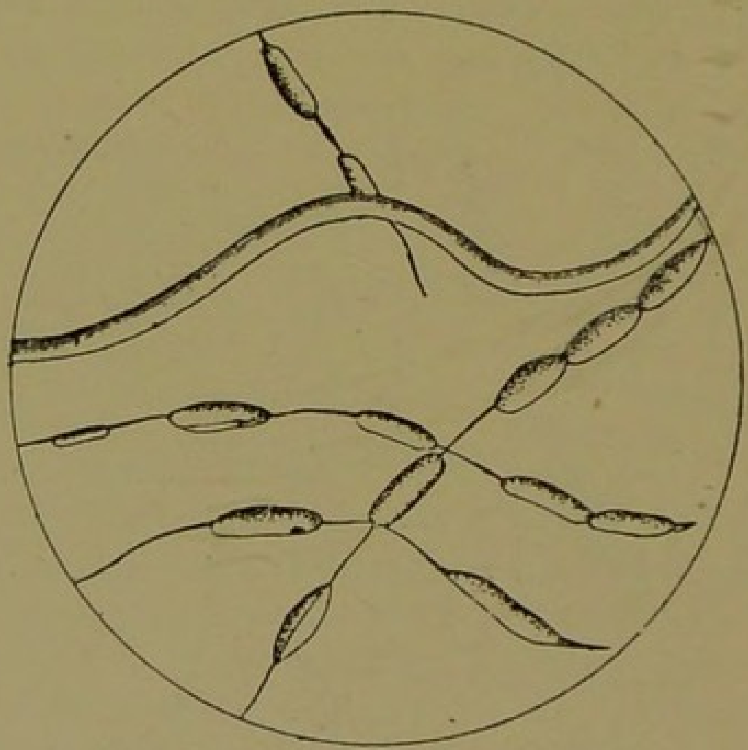


FIGURE 19.—BACILLUS SUBTILIS.

Bacillus Subtilis is also of the order Schizomycetes. It has a characteristic shape, and acts on lactic acid, producing butyric acid, carbon-dioxide, and hydrogen gas.

$$2C_3H_6O_3 = C_4H_8O_2 + 2CO_2 + 2H_2$$

Lactic acid. Butyric acid. Carbon-dioxide. Hydrogen acid.

This fermentation appears subsequent to the lactic fermentation, and when it obtains, indicates considerable production of lactic acid from the sugar in the dough.

The **Bacterium Termo** is one of the common microbes of putrefaction, and breaks up organic bodies into such substances as amides, acetic, propionic,

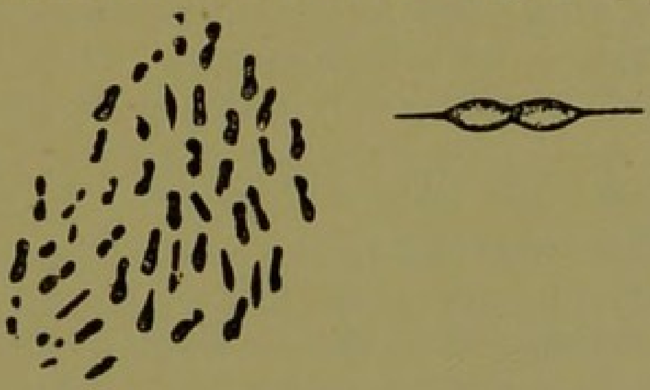


FIGURE 20.—BACTERIUM TERMO.

butyric, and other fatty acids, ammonia, sulphuretted hydrogen, carbon-dioxide, hydrogen, nitrogen, and putrid gases. Certain bodies termed antiseptics have the power of preventing these changes in organic matter. Salt, boracic acid, and salicylic acid are well known antiseptics.

Ropy or Viscous Ferments.—The chief viscous ferment is a micrococcus which acts on sugar, converting

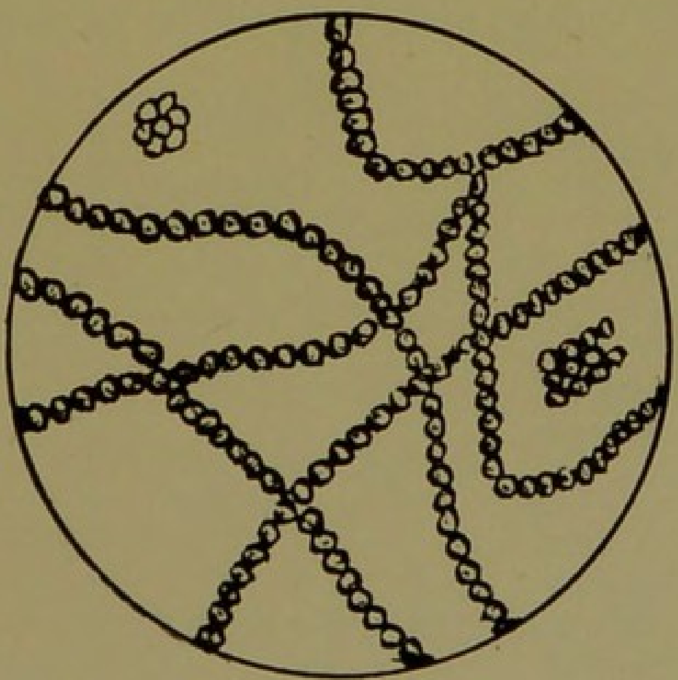


FIGURE 21.—VISCOUS FERMENT.

it into mannite, dextrin, CO_2, and water. This fermentation often takes place in beer, and is accompanied with a thickening of the liquor. It very rarely appears in bread, but is more common in currant cakes.

Mycoderma Aceti.—This belongs to the same class as the above mentioned ferments, but many chemists do not look upon it as a true ferment. It acts on ethylic alcohol inducing oxidation, resulting in the production of acetic acid.

The change really takes place in two stages, according to the following equation :

$$\left.\begin{array}{ccccc} 2\left\{\begin{array}{c}CH_3\\ CH_2HO\end{array}\right\} & +\,O_2 = & 2\left\{\begin{array}{c}CH_3\\ CO\ H\end{array}\right\} & + & 2H_2O \\ \text{Alcohol.} & \text{Oxygen.} & \text{Acetic Aldehyde.} & & \text{Water.}\end{array}\right\}\text{1st stage.}$$

$$\left.\begin{array}{ccc} 2\left\{\begin{array}{c}CH_3\\ CO\ H\end{array}\right\} & +\,O_2 = & 2\left\{\begin{array}{c}CH_3\\ CO\ HO\end{array}\right\} \\ \text{Acetic Aldehyde.} & & \text{Acetic Acid.}\end{array}\right\}\text{2nd stage.}$$

This action goes on in the mother liquors of the vinegar manufacturer.

CHAPTER XI.

UNORGANISED FERMENTS (ENZYMES).

UNORGANISED ferments are nitrogenous inanimate substances, having the power of producing molecular changes in certain bodies brought in contact with them. Their general characters were given in Chapter IV., so it only remains to study a little more in detail the nature of the fermentations which they set up in suitable media under favourable conditions.

Broadly speaking, we may divide the unorganised ferments into two classes:

(1) Those which act on the carbo-hydrates, starch, dextrin, cane sugar and cellulose.

(2) Those which act on proteids or albuminoids.

The former are termed amylolytic ferments, the latter proteolytic ferments.

The following tables give at a glance the general classification:

Amylolytic	Vegetable.	Diastase	Converts starch into sugar.
		Cerealin	” ” ”
		Sol. albuminoids	” ” ”
		Cytase	Dissolves cellulose.
		Zymase (yeast)	Converts cane sugar into dextrose.
	Animal.	Ptyalin	Converts starch into sugar.
		Pancreatic diastase	” ” ”
Proteolytic	Vegetable.	Veg. trypsin	Converts proteids into peptones and amides.
		Sol. albuminoids	Converts proteids into peptones
	Animal.	Pepsin	” ” ”
		Trypsin	Converts proteids into peptones and amides.

The action of these unorganised ferments is little understood, but there is a consensus of opinion that the action essentially consists of an assumption of water and a deduplication of the original molecule, the action going on until the whole of the fermentable substance has been changed. For this reason these ferments are often termed **hydrolytic** agents, and the process **hydrolysis**. A remarkable feature is that in nearly every instance we have produced, besides the main substance a bye-product, which usually remains unacted upon. The ferments are usually associated with some form of albuminoid matter, and it is doubtful how far the proteid is connected with the ferment as to functional activity.

Diastase and Diastasis.—The best known enzyme is diastase, the active ferment formed in germinating seeds and present in malt extracts, and its properties and action on starch have been very carefully studied by Brown, Heron, Morris and others. Only a brief account may be given here, but a full resumé will be found in the author's "Dietetic Value of Bread" (pp. 260-262) of the latest researches on the subject.

The *final* products of the action of diastase on starch are:

(1) Maltose.

(2) A stable achroo-dextrin, which does not give a colouration with iodine.

But there are many intermediate products produced during the action of the ferment. At a favourable temperature (150°F.), and when starch is not in excess, the proportions of sugar and dextrin are usually four to one, and no starch remains in the mixture. During the earlier periods of the action a certain quantity of unstable erythro-dextrins are formed, which give a rich red colour with iodine, and, according to some authorities, loose combinations of maltose and erythro-dextrin make their appearance as the immediate antecedents of the final maltose. However, it is certain that when diastasis is complete, maltose and achroo-dextrin are produced, and that during the action of the ferment the more unstable erythro-dextrins appear as intermediate products.

The action of diastase on raw starch is comparatively slow, but gelatinised or broken down starch granules are acted on vigorously. Temperature has a great influence on the activity of diastase, and has some effect on the *proportions* of the final products. A low temperature arrests or retards the diastasis, while at 175°F. to 180°F. the diastase is destroyed and the action ceases. At temperatures between 120°F. to 150°F. the maximum quantity of sugar is produced, while at higher temperatures, from 160°F. to 167°F., the maximum quantity of dextrin is obtained. The author, simultaneously with Jago, in the spring of 1894 performed a large number of experiments with Montgomerie's malt extract and flour at different temperatures, and he found that by mashing at 150°F. for three hours, practically four parts of maltose and one part of achroo-dextrin were produced in the mash, while by mashing at 167°F. for one hour two parts of maltose only and three parts of *erythro-dextrins* were formed. The erythro-dextrins were, however, extremely unstable, and the author found them to disappear invariably in the doughing stage, being probably hydrolysed by the yeast, soluble albuminoids, or even by microbes. Jago obtained very similar results. It appears from this that no matter what proportions of maltose and dextrin be formed in the preliminary mashing stages, in the resulting bread the ratio of maltose to dextrin, as the result of diastasis, is very near four to one.

The following equation gives arbitrarily the change:

$$5\left\{\underset{\text{Starch.}}{(C_{12}H_{20}O_{10})3}\right\} + \underset{\text{Water.}}{12H_2O} = \underset{\text{Achroo-dextrin}}{(C_{12}H_{20}O_{10})3} + 12\underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}$$

Cerealin is found in the outer layer of square shaped cells, belonging properly to the endosperm. Its action is chiefly on starch converting the latter into sugar, but some authorities claim that it also acts on proteids. As these cells usually come away with the bran, cerealin is found in that product, and this fact explains why meals containing bran often ferment, and do not keep so long as ordinary flour.

Soluble Albuminoids are bodies which, though albuminous, are more or less diffusible. Certain of the soluble albuminoids of dough possess limited diastasic and peptonising powers, being capable of converting starch into sugar and softening insoluble proteids like gluten.

Cytase is not of much interest to the baker. It appears in germinating seeds, and its action is to dissolve the cellulose cells which lock up the starch and albuminous matters of the endosperm.

Zymase or Invertin is present in yeast, and has the power of converting maltose and cane sugar into dextrose and lœvulose. Many writers state that zymase has the power of acting on starch. But the author has never been able to obtain satisfactory evidence of the diastasis of pure starch by zymase.

Ptyalin is the fermentive constituent of saliva, one of the digestive juices, and acts very vigorously on gelatinised starch. Its action is comparable to that of diastase on starch, and resembles to a remarkable degree "diastasis." The final products of its activity are maltose and a stable achroo-dextrin. As in the case of diastasis, various intermediate bodies are formed, chiefly erythro-dextrins. Ptyalin does not act on raw starch, and the fermentation is closely dependent on temperature, the most favourable being 40°C. It will only act in a neutral or alkaline medium.

Pancreatic diastase is a very similar ferment to Ptyalin found in the secretion of the pancreas (sweetbread). It is one of the most active constituents of the pancreatic juice, and acts only on starch. Unlike ptyalin, it will rapidly convert raw starch into maltose. It works chiefly in the small intestine.

Pepsin is found in the gastric juice. Like the previously mentioned ferment it is a nitrogenous body, but acts exclusively on proteids or albuminoids in an *acid* solution. In the human stomach, pepsin works in conjunction with a little free hydrochloric acid, converting proteids into peptones, with the production of a bye-product termed para-peptone. It is important to note that no amides are formed by pepsin. Peptones differ from proteids in being readily diffusible through moist membranes. Pepsin often forms a constituent of "yeast foods" and acts in two ways, converting the insoluble proteids into diffusible peptones, and acting itself as a direct yeast nutrient.

Trypsin is one of the ferments of pancreatic juice, and converts proteids into peptones in an *alkaline* medium, with the formation of alkali-albumin as a bye-product. The action chiefly goes on in the small intestine. Trypsin has, however, a further action on certain peptones, breaking them down into the amides, leucin, and tyrosin. In this it resembles very much the vegetable trypsin described in Chapter IV.

Having briefly sketched out the more important facts connected with fermentation, we may now pass on to a study of processes and machinery involved in the manufacture of the raw flour into bread.

CHAPTER XII.

STORAGE, SIFTING AND BLENDING OF FLOUR.

THE various grades of flour should be stored in a *dry* warehouse or room, above the level of the road, and where machinery is used it is convenient to have the flour either on the same floor as the blender, or

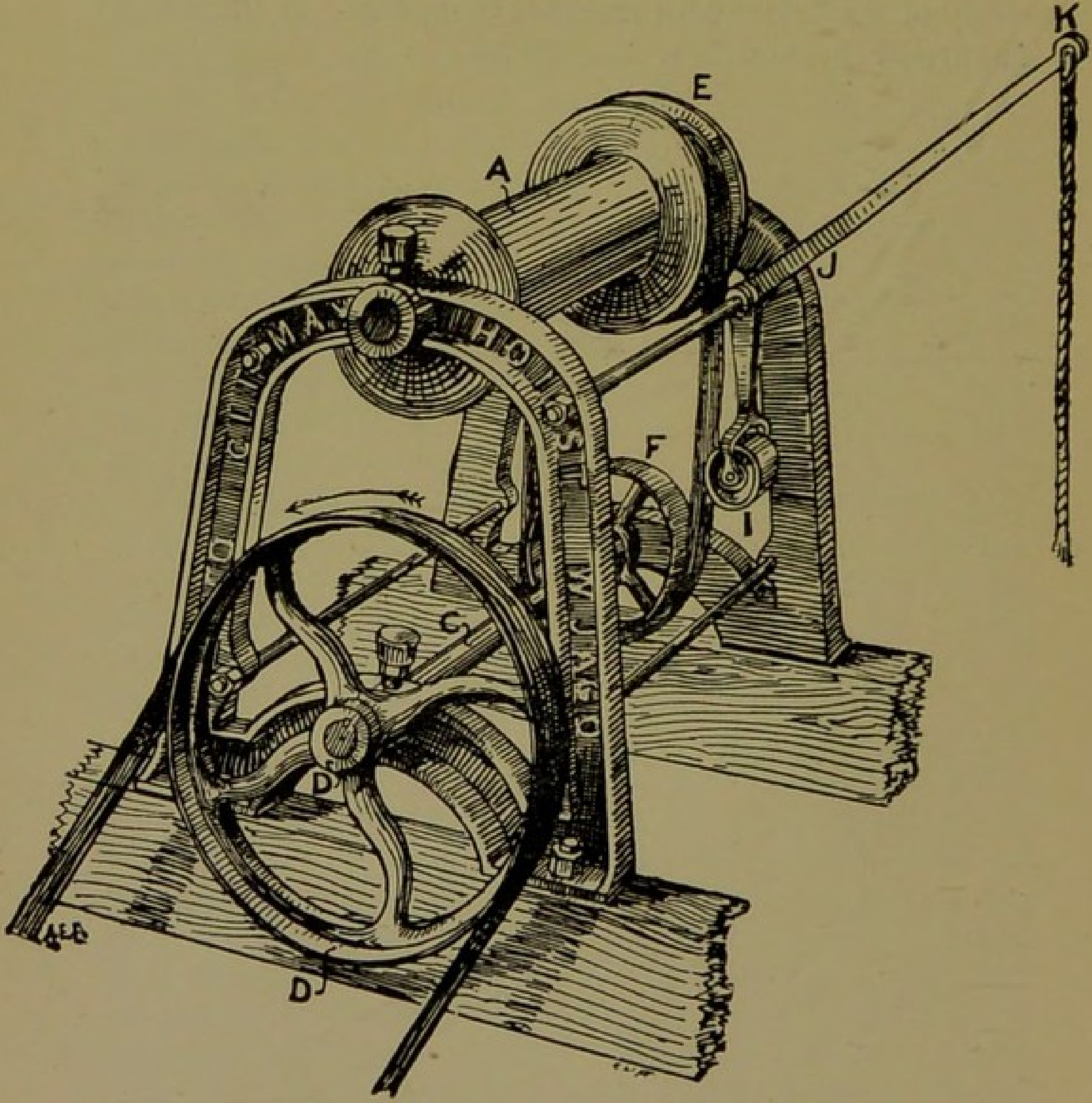


FIGURE 22.—CLIMAX HOIST.

on the floor above. In small bakeries, these conditions do not always obtain, but usually a few judicious alterations, and the employment of a sack hoist, render the storage of the flour above the level of the bakehouse possible, and the outlay is more than compensated for by the convenience and the saving of time and labour. If possible the hoisting arrangements should be under cover, the chain passing up through trap-doors from the van beneath, or at least the pulley should be protected by a "lucombe" constructed of galvanized iron.

Figure 22 shows Jago's Climax Flour Hoist. The arrangement is of the simplest character. By means of a projecting arm a pulley is suspended at sufficient distance from the door to prevent a sack from scraping the wall, and the chain is attached to the iron barrel A. The machine may be adapted either for power or hand.

Another form of hoist is illustrated in Figure 23, adapted specially for quick and easy hoisting by hand.

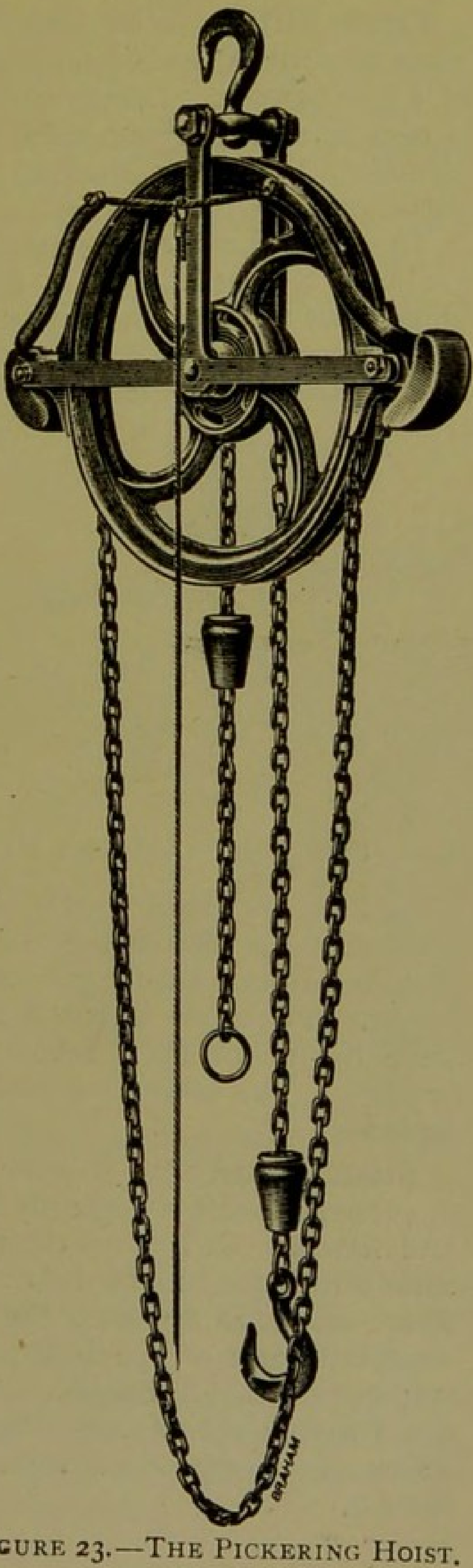


FIGURE 23.—THE PICKERING HOIST.

Flour Sifting.—The object of sifting flour is to remove impurities, and to reduce the flour to the condition of a fine powder. During the sifting operations the flour is also aerated. Flour may be sifted before or after blending, the latter method perhaps being the more common.

There are many sifting machines in the market, both for power and hand, and, in many cases, they are combined with blending machines. For small bakeries the hand sifter illustrated in Figure 24 is well adapted. It rapidly sifts flour either into a sack, trough, or tub.

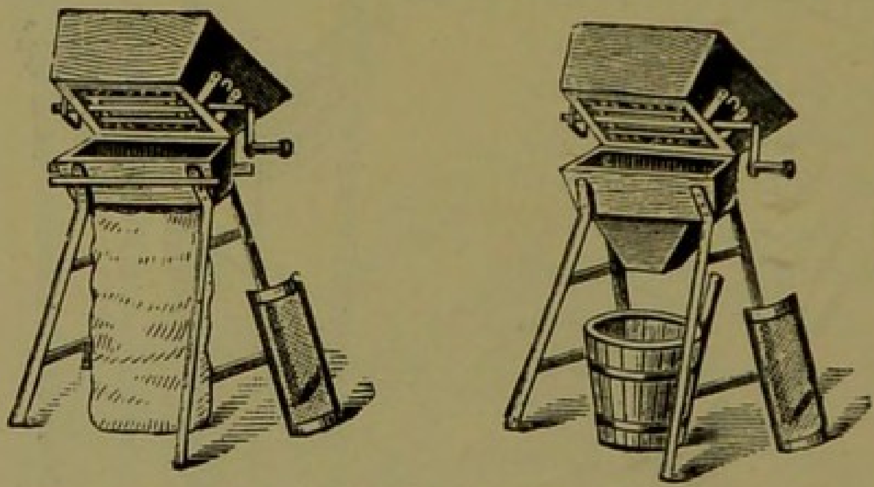


FIGURE 24.—KÜPPER'S HAND SIFTING MACHINE.

In large bakeries power sifters are required either fixed above or below the blender. The Climax sifter may be described to give a fair idea of the general action. The flour is sifted through a semi-cylindrical sieve by means of a revolving series of longitudinal brushes. The sieves are easily removed, cleaned, and replaced.

Flour Blending.—Flours vary very considerably as to properties, differing greatly in colour, strength, stability, and flavour. It is often desirable to blend two or three widely differing flours, in order to obtain a doughing flour which shall possess the several characteristics in a modified form of the individual flours. For instance, soft well-flavoured English flours are often blended with the stronger spring American flours, in order to tone down the harshness of the latter, and to improve the flavour.

No hard and fast rules can be laid down as to the particular flours to blend. The baker must be guided by the kind of bread he requires to turn out, and the properties which he finds his bread lacks. For sponges, blends of hard flours should only be used, the softer varieties being avoided, and usually a lower grade may be used in the sponge than in the dough. For doughs, a certain percentage of softer flours may be employed. Generally speaking, it may be said that:

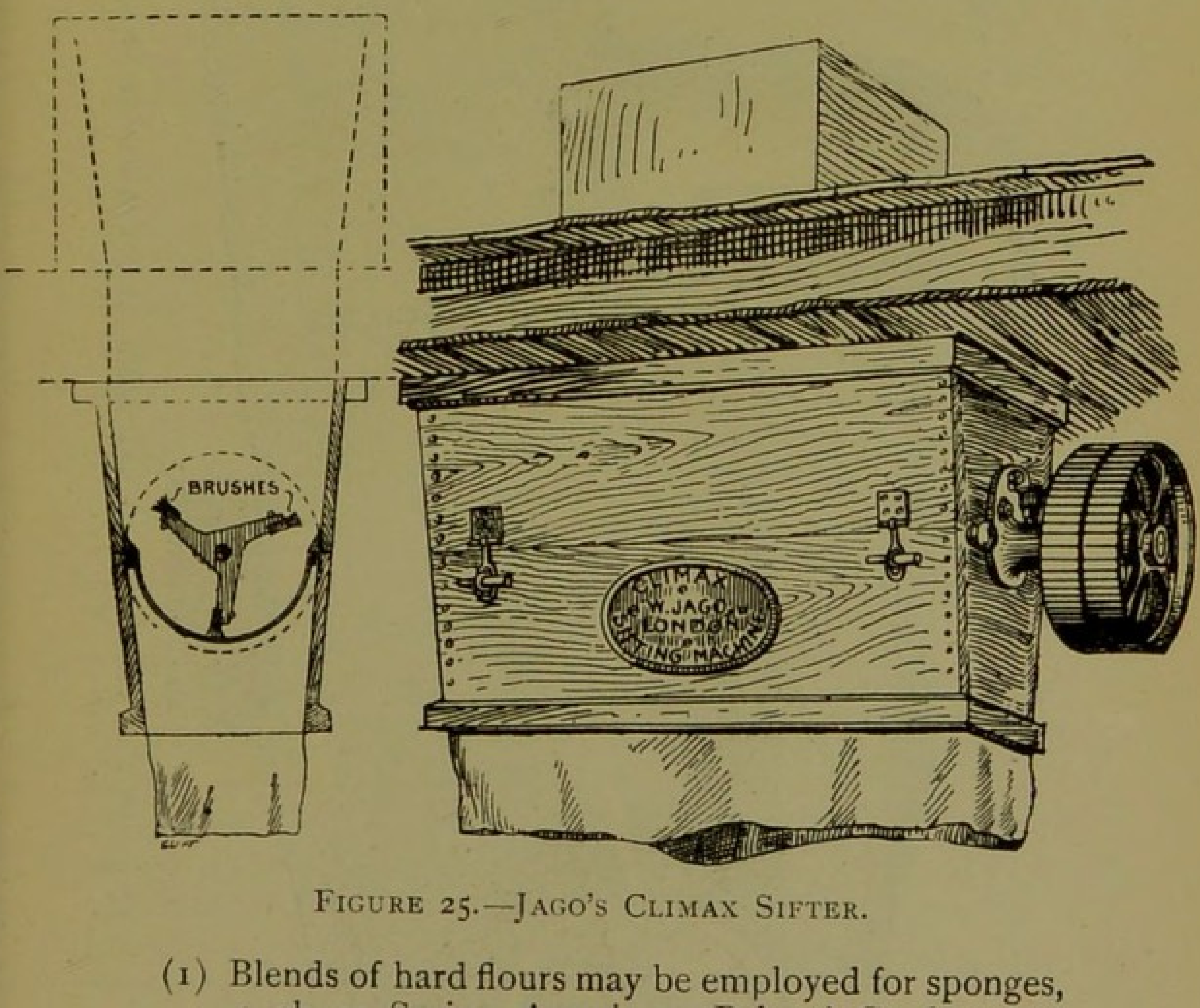


FIGURE 25.—JAGO'S CLIMAX SIFTER.

(1) Blends of hard flours may be employed for sponges, such as Spring American, Bakers' Grades, and Russian.

(2) For doughs, blends of hard patents with softer flours may be used. Spring American Patent, Hungarian, soft English, and some Indian flours are suitable for this purpose.

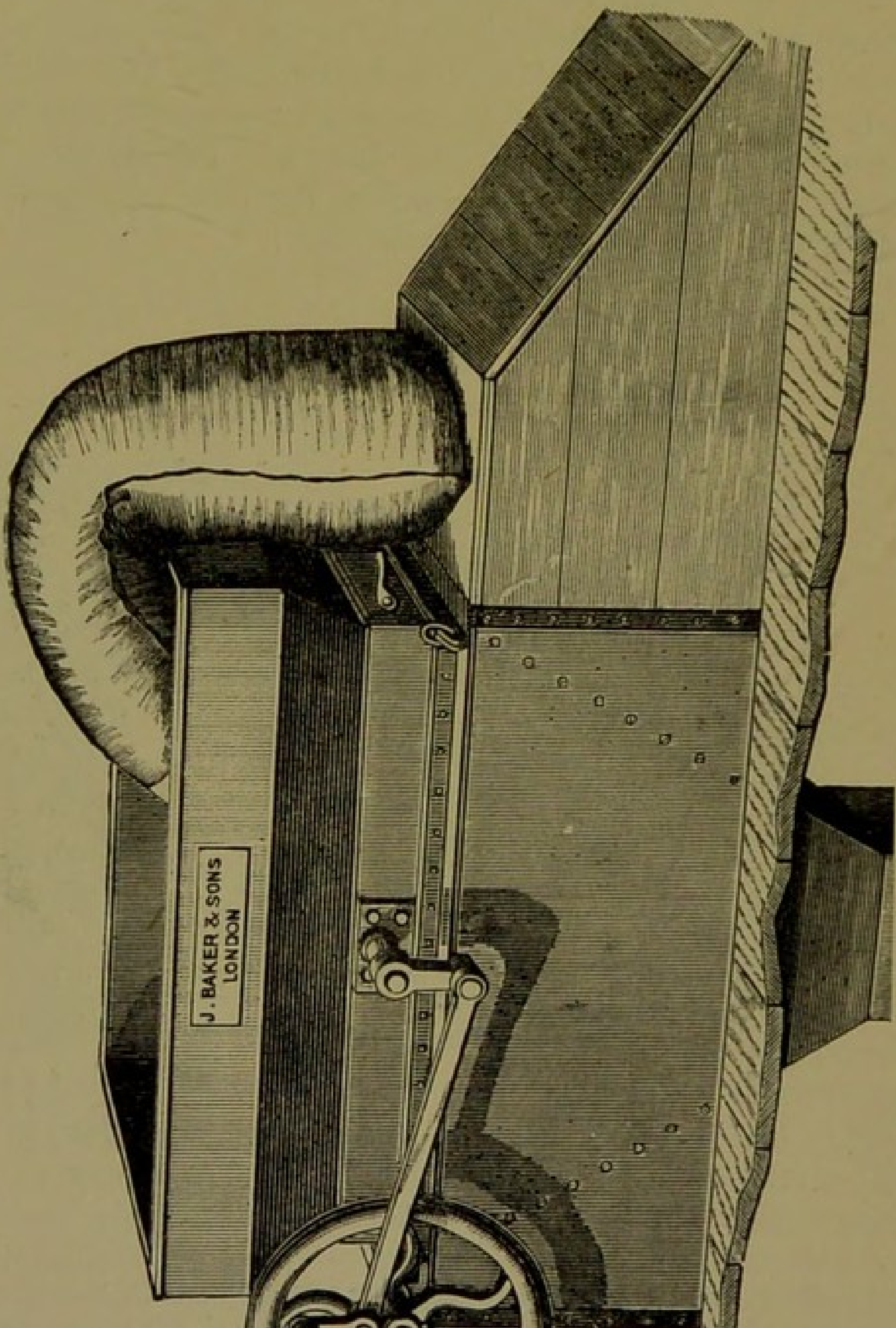


Figure 26.—Hand Sifter and Blender Over Flour Shoot.

The main points which the baker must keep before him in flour blending are:

(1) *The price of the bread* determines the proportions of high-class and low class flours.

(2) *The colour of the bread*, depending chiefly on the relative proportions of patent and lower grades in the blend.

(3) *The flavour*, depending on the relative quantities of Hungarian or English.

(4) *The boldness of loaf and yield*, influenced largely by the proportion of hard stable flours in blend.

(5) *Bloom, pile, and texture*, influenced by the proportion of the high-class flours, like Hungarian and first patent brands.

The best blends for individual requirements are those produced by the experience of the baker. If, for instance, a dough is soft, and gives too much, a larger proportion of hard spring American patent in the blend will remedy the defect. If the dough is too harsh, and the bread lacks flavour, the proportion of Hungarian or English in the blend may be raised. The best results are obtained where the blended flours are allowed to stand for some time before use, so as to become thoroughly incorporated and matured But unfortunately the exigencies of business do not always allow of such storage, and usually the flours are blended straight away just before use.

Hand-blended flours without machinery are not usually satisfactory, especially where the blending is done rapidly. There are, however, a large number of admirable machines in the market for this purpose, which thoroughly and effectively blend flours with great rapidity, and these sifters and blenders are usually placed over the doughing machine, so that the blended flour runs directly down the spout into the dougher, ready for mixture with the water and yeast.

Usually a sifting machine is attached to a flour blender, so that the two operations are performed in the one machine. There are many admirable hand blenders now in the market, which are so constructed as to be readily fixed over a shoot communicating with a trough or hand doughing machine.

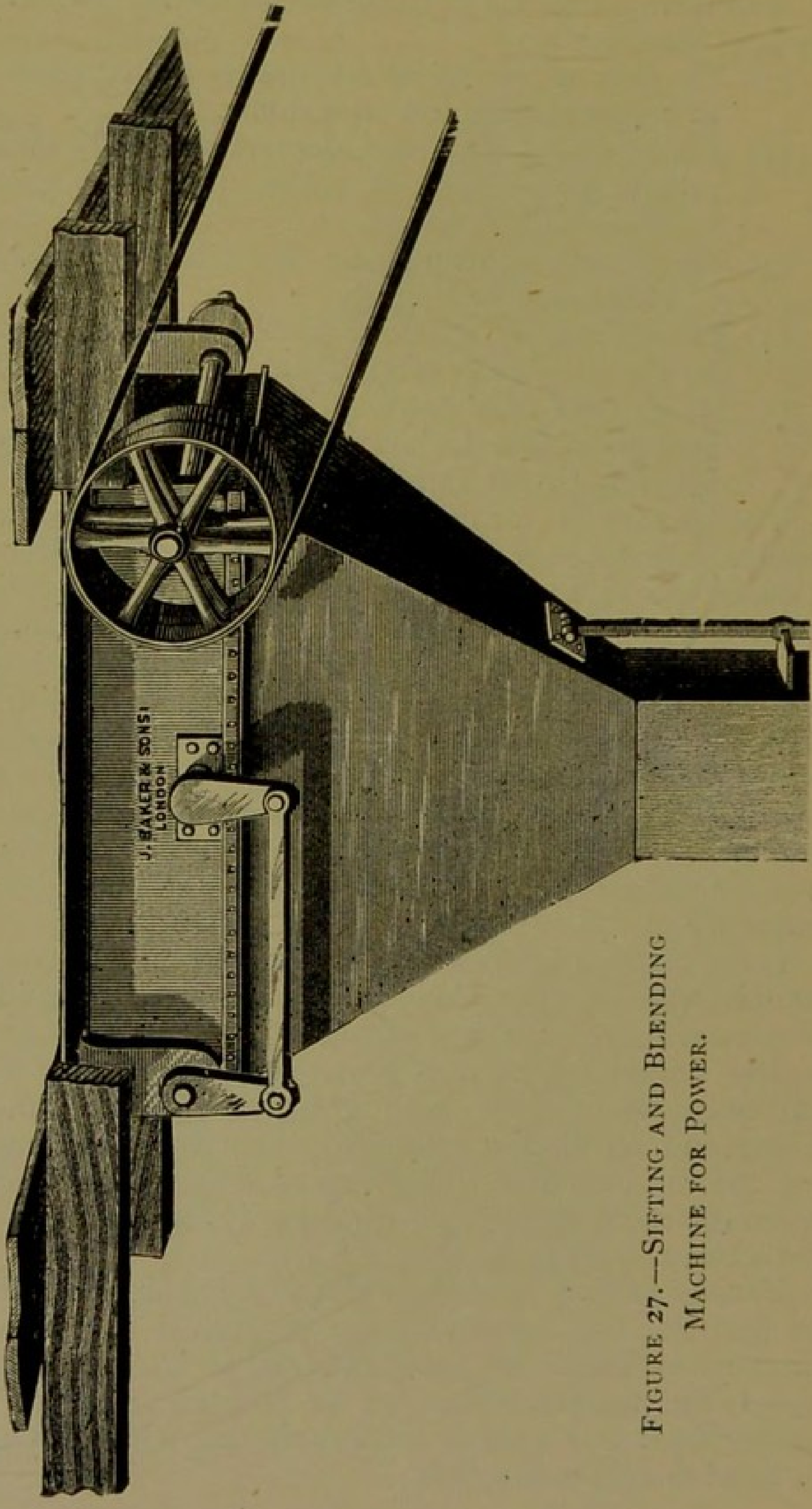


FIGURE 27.—SIFTING AND BLENDING MACHINE FOR POWER.

In Figure 26 an illustration is given of a combined flour sifter and blender for hand, the blended flour running away by the shoot to a doughing machine below. This is a very convenient arrangement for a small bakery.

Where gas, oil, or steam power is available the machine illustrated in Figure 27 is suitable. The feed hopper is almost flush with the floor of the flour room, in order to allow the sacks being tilted without lifting. The hopper is provided with separate divisions for the reception of flours, which, by means of regulators, run at the required relative speed into the machine. The flour is thoroughly blended and sifted, and is delivered to the doughing machine by the shoot.

In some cases arrangements are made for the flour to be carried away and delivered at any suitable point by means of screw conveyers.

Another form of sifter and blender is figured in diagram 28. The Climax Blender consists essentially of a wooden trough, semi-cylindrical at the bottom, and fitted with a revolving mixing blade, which turns the flour over gently from the circumference to the centre, and gives it at the same time a motion from end to end. The exit of flour to the sifter beneath is regulated by a valve manipulated by an outside lever. Underneath the valve a spiral conveyer takes the flour to the sifter. This machine is adapted for large bakeries, being capable of blending 2,800 lbs. in a few minutes.

A similar machine for small bakeries is shewn in Figure 29, the sifter being situated beneath the blender. In most cases it is usually found convenient to place the doughing machine beneath the delivery spout of the blender, so that the flour is delivered direct to the dougher. By this arrangement much labour is saved in the conveyance of the flour, and the water may be added by a pipe from the attemperating tank without any trouble, at the proper temperature and in proportions required. The thorough sifting and blending of the flour is favourable to an even texture in the bread, and reduces the probability of obtaining streaks and "knots" in a loaf to a minimum.

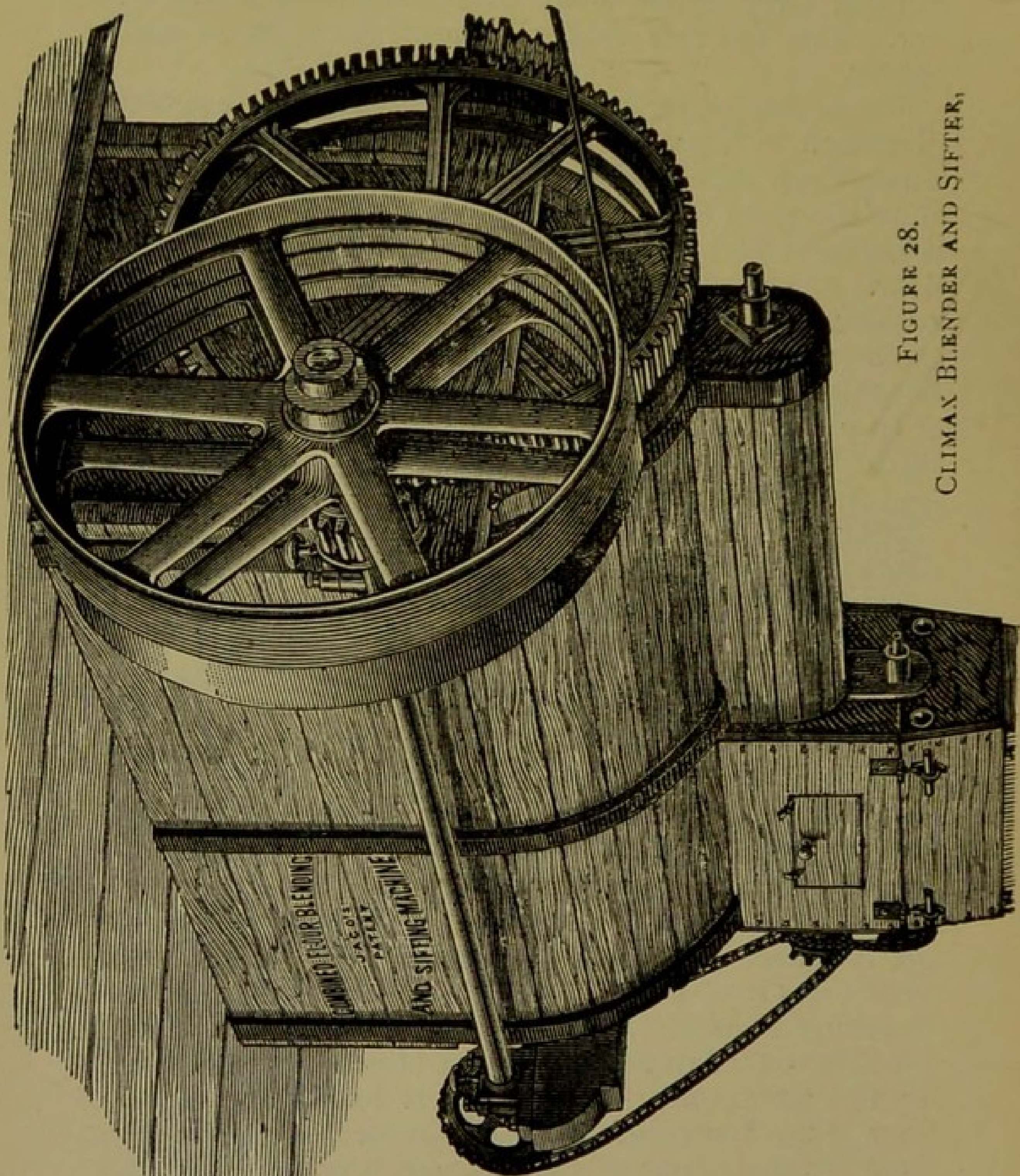


FIGURE 28.
CLIMAX BLENDER AND SIFTER.

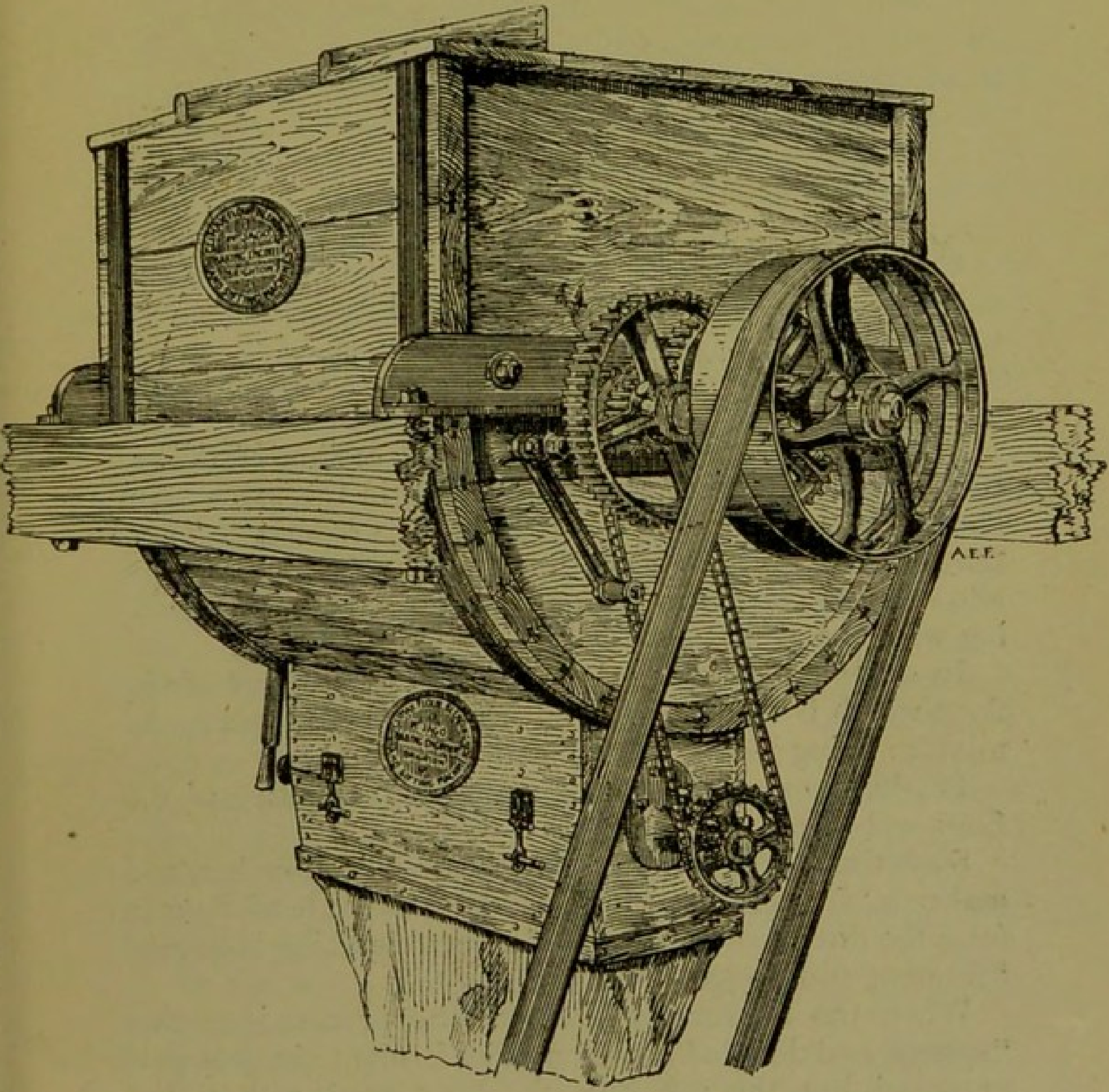


FIGURE 29.—CLIMAX SMALL BLENDER SIFTER.

The thorough sifting and blending of the flour is favourable to an even texture in the bread, and reduces the probability of obtaining streaks and "knots" in a loaf to a minimum.

CHAPTER XIII.

ATTEMPERATING AND MEASURING OF WATER. FERMENTS.

AFTER the sifting and blending operations, the flour is ready for the manufacture into bread.

There is a very wide difference in the methods followed by bakers in different towns, and even in the same town itself. In many cases the baker first prepares a "**ferment**" consisting of yeast, potatoes and water, and allows fermentation to go on vigorously before proceeding with the next stage.

In other cases a slack dough is made with *part* of the flour which is to be employed with water and yeast, the mixture being technically termed the **sponge**.

Lastly, the sponge is mixed with the remainder of the flour and forms the **dough**.

Sometimes a baker omits the "sponge" altogether, and makes a "ferment" which he mixes with the total flour to form the dough. This method of breadmaking is termed "ferment and dough."

When the ferment is omitted, the process is termed "sponge and dough." Often neither ferment nor sponge is prepared, but the *whole* of the flour used with water, yeast, &c., to form the dough straight off.

The *quantity* and temperature of the water used in the bakehouse are most important factors in the production of good bread, and it is convenient for the baker to have some form of instrument to take temperatures and to measure water.

The temperatures of water, sponges and doughs may be indicated by the use of the mercurial thermometer which registers accurately the temperature of the body in contact with the bulb and glass. The rough and ready method of taking temperature by the hand and arm is

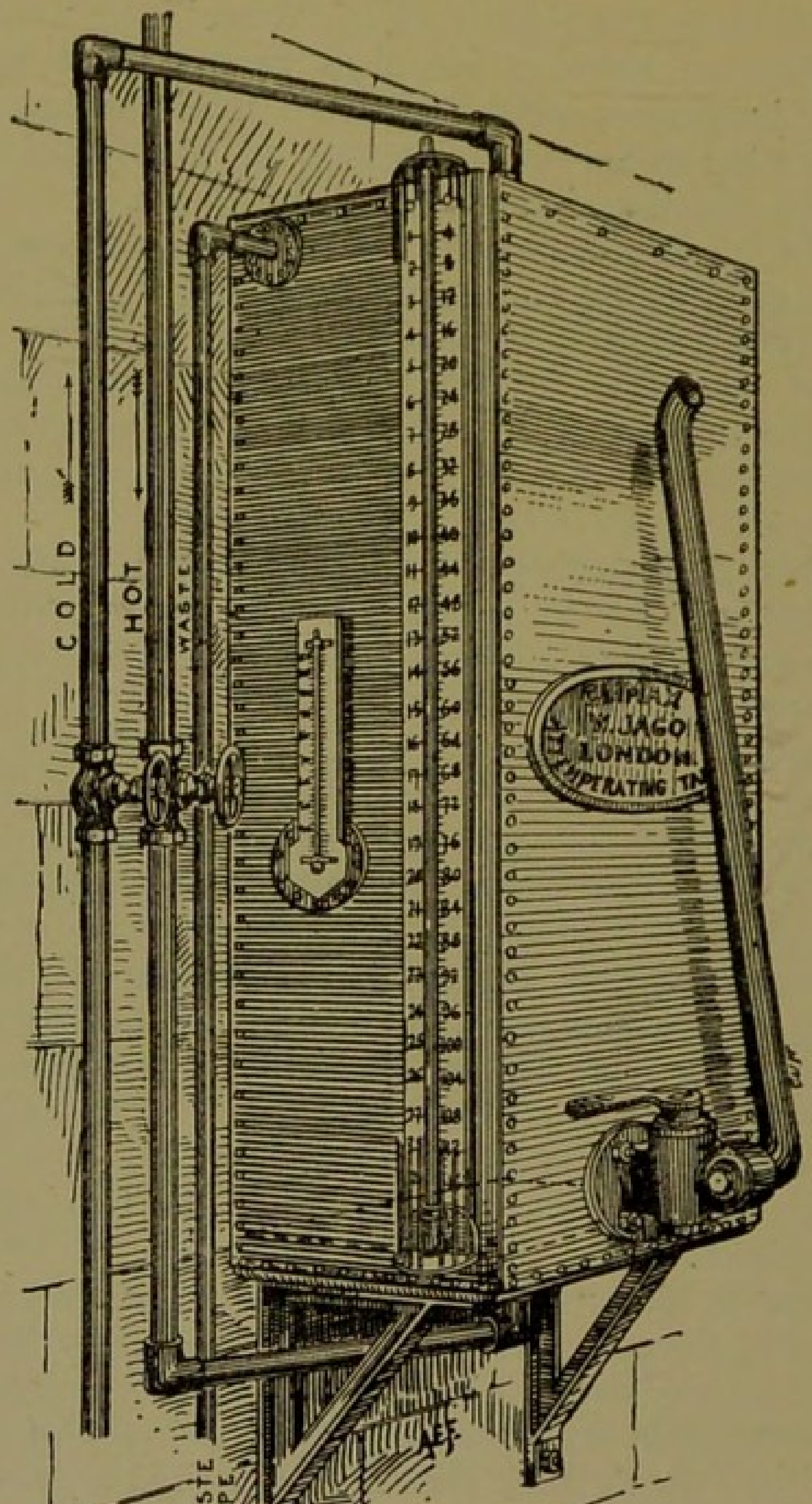


FIGURE 30.—JAGO'S CLIMAX WATER ATTEMPERATING AND MEASURING TANK.

Another form of attemperating apparatus is shewn in Figure 31.

In this form the hot and cold water mix *before* passing into the tank, the water being withdrawn by a tap at the

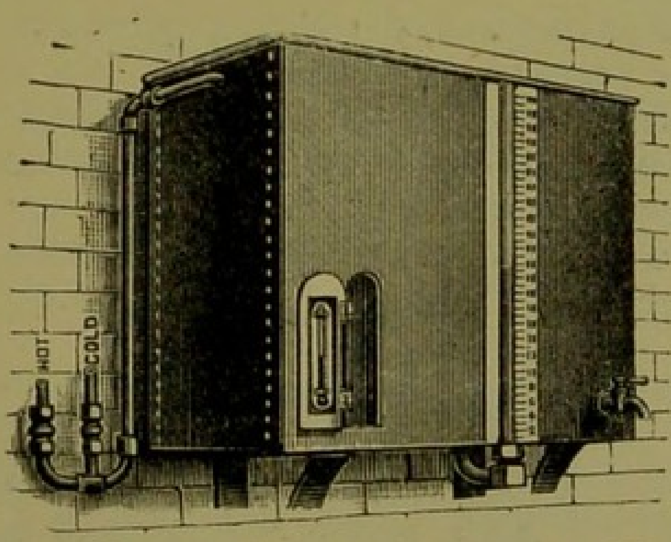


FIGURE 31.—MASON'S ATTEMPERATING AND MEASURING APPARATUS.

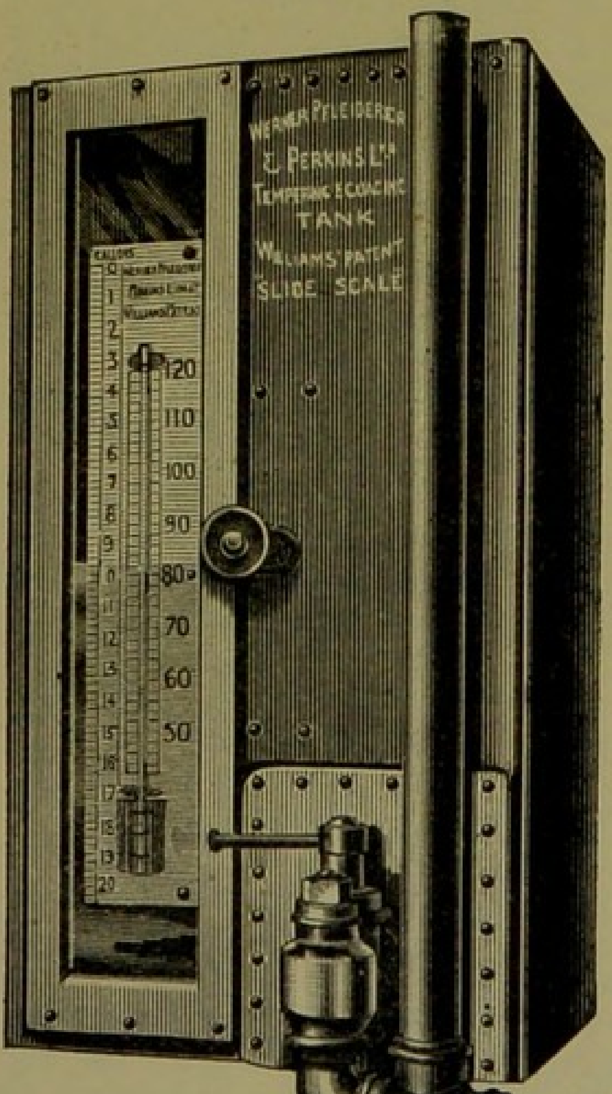


FIGURE 32.—WERNER AND PFLEIDERER'S WATER MEASURING TANK.

right corner of the tank, to which may be attached a hose carrying the water to the trough.

The thermometer and gauge are in the front. The machine may be conveniently fixed over the trough, the hot water being supplied from the oven.

In Figure 32, Werner and Pfleiderer's water measuring and tempering tank is shewn, fitted with William's sliding

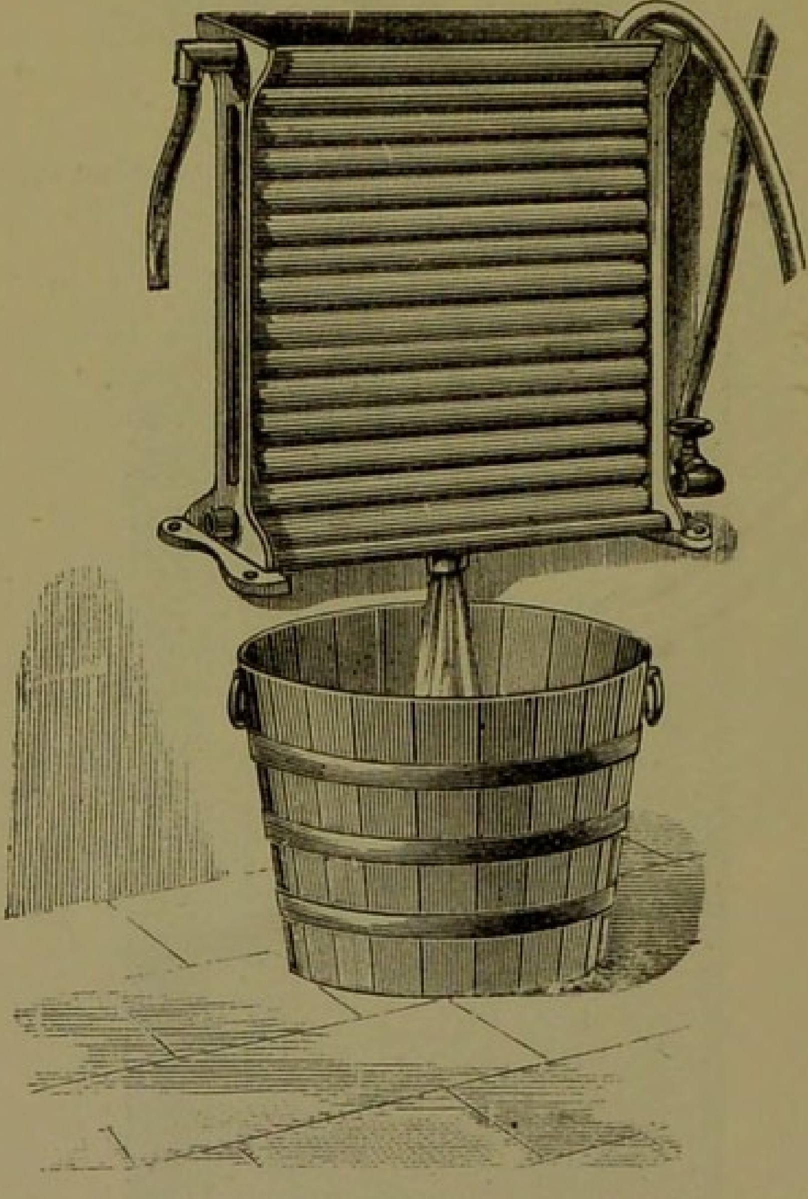


FIGURE 33.—BAKER'S CAPILLARY REFRIGERATOR.

scale. It is made for fitting to the wall, and is provided with hot and cold water supply, thermometer and gauge.

Ferments are liquors prepared from potatoes with or without admixture with flour, together with water and yeast. The following may be taken as a type of how ferments are prepared:

8 lbs. of sound potatoes are taken to each sack of 280 lbs., thoroughly washed, and boiled or steamed. The potatoes are then mashed in a ferment tub, and the whole allowed to cool down to 80°F., the bulk being made up to two gallons by the addition of water and 2 lbs. of flour.

The yeast is then added in suitable proportions, and the whole allowed to stand until the ferment rises and falls once, usually in from 3 to 6 hours. The ferment is now ready, and should be strained before being delivered to the sponge or dough. In some cases the ferment is made of flour and yeast alone, and in others malt extracts or yeast foods are employed.

Where potatoes are used it is most important that they should be of the best quality and very carefully cleaned. The latter operation is best done by means of a machine specially designed for the purpose. The ferment may be "sown" or "pitched" with any kind of yeast, either brewers', patent, or distillers'.

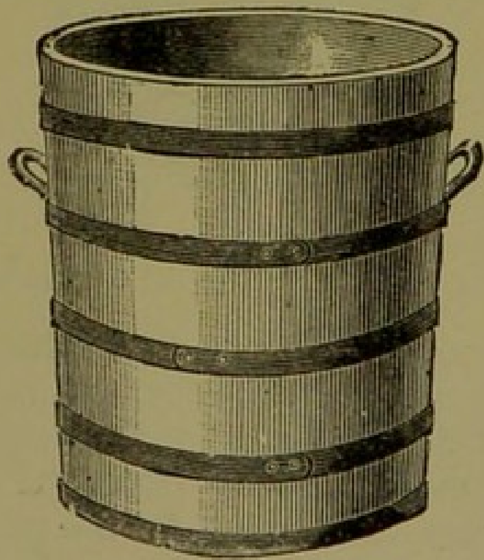


FIGURE 34.—FERMENT TUB.

Ferments should be set at a low temperature, and kept at a uniform heat. To ensure a uniform low temperature a contrivance termed "the Capillary Refrigerator" has been invented. The liquor trickles down over the outer surface of the refrigerator, and as *cold* water enters at the bottom, and is gradually forced through a continuous pipe, it becomes warmer as it ascends, the *ferment* liquor gradually becoming *cooler* as it descends.

Ferment tubs are usually made of non-absorbent wood like teak or oak, and should be provided with handles for convenient moving.

It is most important that all tubs should be thoroughly cleaned, and after use should be scalded and cleansed ready for future occasions.

The object of preparing a ferment is to encourage a growth of new yeast cells, and to stimulate matured cells to healthy activity. Potatoes contain starch, dextrin, sugar, and certain extractive bodies, including amides, and these act as stimulants to the development of yeast cells. In the ferment the soluble albuminoids under the influence of yeast acquire diastasic powers, whereby some

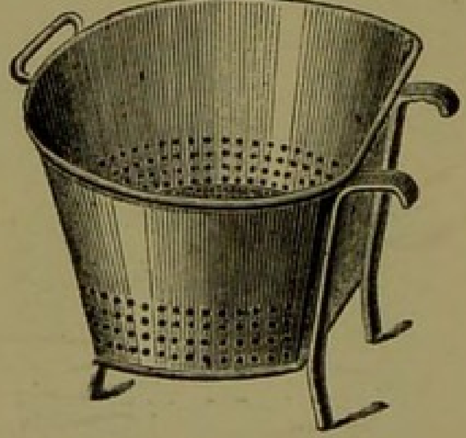


FIGURE 35.—FERMENT STRAINER.

of the starch is converted into sugar, the result being a vigorous growth and development of yeast cells. This propagation is aided by the soluble nitrogenous matter of the ferment, whether derived from the potato, or from the malt, or yeast food used in the preparation of the ferment. Primarily, then, the ferment is really a medium prepared to facilitate the development of vigorous yeast cells. It is important to note that if the ferment be allowed to stand too long after the first fall back, there is a danger of the souring fermentations obtaining a footing. The same remark is true if the ferment be worked at too high a temperature. Unless the utmost care be exercised potatoes are apt to be a source of uncleanliness in the bakehouse, and many objections have been urged against their use, but in justice it must be said that potatoes render the bread moist and produce a characteristic flavour. Where malt extract and similar bodies are used no potatoes need be employed, there being ample yeast food in the extracts, and the employment of these potato substitutes is rapidly increasing. When the ferment is ready it should be carefully strained before being used in the sponge or dough.

CHAPTER XIV.

SPONGES.

SPONGES.—Many bakers divide the main operation of bread-making into two parts—forming a "slack" mixture with part of the flour (from 70 to 100 lbs. per sack), and subsequently mixing in the remainder of the flour to form a stiffer dough. The first mixture is technically termed the "sponge."

Of late years, however, bakers have largely discarded the "sponge" method of bread-making in favour of doughing right off, although there is much to be said in favour of the former method. In the first place, a larger proportion of *hard* flours may be used where a sponge is made, for the tenacious harsh gluten is broken down and peptonised by the agents described in the chapter on unorganised ferments, during the sponge fermentation; and, as the mixture is slack, these changes go on more rapidly than in the stiffer dough. The breaking down of the stiff gluten also renders the subsequent mixing somewhat easier, and thus the labour is lessened.

Secondly, division of the operation allows the baker to select softer and well-flavoured flours for the doughing stage, with the result that a bolder and better flavoured loaf is produced by the use of the two varieties of flour at the two stages. Secondly, less yeast is required in the sponge method, for reproduction may take place in the slack mixture, resulting in the formation of new cells, and the old cells work under more favourable conditions, so that they are not exhausted so quickly as when they are working in a stiff dough. Lastly, bread made from sponge and dough has a characteristic flavour. The sponge is usually "set" by mixing from 70 to 100 lbs. of flour per sack with the ferment or yeast, together with sufficient water to make a slack mixture, and is frequently set in oaken sponge tubs, the general practice being to "break" them before mixing with the remainder of the flour to form the dough.

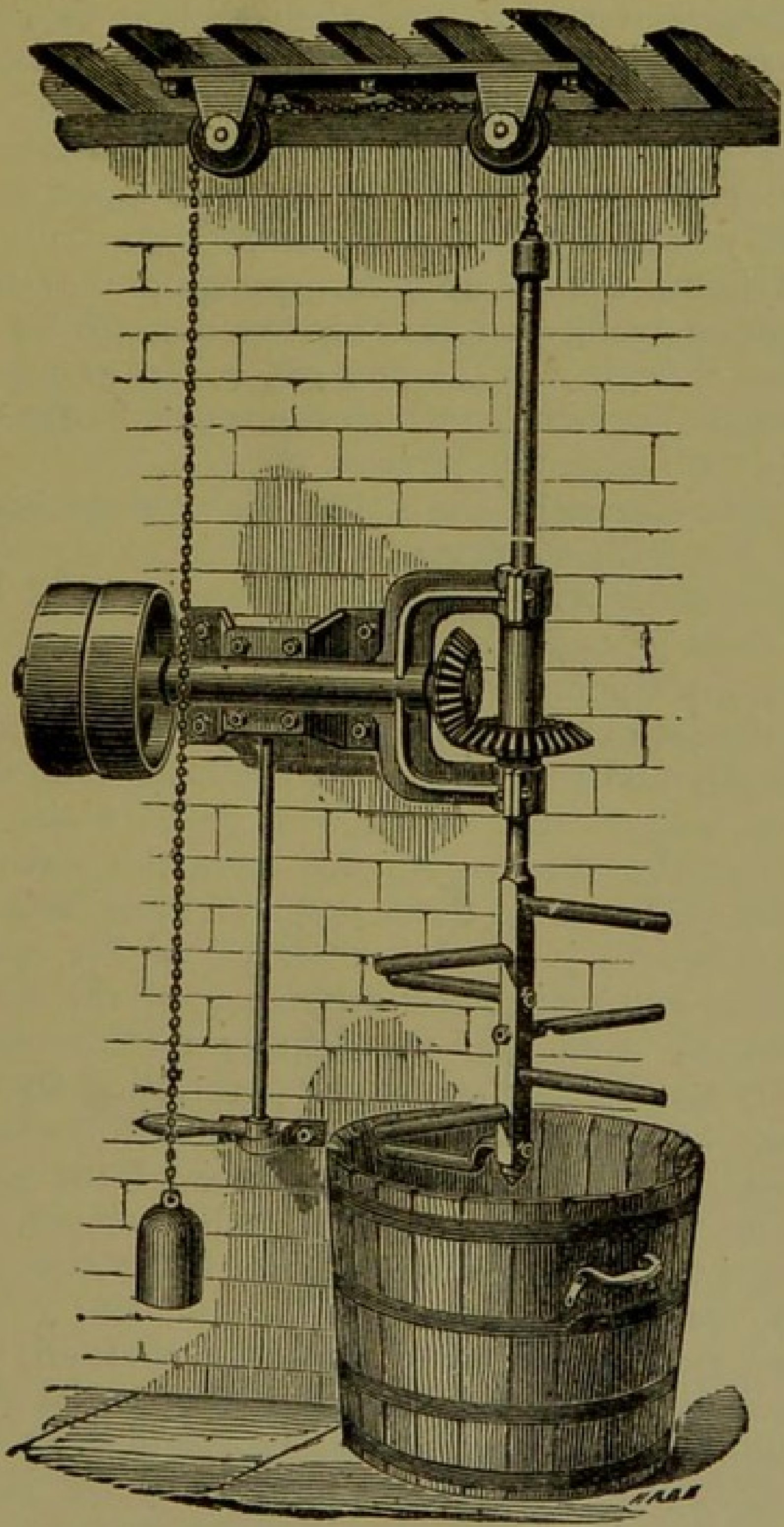


FIGURE 36.—BAKERS' SPONGE-STIRRING MACHINE.

In Figure 36, a diagram is given of a sponge-stirring machine, which effects a great saving of time and labour.

It consists of a vertical spindle fitted with a turnstile at the lower part, which fits into a socket in the bottom of the sponge tub. The spindle is counterpoised by a weight to lessen labour, and the machine is designed for power. When the sponge is ready for stirring, the spindle is raised and the sponge tub placed in position beneath. The spindle is then lowered into the socket and the power applied. The turnstile rapidly rotates, thoroughly breaking up the mixture.

Hard flours are suitable for sponging purposes, the crude gluten being considerably toned down by the fermentation going on in the mixture, and also on account of the longer time during which the tough gluten is subjected to the fermentive process.

The temperature of the sponge is a most important point. Generally speaking from 75° to 80°F., is favourable to satisfactory working. Sponges should be protected from draughts, and, indeed, from any sudden changes of temperature.

The time which a sponge takes to "ripen" varies with the quantity and variety of yeast used, the kind of flour, and the temperature. Distillers' yeast works quicker than brewers', and sponges made from the softer flours are ready quicker than those prepared from hard flours.

Bakers usually judge the condition of the sponge by the general appearance and distension of the mass. As fermentation goes on the carbon-dioxide produced gradually distends the sponge by permeating the gluten, and the whole mass slowly rises towards the top of the vessel. Soon the expansive force of the gas overcomes the cohesion of the gluten, and it escapes, with the result that the sponge falls, or, as the baker says, "turns," "drops," or "falls back."

As a general rule it may be stated that an ordinary sponge made from hard flours and compressed distillers' yeast will be ready when it commences to drop the first time, while one containing brewers' yeast is usually ready on the second turn. However, no hard and fast rules can be laid down, as so much depends on the quantity and character of yeast and the kind of flour employed.

The changes which go on in the sponge may be summarised as follows:

(1.) There is a normal alcoholic fermentation of the sugar of the sponge resulting in the production of alcohol and carbon-dioxide.

(2.) There is a partial peptonisation of the gluten resulting in a softening and mellowing of the tough mass.

When this mellowing reaches a point at which the gluten is just tenacious enough to hold gas, without being unduly stable, the sponge is just ready to be taken, and is, in the language of the baker, ripe. If this softening be allowed to proceed too far, the bread is "yeasty" in flavour and liable to turn sour.

The golden rules to follow in sponging are:

(1.) Work at as low a temperature as possible compatible with a fairly active fermentation.

(2.) Do not work the sponges too quickly.

(3.) Use as little yeast as possible.

If the sponge be worked at high temperatures, there is danger of the souring ferments gaining a foothold.

CHAPTER XV.

DOUGHING.

THE sponge, when ready, is used in the preparation of another mixture, in which the remainder of the flour is employed with water and salt, to form a stiffer mass, technically termed the dough.

Suitable Flours.—Where the sponge method is followed soft flours may be largely used in the doughing stage, but when the system of ferment and dough, or doughing straight off, is the rule, the division of the blends of flour into two varieties—hard and soft—for the two stages is not applicable, *one* suitable blend only being employed.

The sponge when ready is converted into dough by the addition of the flour, salt, and water, the flour being weighed, and the water measured. The quantity of salt required varies from 2½ to 6½ lbs. per sack, according to the particular taste of the district, and the kind of flour employed.

Quantity of Water.—In order to form some estimate of the quantity of water which a given blend of flour requires, a few preliminary experiments should be performed with the pipette as directed in Part IV. Usually the quantity of water which should be employed is estimated by the stiffness of the dough as measured by the sense of touch and resistance to the hands, but much time is saved, and better results secured, if the operator has already obtained reliable data by the preliminary tests.

Mixing.—The sponge should be thoroughly broken up when mixing with the doughing flour, in order to distribute evenly the yeast and gas produced. In a large number of bakeries the doughs are mixed by hand, but of late years machines specially designed for this purpose have come largely into use, and there can be little doubt that as time goes on machine-mixing will entirely replace the older system of hand labour.

There is everything to be said in favour of machinery for dough mixing. It saves labour and time, and is more cleanly, when the machines are properly looked after.

Hand Kneaders.—Some dough-mixers are constructed to work by hand, and the general nature of such machines will be readily gathered by a study of

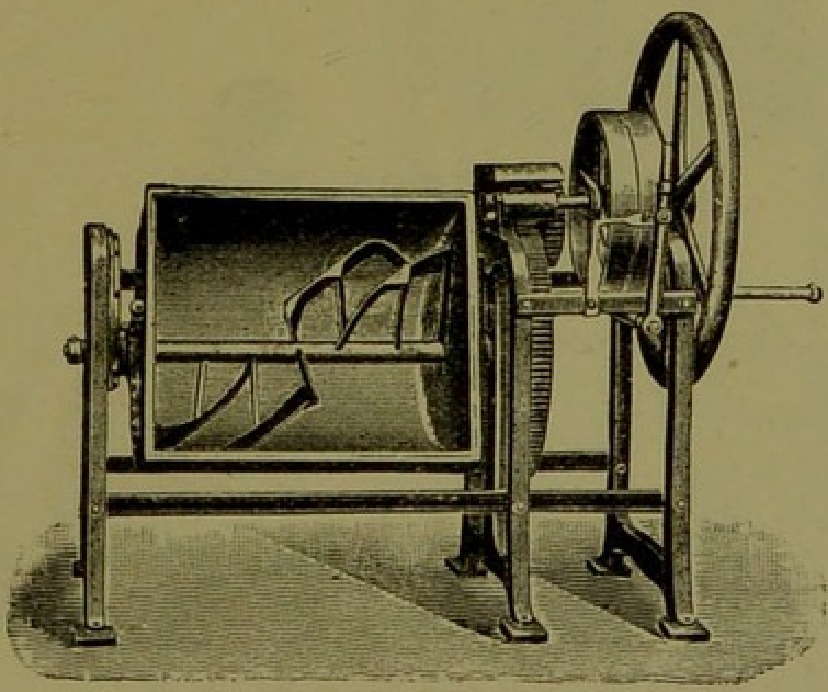


FIGURE 37.—KÜPPER'S DOUGHING MACHINE.

the diagram of Küpper's dough mixer (Figure 37), which is admirably adapted for small bakeries.

Power Kneaders.—There are a large number of doughing machines in the market specially adapted for power, in which a large quantity of flour may be rapidly and efficiently mixed, with very little labour. The following figures and descriptions of some of the best known will give some idea of their nature and action.

Figure 38 shows Werner & Pfleiderer's machine being charged. When ready the flour and sponge are thoroughly mixed by two revolving arms which turn the dough over and over, thoroughly incorporating the different ingredients. By studying Figure 39 the reader will get a better idea of the nature of the kneading arms. The machine is so constructed as to be counterpoised when charged, by the two heavy weights shown in Figure 38. This arrangement allows the machine to be easily tilted for emptying.

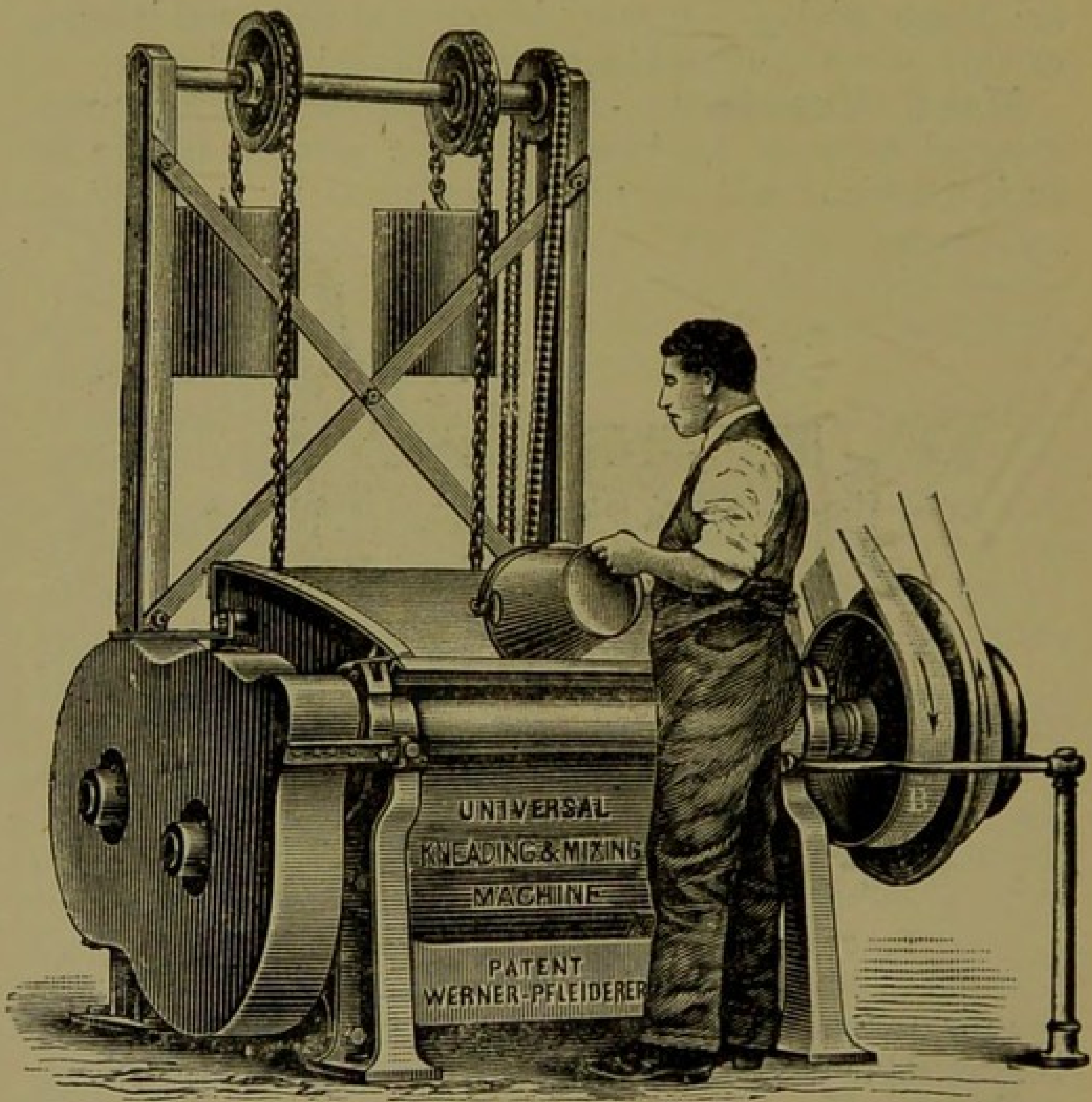


FIGURE 38.—WERNER AND PFLEIDERER'S KNEADER.

Thomson's doughing machine is shown in Figure 40. In this machine there are two sets of kneaders, one external gathering the dough from the sides of the machine and passing it inwards and upwards, while the inner set work in an opposite direction and at a quicker rate. The kneading arms are supported and driven from both ends of the machine, and have a vertical and horizontal action on the dough. When ready, the movement of the arms may be altered so as to gather the dough into one mass which is then automatically and cleanly discharged.

Melvin's machine has five steel mixing blades, and their action is reverse to each other in such a way as to give a gentle turning over and pressing motion to the dough alternately. The machine is sometimes fitted with two sets of driving pulleys of different diameters, so as to give a quick and slow speed, the former for stirring or breaking up the sponge, and the latter for preparing the dough. The machine is discharged by turning the tilting gear handle, the blades at the same time scraping the

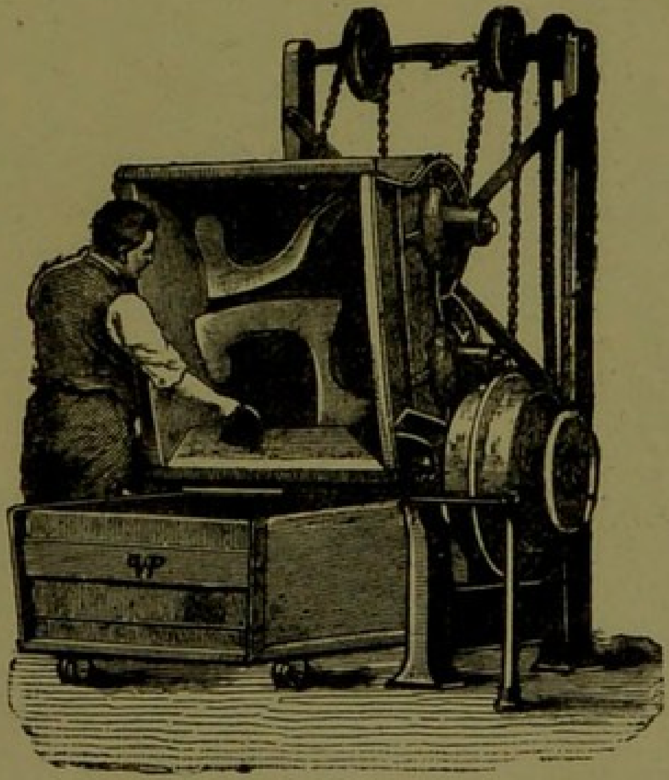


FIGURE 39.—WERNER AND PFLEIDERER'S KNEADER BEING EMPTIED.

sides and bottom clean. The bearings of the shafts to which these blades are fixed, are covered with a special gun metal to resist the corrosive action of the salt.

The top of the apparatus is arranged so as to allow of the flour being fed into the machine direct from the sifter or flour bin.

Mason's Patent Cylindrical Kneader is shown in Figure 42. The kneading arms spring from a central revolving axle, and give a kind of spiral movement to the dough, securing thorough mixing. The machine is fitted with a tilting gear for emptying.

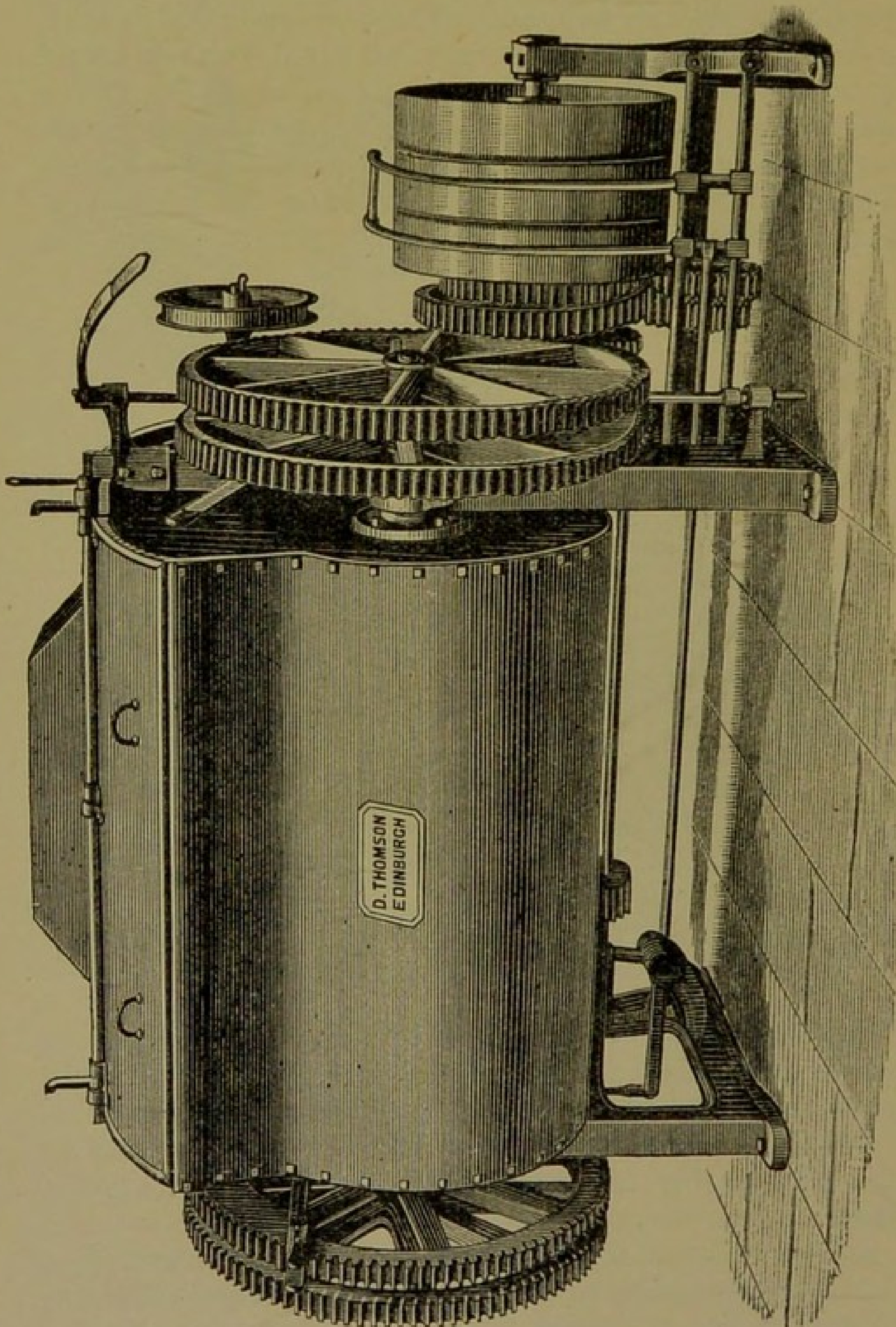


FIGURE 40.—THOMSON'S NEW PATENT KNEADING MACHINE.

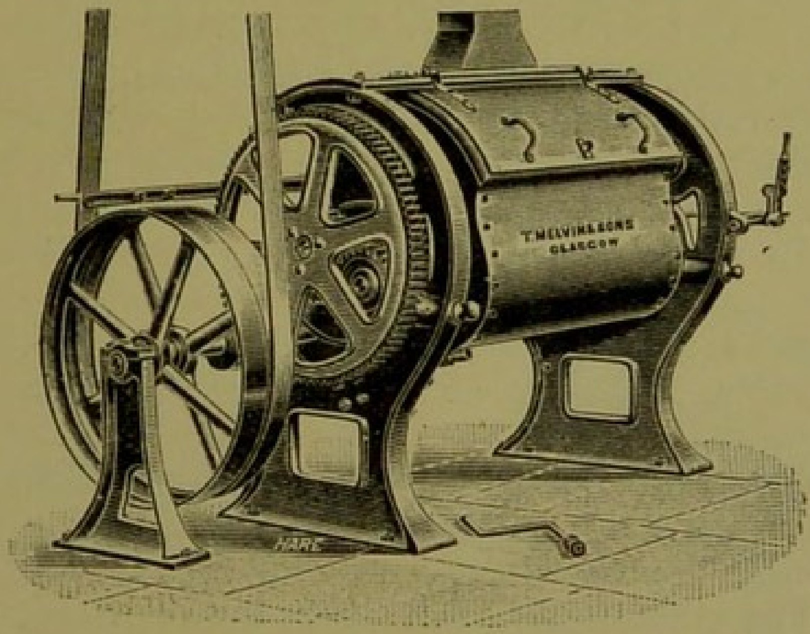


FIGURE 41.—MELVIN'S DOUGHING MACHINE.

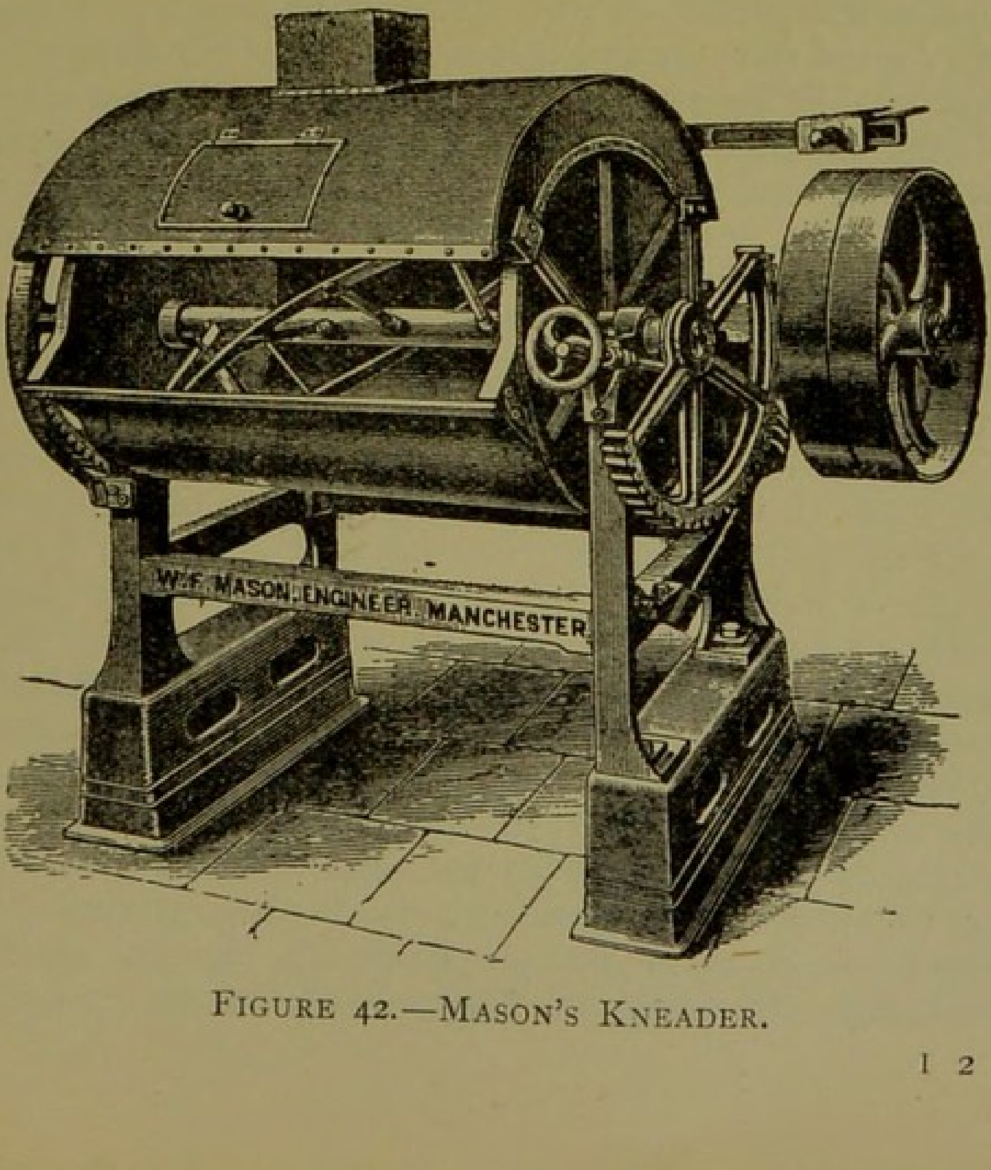


FIGURE 42.—MASON'S KNEADER.

A good doughing machine should secure the following objects:

(1) Thorough mixing of the ingredients.
(2) Powerful motion of arms.
(3) Uniform movement of arms.
(4) Two motions, slow and quick.
(5) An easy discharge.
(6) A clean discharge.
(7) An action corresponding to that of the human arm, to secure the natural "spring" of the elastic mass.

Duration of Doughing Operations.—The length of time which a dough should be allowed to stand varies within wide limits and depends upon:

(1) The method of breadmaking followed.
(2) The kind of flour used.
(3) The variety of yeast employed.

The dough should be taken when the softening processes and aeration are just sufficient to produce a bold loaf of good flavour, and it is only by experience that the baker can judge when the dough has reached that stage.

If the dough be allowed to stand too long, the peptonising action and fermentation produce an ultra-softening of the mass, and the resulting loaf is runny, and crumbles in the centre when cut. The loaf is also liable to become clammy at the base when allowed to stand. It is deficient in flavour, and has a tendency to develop sourness. On the other hand if the dough be taken too soon the loaf is small, close in texture, lacks flavour, and may turn out foxy. The indications of a ripe dough are generally judged by appearance and "feel." A ripe dough is well risen and indicates activity of the yeast, while on parting small portions from the general mass elasticity and silky texture is seen, and while moderate tenacity should be shown, too great resistance to breaking should not be experienced. Many bakers do not take the dough at the first "rise," but "cut back" the dough, by cutting off pieces and ejecting the gas by folding them over the mass. This dividing process also allows some gas to escape from the dough, so that the dough "falls back" and becomes more compact, besides acquiring a somewhat fibrous structure. It is usual in such cases to take the dough on the second rise, but often a second "cut back" is given.

No hard and fast rules can be given, as there are many circumstances which affect the ripening of the dough, but speaking generally it may be said that:

(1) Off hand doughs require to stand longer than those made from sponges.

(2) Doughs made from hard flours require longer fermentation than those made from softer flours.

(3) Doughs made with brewers' or patent yeast require to stand longer than those made with distillers' yeast.

(4) Doughs made with yeast foods or malt extract are ready quicker than those prepared in the ordinary way.

For a large trade, where the doughs are required to be ready quickly compressed distillers' yeast is best, as it works far more rapidly than brewers' yeast, and the use of a yeast food is to be recommended.

The changes which go on in the dough are much the same as those which occur in the sponge, and are commonly spoken of as "panary fermentation."

There is a splitting up of the sugar of the dough into alcohol and carbon-dioxide, the latter acting as the distending and aerating agent of the mass. There is also a breaking down or peptonisation of the crude and insoluble gluten, resulting in a general softening of the dough.

There appears to be no reproduction of yeast cells in dough, the stiffness and texture of the mass not being favourable to propagation, therefore the fermentation in dough is carried on by the yeast cells introduced from the ferment or sponge. There is a slight loss during the doughing operations averaging from two to three per cent.

Weighing.—The dough being ready, the next operation is scaling. Usually the half-quartern loaves are weighed in at from 2 lbs. 2 ozs. to 2 lbs. 4 ozs., according to the character of the dough, stiff or otherwise, and the variety of bread required. Crusty bread loses more in the oven than batch bread, and slack doughs than stiff doughs.

As a rule 2 ozs. is not sufficient to allow for loss by evaporation from the time the loaf enters the oven until it is weighed to the purchaser.

Moulding is the operation of beating and pressing the weighed lumps of dough by hand and "shaping" the loaf before baking. The objects of moulding are to evenly distribute the gas through the mass, to impart a definite texture to the resulting loaf, and to properly mould the dough into the required shape.

Inefficient moulding often results in holes being produced in the bread.

In moulding, "cone" flour is used, consisting mainly of dried rice flour. The object of using "cones" is to facilitate the moulding process by preventing the dough sticking to the hand, and to impart a dryness to the external layer of the loaf. The presence of the dry flour on the external surface of the loaf also helps to produce a finely-coloured crust with a good bloom.

CHAPTER XVI.

FUEL AND COMBUSTION.

BEFORE passing on to the consideration of the various classes of ovens, a brief resumé of the principle of combustion is necessary to the clear understanding of the subject.

Combustion is the name given to the rapid oxidation of carbon and hydrogen, whereby sufficient heat is produced to render the mass and detached particles incandescent. The action is essentially oxidation, that is to say, a combination of the oxygen of the air with the constituents of the fuel. The two oxidisable elements in fuel are carbon and hydrogen, the former being converted into CO_2, while the latter is oxidised in H_2O.

The quantity of heat produced is proportional to the completeness of the oxidation, and therefore it follows that the most economical fuel is one which is capable of being fully oxidised in the furnace of an oven. The chief fuels used are:

(1) Coal.
(2) Coke.
(3) Gas.

Coal is composed of carbon, hydrogen, oxygen and nitrogen, and various mineral bodies which remain unoxidised as ash. In ordinary coal a number of hydrocarbons are present in addition to the uncombined carbon. Some kinds of coal like anthracite consist almost entirely of pure carbon. The products of the complete combustion of coal are:

(1) Carbon dioxide.
(2) Water.
(3) Ammoniacal products.
(4) Ash.

but very rarely, indeed, is complete combustion effected in the ordinary baker's oven, and in addition to the above products unconsumed carbon, gaseous hydro-carbons and carbon monoxide escape with the legitimate products of oxidation.

Coal is favourable on this account to the production of "smoke," and is a fruitful source of clogging in flues.

Coke may be regarded as practically consisting entirely of carbon, the volatile hydro-carbons having been driven off in the gas factory. The coke best suited for oven firing is the hard, porous variety in good sized masses.

The oxidation of coke is not quite of the same character as that of coal. There is only a slight production of water, and practically no escape of unoxidised carbon, but there is a large production of a secondary product in the hottest part of the furnace named carbon-monoxide, which is in turn burnt at the surface of the fire.

The action may be described as follows: The oxygen of the air passes into the lower part of the hot coke, and combines with the carbon according to the following equation:

$$C + O_2 = CO_2$$

The CO_2 formed rises through the middle part of the fire over red and white hot carbon, and immediately takes up another atom of carbon producing the monoxide.

$$\underset{\text{Carbon-dioxide.}}{CO_2} + \underset{\text{Carbon.}}{C} = \underset{\text{Carbon-monoxide.}}{2CO}$$

The CO continues to rise until it comes to the surface of the fire, and there meeting the oxygen of the air is oxidised into CO_2.

$$\underset{\text{Carbon-monoxide.}}{CO} + \underset{\text{Oxygen.}}{O} = \underset{\text{Carbon-dioxide.}}{CO_2}$$

It is clear that should any of the CO escape unconsumed there will be a loss of heat equal to three quarters of the total heat-producing power of the original carbon. It is most important therefore that where coke is used efficient means should be adopted to admit sufficient air to the fire surface to ensure the complete combustion of the CO, by leaving the furnace doors slightly open.

The advantages of coke are:

(1) It is smokeless.

(2) Under proper conditions it is fully oxidised.

(3) It is economical.

The heat in the furnace where coke is employed is very intense and localised, and specially-constructed flues are required to evenly distribute the heat to the oven.

Gas is chiefly composed of gaseous hydro carbons (compounds of carbon and hydrogen) which are finally oxidised into CO_2 and H_2O.

With the ordinary burner gas gives out *light* as well as heat, as the oxidation just stops short of completion, whereby the carbon particles are rendered incandescent but not wholly consumed. Where the object is to obtain *heat* and not light, burners should be employed which effect a complete combustion of all the carbon and hydrogen. Such burners are constructed on the principle discovered by Bunsen, whereby air is introduced through a hole in the pipe, and mixes with the gas before it emerges from the aperture, the flame being blue and non-luminous. Under these conditions the air surrounding the gas, together with the mixed air, completely oxidises the gas, and no unconsumed carbon escapes.

Use of Steam.—In many ovens arrangements are made for the admission of steam to the furnace through the bottom bars. The steam is conducted by special pipes to the furnace and is forced in through small holes, the surface of the fire presenting the appearance of hundreds of miniature volcanoes, due to the upward ejection of jets of steam, and it is claimed that a saving is effected in the fuel. The economy of employing steam is undoubtedly due to the more complete oxidation of the fuel, which it brings about by producing a freer draught of air through the fire. There is no gain as to actual units of heat, but it follows that if there be more complete oxidation *with* steam than *without*, more heat will be produced in the former case from a given weight of fuel, and therefore a *less* quantity of fuel will do a given amount of work than if steam had not been employed. According to Jago, the action in the furnace is modified when steam is admitted, part of the steam being broken up when in contact with the white-hot carbon, according to the following equation :

$$\underset{\text{Carbon}}{C} + \underset{\text{Water}}{H_2O} = \underset{\text{Carbon-monoxide}}{CO} + H_2$$

and then the CO and H are oxidised as follows by the air admitted to the fire :

$$CO + H_2 + O_2 = CO_2 + H_2O$$

The chief objects the baker should keep in view in the choice of fuel and oven are :

(1) To produce as little smoke as possible, thereby preventing waste, blocking up of flues, prosecutions, &c.

(2) To secure as perfect an oxidation as possible, thus economising the outlay.

CHAPTER XVII.

OVENS.

TEMPERATURE.—The temperature of an oven for baking bread should range from 450°F. to 500°F. Mercurial thermometers cannot be depended on to indicate accurately such a high temperature, consequently an instrument termed "a pyrometer" is employed. In the pyrometer the temperature is measured by the expansion of a bar of metal, which acts by levers on the hand moving over the index. All metals expand on being heated, and the exact amount of expansion for every degree being known for every metal, it is easy to indicate the temperature by measuring on a dial the expansion of the bar. Figure 43 gives a diagram of an oven pyrometer.

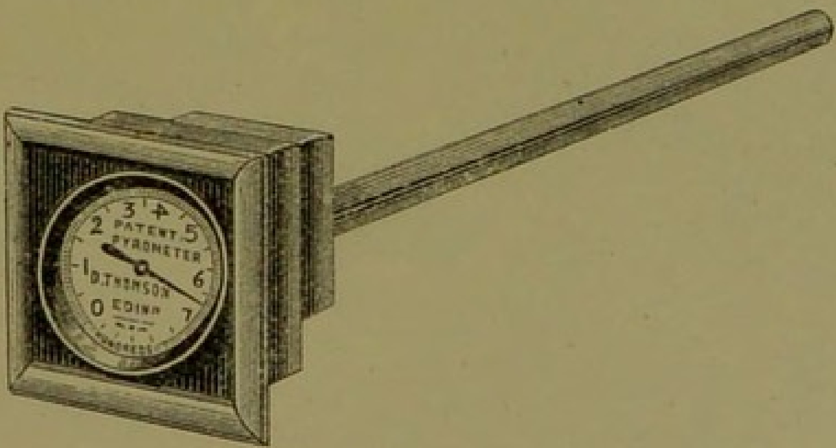


FIGURE 43.—THOMSON'S PYROMETER.

Flash heats and Solid heats.—The baker applies the former term to an intense wave of heat lasting only for a *short* time. The action of a flash heat is mainly superficial, acting chiefly on the crust, producing "bloom" on the loaves.

A "solid heat" on the other hand is a continuous heat at a lower temperature than a flash heat, and has the effect of gradually but thoroughly baking the loaves to the centre.

Lighting.—The old-fashioned peel ovens were illuminated by a naked gas light on a moving bracket. This method is not to be recommended, as the products of combustion escape into the oven every time the jet is directed inside, often leaving a dirty stain of carbon, &c., on the roof and side of the oven. There are many patent lights now on the market in which the waste products do not pass into the interior of the oven, and the illuminating power is concentrated by means of a lens.

Figure 44 will give a fair idea of what a good oven light should be.

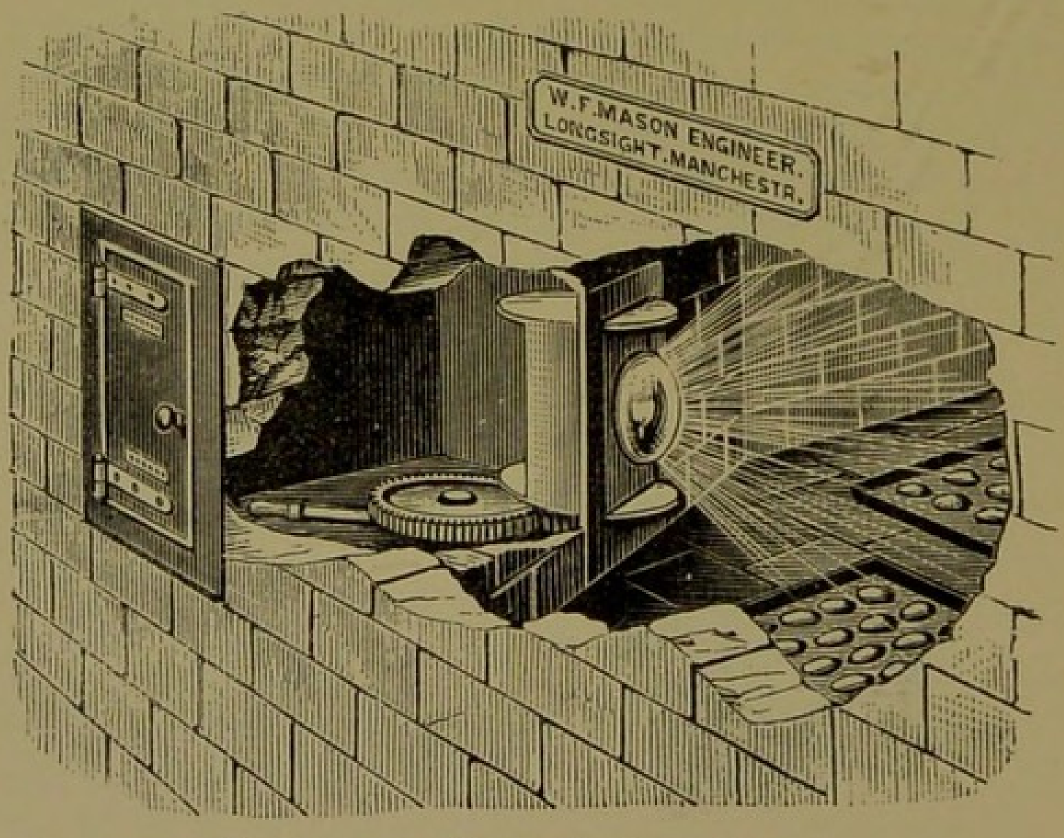


FIGURE 44.—MASON'S OVEN LIGHT.

Kinds of Ovens.

The Peel Oven is characterised by a small door, about 2 ft. in diameter, through which the goods are placed in and drawn out. The loaves are put into place by a long rod bearing a flat spade at the end, the whole being termed a "peel." The disadvantages of the peel oven are:

(1) It takes a long time to charge and empty.
(2) The loaves placed in first are the last withdrawn, and are consequently longer in the oven than those in front.

In the improved peel oven the flues and chambers are so arranged that the back part of the oven is at a lower temperature than the front, thus compensating for the varying times to which the bread in different parts of the oven is subjected to the heat.

Drawplate Ovens.—In this kind of oven there is a plate which is so constructed as to be easily pushed in and drawn out of the oven. The plate practically forms the baking surface, and may be constructed of iron or tiles on an iron framework. To charge the oven the plate is withdrawn and the goods placed in the proper position, and then the plate is slid into the baking chamber. When the goods are done the plate is again withdrawn, carrying with it the baked goods.

The advantages of the drawplate oven are:

(1) It saves time.
(2) No oven light is needed.
(3) All the goods are in the oven for the same length of time.

Decker Ovens are placed in tiers, one above the other, much like the decks of a ship. The advantages of this arrangement are:

(1) Economy of space.
(2) Economy of fuel, inasmuch as part of the waste heat of the lower oven is used to heat the upper.

Decker ovens require to be constructed on right principles and carefully built, in order to secure an equable temperature in both ovens, and to prevent the upper oven being cooler than the lower one.

Continuous Ovens are those in which it is possible to bake continuously batch after batch without any break or delay. This is secured by so arranging the firing that it can be done independently of the baking.

Portable Ovens are usually constructed of iron, and are built on wheels, so as to be easily moved about. They are largely employed in armies and expeditions.

Steam Ovens.—In a steam oven the heat of the furnace is not employed directly to heat the oven, but to convert water into steam, the latter heating the oven. Water boils at ordinary pressure at 212° F.; but the boiling-point may be *raised* by pressure. If a certain quantity of water be enclosed in sealed iron tubes and heated by a furnace, the temperature of the water and steam will rise far above 212° F., and is only limited by the intensity of the furnace and the strength of the tubes. In most steam ovens the water is contained in iron tubes, which are so arranged as to heat the oven chamber uniformly. Sometimes steam ovens are spoken of as "hot water ovens." The chief advantages of steam ovens are:

(1) The heat is uniform and "solid."
(2) The interior of oven is free from contamination.
(3) They are usually simple in construction and need little attention.

One of the disadvantages is that it is not possible to get a "flash heat."

Hot Air Ovens.—In this variety of oven, hot air and heated gases are mainly employed to distribute the heat to the floor and roof of the oven chamber, by means of specially-arranged flues and channels. There is no contamination of the air in the baking chamber of these ovens by the products of combustion.

Vienna Ovens have special arrangements for the introduction of steam into the baking chamber, for the production of glazed goods, the action of the steam being to convert the outside layer of starch into dextrin.

The limit of this series will not permit of a very lengthy description of ovens, and only a brief account may be given of a few types.

Jago's Climax Oven (Figure 45).—In this oven the baking chamber is surrounded by flues conveying hot air from the furnace. In the diagram two ovens are shewn, one above the other, the lower one being a drawplate while the upper one is a peel. The furnace is preferably placed at the back, but may be constructed at the front or side.

The heat from the furnace first passes through flue No. 1, underneath the bottom oven and then through flues Nos. 2 and 3 heating the top and bottom of each oven in the series. The walls are two feet thick and the flues are all perfectly straight, being easily cleaned and inspected. The ovens are continuous and specially designed to burn coke, and when properly attended to, the upper ovens are always at a temperature capable of

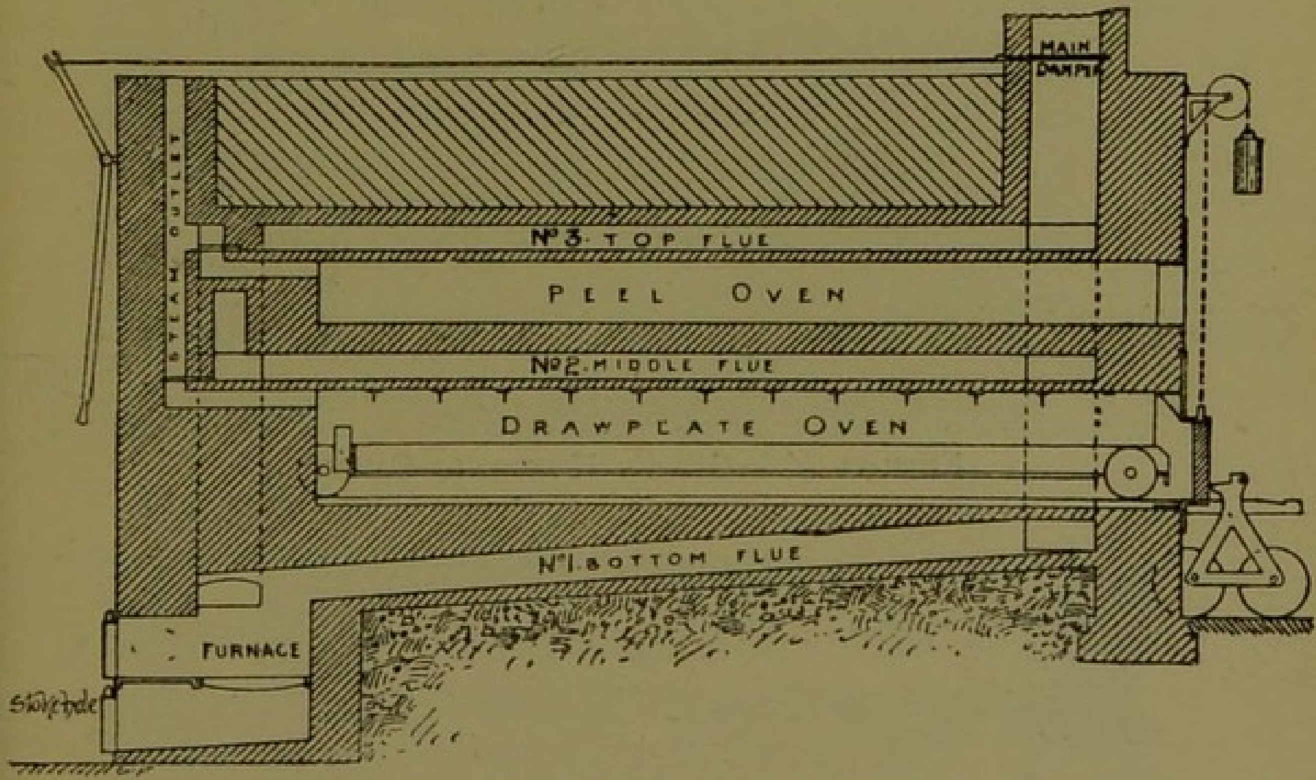


FIGURE 45.—JAGO'S CLIMAX OVEN.

efficiently baking bread. "Flash heats" can also be obtained easily.

Geen's Hygienic Oven.—In Figure 46 will be found a section of this well-known oven in which the baking chamber is heated by hot air.

The diagram shews two ovens, the sole of the bottom one being protected from the direct heat of the furnace by an air space.

The heated gases first pass under the sole of the bottom oven, from back to front, and thence between the crown of lower and floor of upper oven by two flues to the back

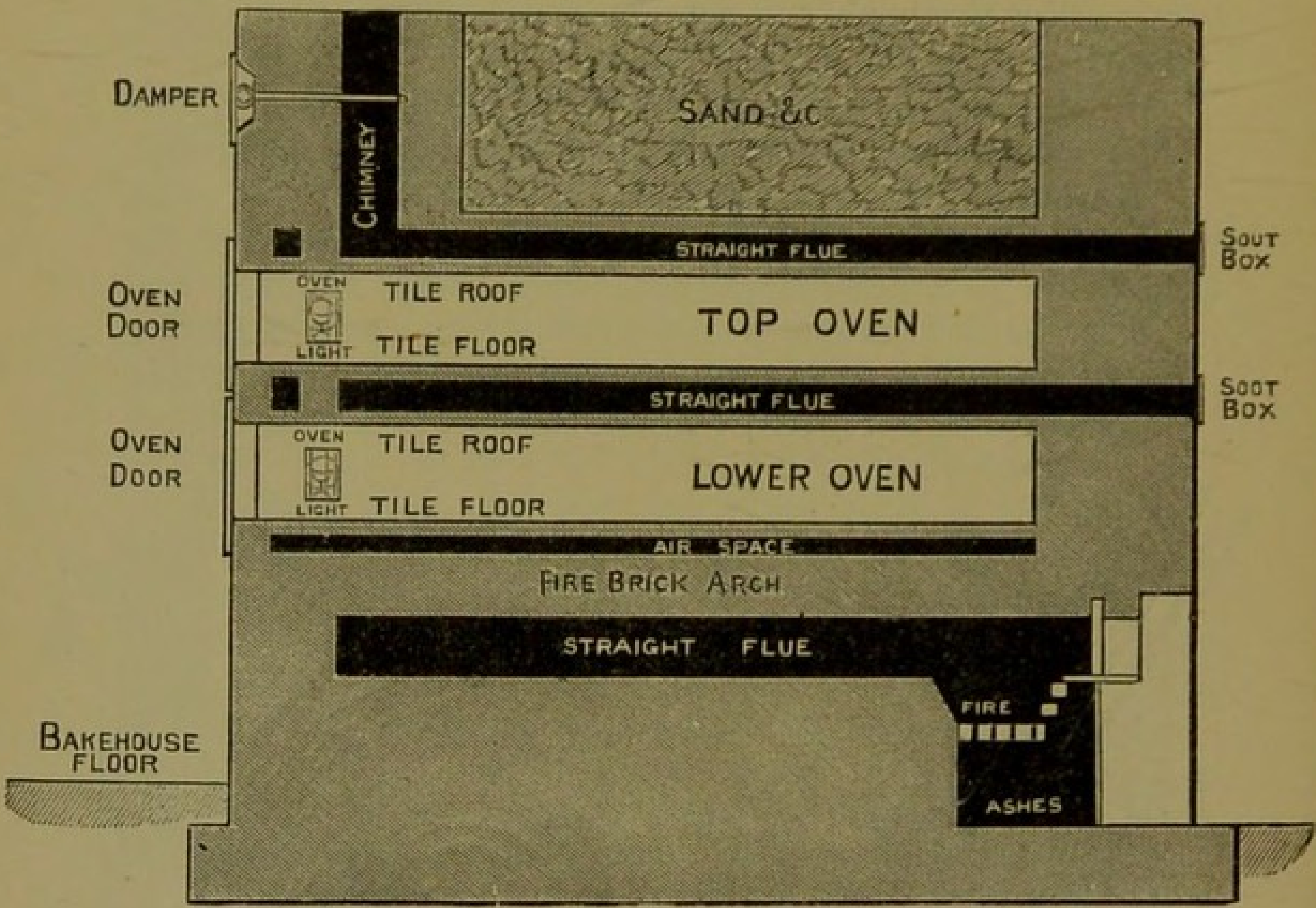


FIGURE 46.—GEEN'S HYGIENIC OVEN.

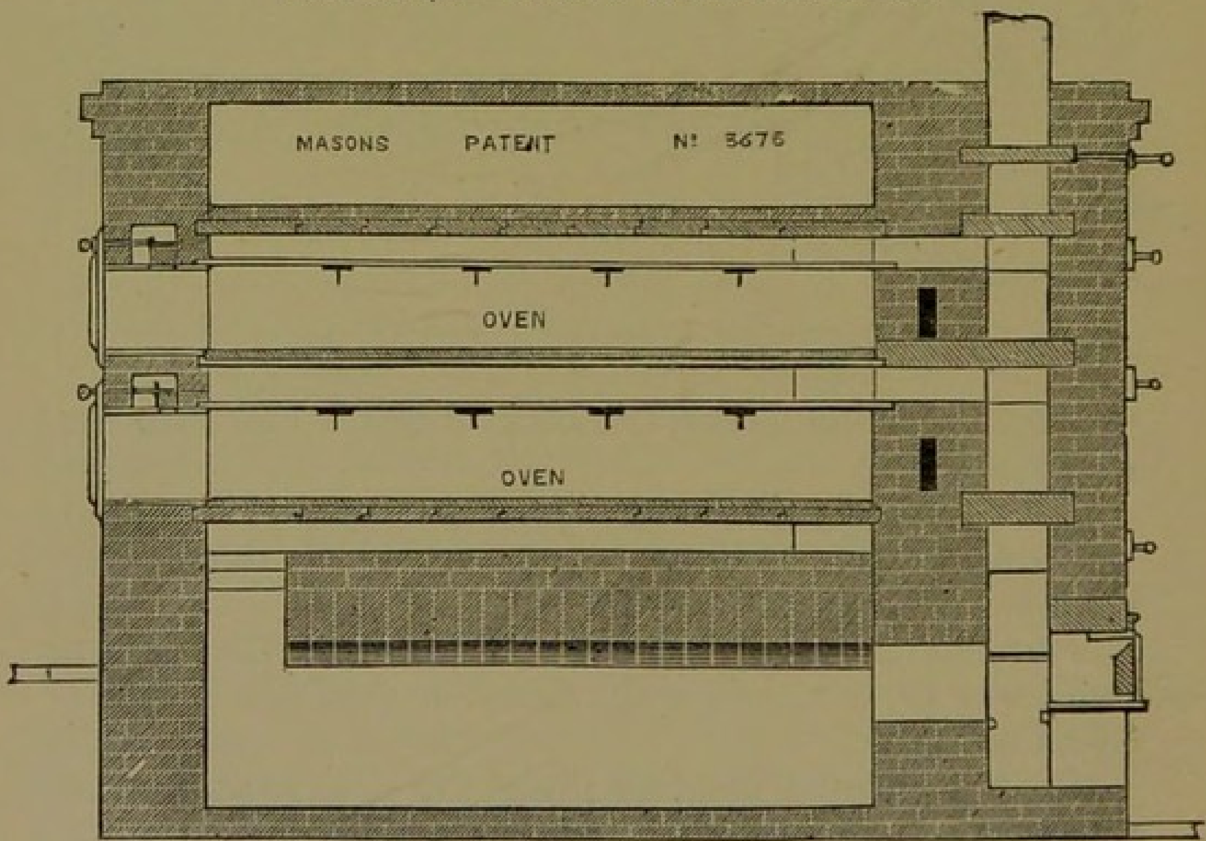


FIGURE 47.—MASON'S HOT-AIR OVEN.

(where the two flues join), and returning by the single flue down the centre to the front again. The hot air is then conducted to the crown of the upper oven (the arrangement of flues being similar to that between the two ovens), and finally passes out by the chimney. The passage of the heated gases outwards is regulated by means of a damper. The flues are all straight and easily cleaned, and the furnace is placed at the far end of the right side. They are continuous and will burn either

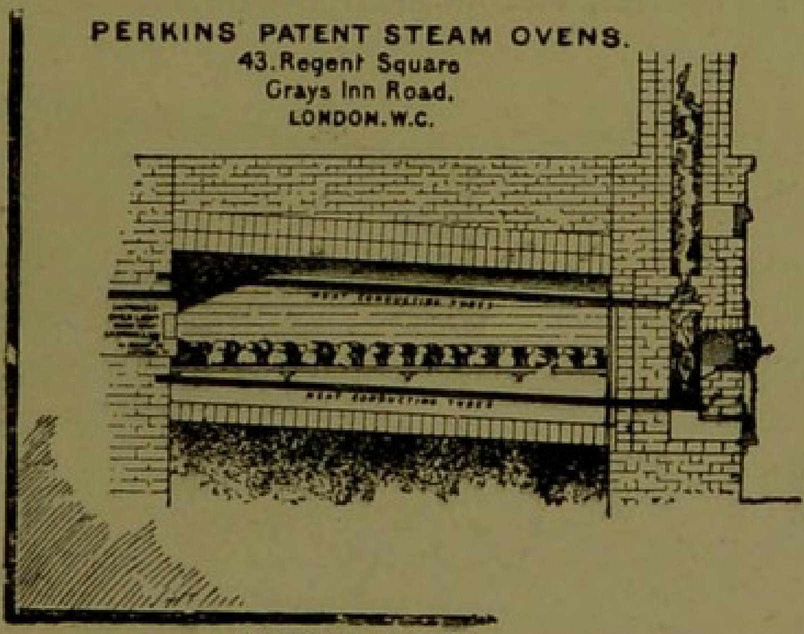


FIGURE 48.—PERKINS' STEAM OVEN.

coke or coal without smoke. The arrangements admit of "flash" heats at will, and when properly fired the upper oven is never appreciably cooler than the lower one.

Mason's Hot Air Oven.—In this oven the furnace is placed at the base, and may be at the side, front, or back.

The heated gases from the furnace first pass through a main flue and come in contact with the oven sole in front, and then pass to the back. They are then conducted between the ovens, and finally pass over the roof of the upper oven, and thence to chimney. There is an air-space between the back of the oven and the furnace, preventing the direct radiation of heat from the furnace. By special arrangements and the use of dampers, the heat may be directed to different parts of the oven as needed, and is thus under the direct control of the baker. The ovens are continuous, and both ovens are nearly of the same temperature, when properly fired and managed.

Perkins' Steam Oven.—The baking chamber is heated by super-heated steam contained in strong pipes.

The furnace is constructed at the back of the oven, and, as in Mason's, there is an air space between the furnace and back oven to prevent the passage of direct heat from the fire to the oven. The steam-pipes are arranged in parallel series, one under the oven sole and the other

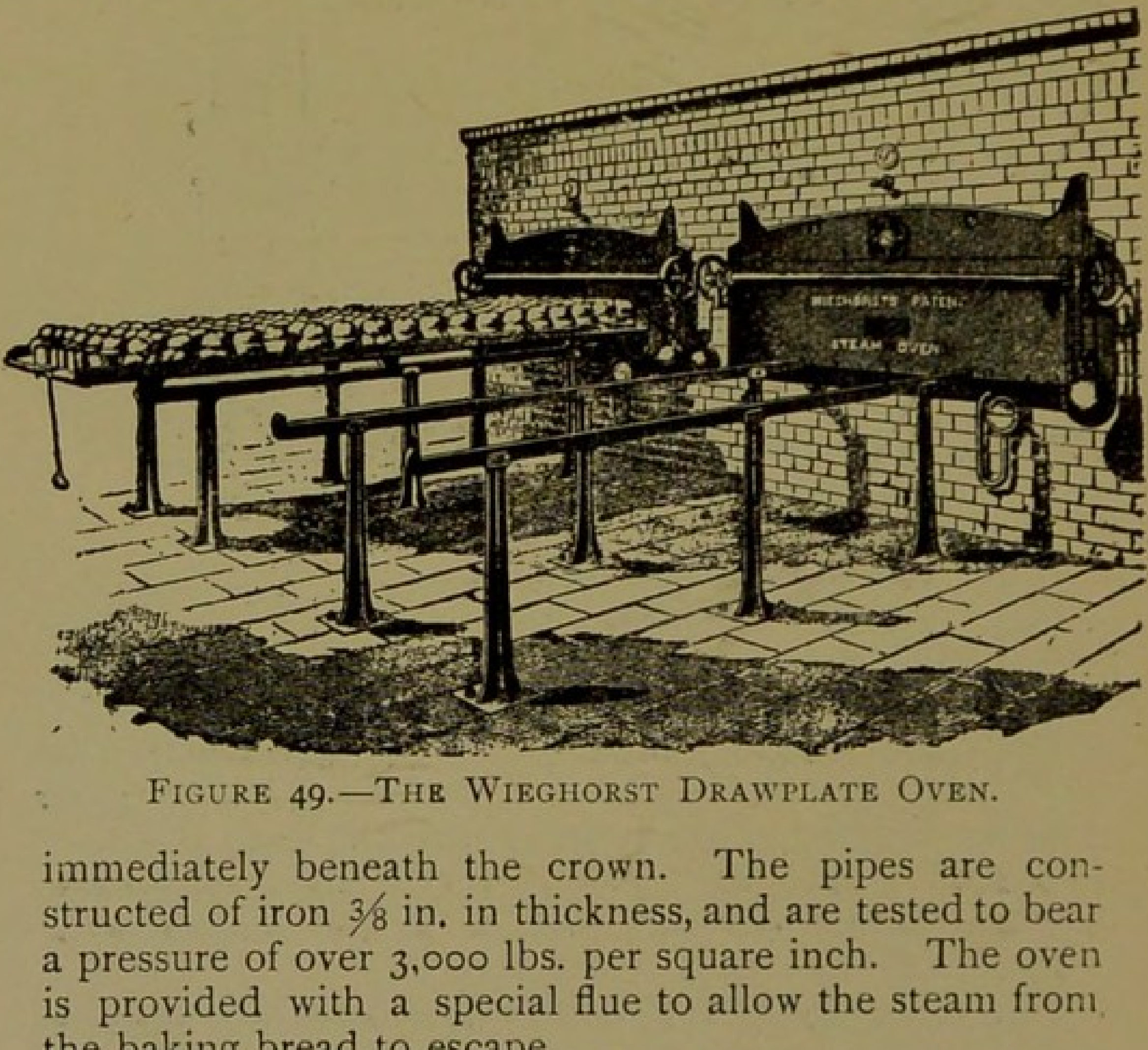


FIGURE 49.—THE WIEGHORST DRAWPLATE OVEN.

immediately beneath the crown. The pipes are constructed of iron ⅜ in. in thickness, and are tested to bear a pressure of over 3,000 lbs. per square inch. The oven is provided with a special flue to allow the steam from the baking bread to escape.

The Wieghorst Drawplate Oven is shown in Figure 49, and will give a general idea of the character of such ovens. On the right the oven is charged, while on the left the batch has just been withdrawn. The plate, it will be observed, travels on a stationary framework.

CHAPTER XVIII.

CHANGES EFFECTED IN DOUGH BY BAKING, STERILISATION IN OVEN, TRANSMISSION, COOLING AND STORING OF BREAD.

DURATION of Baking Process.—The time necessary to properly bake bread depends on the temperature of the oven and the kind of loaf. Large loaves like quarterns require a longer period than smaller ones, but generally speaking the bread is ready in from forty to sixty minutes in good ovens.

Temperature.—Much difference of opinion exists as to the exact temperature of loaves while in the oven, and doubtless it varies, according to the size and form of the loaves. Generally speaking the smaller the loaves, the higher will be the internal temperature, and *vice versa*. The author in a series of careful experiments obtained the following results (specially constructed maximum thermometers were used in the tests):

TEMPERATURE OF LOAVES WHILE IN OVEN.

Series I.—QUARTERNS.

Temperature on F. Scale.

Oven.	Centre.	½ in. from Crust.	Crust.
485°F.	195°F.	218°F.	305°F.
496°F.	198°F.	220°F.	320°F.
468°F.	189°F.	212°F.	304°F.

Series II.—HALF QUARTERNS.

Oven.	Centre.	½ in. from Crust.	Crust.
492°F.	204°F.	246°F.	318°F.
518°F.	209°F.	252°F.	328°F.
485°F,	202°F.	232°F.	306°F.

From these results it may be concluded that the temperature decreases from the crust to the centre, and that the smaller the goods, the higher the temperature of the central portions.

Everywhere in the loaf the heat is sufficient to gelatinise the starch, and coagulate the albuminoids, and in the outer portions to convert starch into dextrin, and probably at times the temperature of the more external portions of crust rises sufficiently high to convert the sugar present into caramel.

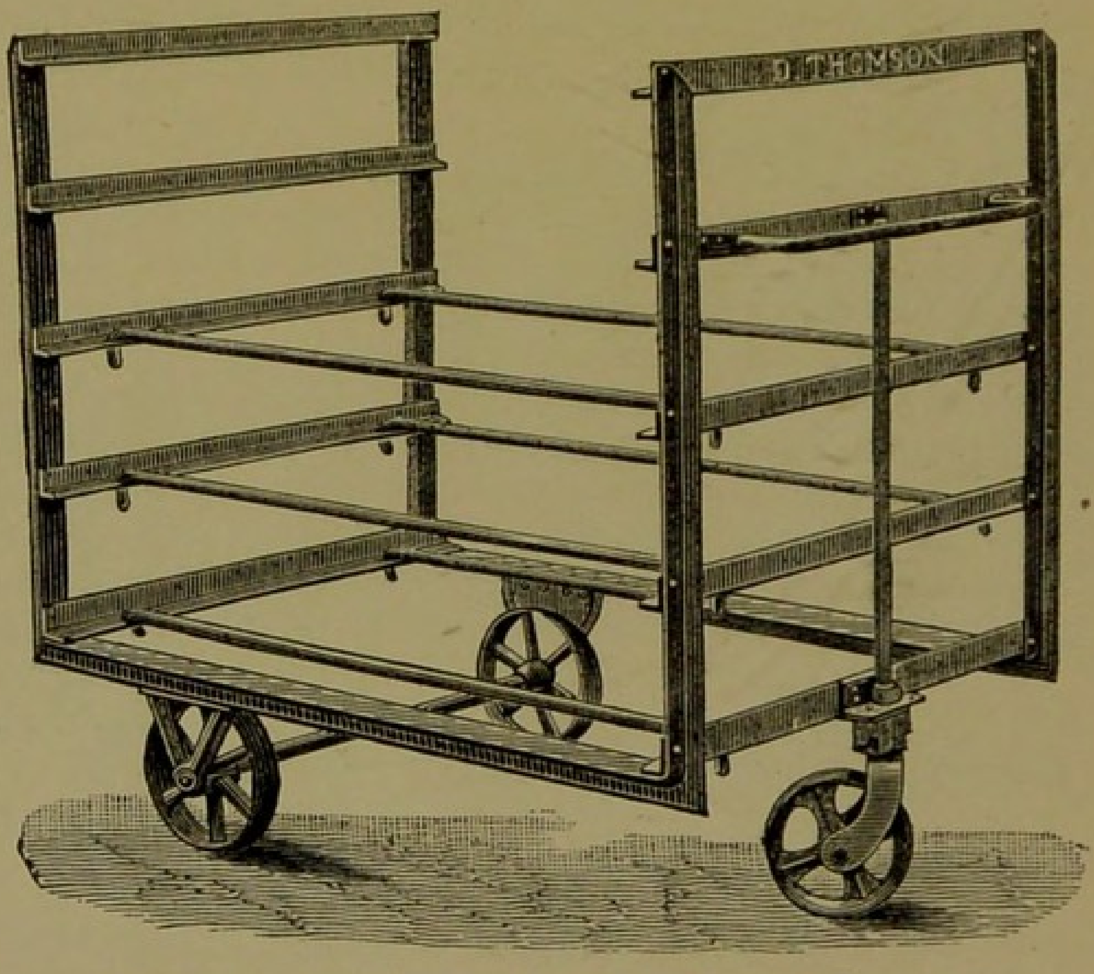


FIGURE 50.—THOMSON'S PORTABLE BREAD CARRIAGE.

The heat of the oven vapourises a portion of the moisture of the loaves, and the steam so generated soon reaches the temperature of the oven itself; consequently the exposed surfaces of the loaves are bathed in superheated steam, which brings about dextrinisation of the starch and other changes.

Summarising the changes we may say:

(1) The albuminoids are coagulated.

(2) The starch is gelatinised.

(3) Part of gelatinised starch is converted into dextrin (mainly in crust).
(4) Part of sugar changed into caramel (in crust).

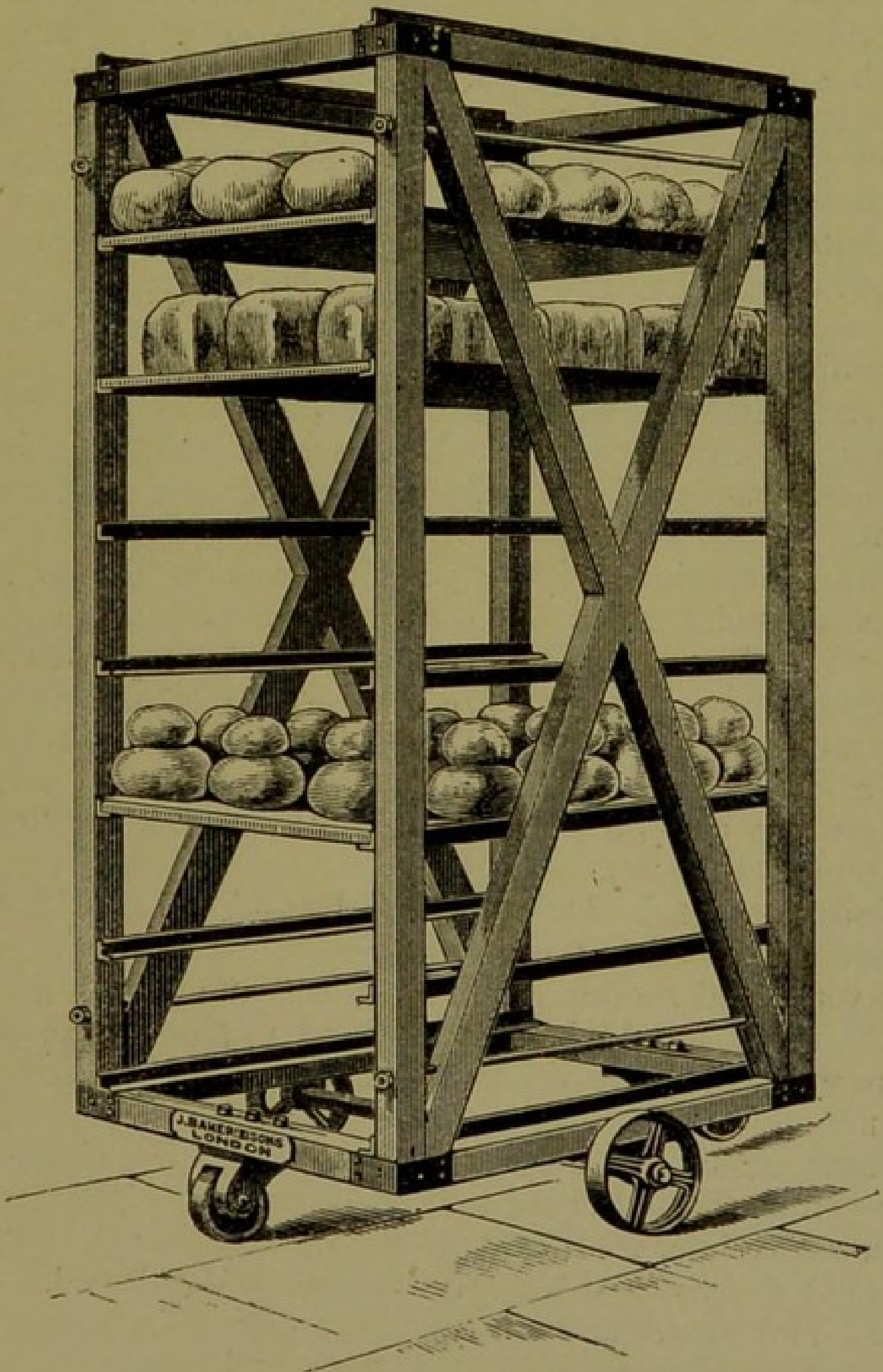


FIGURE 51.—BAKER'S MOVABLE BREAD TRUCK.

(5) The flavour is altered.
(6) Moisture is driven off.

Sterilisation of Bread in Ovens.—Some writers urge that the temperature of the centre of loaves while in the oven is not sufficient to completely sterilise the mass, but from the results of a carefully planned series of experiments with various microbes in dough, details of which will appear in the proper channels, the author has come to the conclusion that most of the micro-organisms in dough are destroyed during the baking process, not so much by the heat alone, but by the nature of the soil in which they are subjected to the temperature. Dough at any temperature above 200°F is practically sterilised, and the fear that disease germs survive the baking process is groundless.

Transmission of Bread.—Bread trucks are most convenient accessories to a bakehouse, and greatly facilitate the conveyance of the loaves from the oven to storing room.

The illustration (Figure 50) gives a good idea of the nature of such a truck. It is 4 ft. 6 in. in height, 4 ft. long and 3 ft. wide, with ledges 9 ins. apart for boards, allowing plenty of free air space. Another form of bread truck is illustrated in Figure 51. It is constructed of oak with angle iron rests for the insertion of bread boards. The shelves are far enough apart to allow free circulation of air round the loaves.

Cooling and Storage of Bread.—The loaves should be cooled as rapidly as possible and stored in dry, well ventilated rooms. It is most important that the air of the room should be free from all unpleasant smells, as new bread is very absorbent and rapidly takes up odours.

Summarising we may say that the chief differences between fermented bread and the flour from which it has been made, from the dietetical standpoint, are:

(1) A distinct and pleasant flavour is developed.

(2) The bread is rendered more digestible, owing to the gelatinisation of the starch and aeration of the loaf.

Part III.

Bread.

CHAPTER XIX.

WHITE BREAD.

BREAD, the finished product of the baker's work, is distinguished from most foods by its digestibility, and the remarkable fact that it does not produce satiety. Bread of good flavour can be eaten at every meal and never palls on the palate like other foods.

This remarkable property, however, does not depend entirely on flavour, but is no doubt connected with the diverse nature of the food stuffs and the digestibility of the constituents.

Bread contains some representative of each division of the main group of food principles, though some of them are only present in small quantities.

Composition.—The following table gives the mean of many analyses of white bread, and may be taken as representing the average composition of ordinary white bread:

WHITE BREAD.

PROXIMATE PRINCIPLE.	FOOD STUFFS.	PERCENTAGE.
Water	Water	37·21
Proteids	Gluten and Albumin	7·65
Carbo-hydrates	Starch	46·46
	Dextrin	3·05
	Sugar	3·82
Fat	Palmitin, Olein	·88
Ash	Salts of Potash, Soda, etc.	·93
		100·00

It will be seen from the table that bread contains all the necessary constituents to support life, but as will be pointed out immediately they are not in the correct proportion.

White Bread differs chiefly from wheat in the following points :

(1) It contains more starch.

(2) It contains less proteids, fat, fibre, and mineral matter.

Digestibility.—Bread when properly manufactured is one of the most digestible mixed foods known. The processes of fermentation and baking so thoroughly break down the constituents that they are rapidly and thoroughly digested by the organs of digestion. The starch granules in bread are completely disintegrated and gelatinised, and they form with the gluten a peculiar combination which is remarkably sensitive to the action of the digestive fluids.

New bread is not so digestible as stale bread, and fermented bread is more easily digested than that raised by mechanical aeration or by the use of baking powders.

Waste.—White bread is a very economical food. Under normal circumstances quite 96 per cent of white bread is assimilated by the human organism.

Food Value.—Bread is a most valuable food on account of its digestibility and the variety of its constituents. But it is not a perfect food alone. The following table will show clearly in what respects white bread falls short of a perfect food. In the first column the constitution of a normal diet is given, and in the second the quantities of the same bodies yielded by white bread :

	Normal diet (adult).	White Bread.
Proteids	4·50 ozs.	2·8 ozs.
Carbo-hydrates ...	14·25 „	19·2 „
Fat	3·00 „	·3 „
Ash	1·00 „	·4 „

The table shows that white bread is deficient in :

(1) Proteids (flesh forming), fat and ash.

(2) That it contains a surplus of carbo-hydrates (starch, &c.).

A careful analysis of the ash of white bread reveals the fact that it is poor in phosphoric acid.

These deficiencies in white bread have led millers bakers, and others to investigate the whole subject, with the result that many patents have been filed with the object of improving our national food in these respects, either by including the bran and germ in the meal, or by adding the germ separately, and many bakers increase the food value of their bread by adding from 2 lbs. to 3 lbs. of pure fat to each batch.

Not only does the addition of fat to the bread enhance its food value, but from experiments in which the butter substitute known as Santilin was used, the author found that it improved the appearance and keeping qualities, and rendered the crust crisp.

White bread is hardly a suitable food for infants below the age of nine months, as it contains far too much starch—a food stuff which the digestive organs of a young infant do not readily digest and assimilate.

Some authors condemn the use of white bread because it is not a perfect food, but such condemnation is absurd. An apple is not a perfect food, and yet everybody admits that apples are most desirable in a diet. The important point is that white bread should be eaten with foods which are *poor* in carbo-hydrates and rich in proteids, and that fat in some form should be added. Thus bread with cheese and butter in suitable proportions forms a perfect diet, and bread with fat meat forms the main support of our stalwart soldiers. At the same time, however, it must be admitted that inasmuch as bread forms the staple food of thousands of the working classes and their children, much good may be done by increasing its nutritious and digestive qualities.

Flavour.—The flavour of fermented bread is very complex but exceedingly pleasant, and is influenced by the kind of flour and yeast used, and the method of bread-making followed. Most people prefer a slightly sweet taste in bread, but the fact that Scotch bread is slightly acid proves that a piquant flavour, if not too pronounced, may be appreciated. The flavour of unfermented bread is somewhat crude, and more simple in character than that of bread raised by yeast. The proportions of Hungarian and such-like flours largely influence flavour, and the use of malt extracts, yeast foods, &c., produces characteristic changes in the taste, which many people regard as improvements. The baker cannot pay too much attention to flavour. A good flavour in bread is often the foundation of a flourishing business. The crust is different in flavour to the crumb, owing to the presence of dextrin and caramel.

Staleness is characterised by a gradual hardening of the loaf and a change of flavour. It is accompanied by an evaporation of water. Staleness is not, however, entirely due to the loss of moisture, as a stale loaf may be partly restored to its original condition by subjecting it to the temperature of the baker's oven for a short time.

It is probable that the evaporation of moisture is accompanied by obscure molecular changes.

CHAPTER XX.

WHOLEMEAL BREAD.

OF late years an enormous demand has sprung up for brown bread, on account of its supposed superiority to white bread in nutritive and digestive qualities, and most bakers include a fair proportion of wholemeal goods in their weekly sales. Wholemeal is prepared by reducing the *whole grain* to varying degrees of fineness, so that it contains the bran and germ. From the analyses given in Chapter V. it would appear that wholemeal is certainly more nutritious than white flour, but there are other considerations which make it doubtful whether wholemeal is in all cases a desirable food.

Composition.—The composition of wholemeal bread varies considerably according to the kind of wheat used in its preparation. But the following analysis may be taken to represent the average, and for the purposes of comparison the composition of white bread is also given.

The meal employed was the Pure Imperial Wholemeal, specially milled by Young & Wright, of Ponder's End Mills, for the production of *fine* wholemeal bread.

	Wholemeal Bread. (Made from Wright's Meal.)	White Bread.
Water	40·25	37·21
Proteids	11·85	7·65
Carbo-hydrates ...	42·93	53·33
Fat	1·63	·88
Fibre	1·89	·—
Ash	1·45	·93
	100·00	100·00

From the table it will be gathered:

(1) That wholemeal bread is richer in proteids, fat, ash, and fibre than white bread.

(2) That it is poorer in carbo-hydrates than white bread.

Wholemeal bread contains slightly more sugar and dextrin than white bread, and the ash is richer in alkaline phosphates. It also holds water more freely, and therefore keeps moist longer than white bread.

Digestibility.—The ratio of digestibility largely depends on the lightness of the loaf and the fineness of the bran particles. Wholemeal bread, unless very carefully made, is liable to become sodden and heavy, and in this condition wholemeal is very indigestible. But if properly aerated and composed of *fine* meal, it is more digestible than white bread, and may act beneficially as a healthy stimulant to the activity of the digestive organs. The general remarks on the digestibility of white bread apply equally to wholemeal.

Waste.—Wholemeal bread is more wasteful than white bread, inasmuch as it contains considerably more of the indigestible fibre. Further, the presence of the indigestible bran particles may lead to an increase of the waste of other foods. From the results of careful experiments, details of which are given in the author's "Dietetic Value of Bread," pages 185-200, the author has come to the conclusion that the waste in wholemeal bread largely depends on the size of the bran particles.

The following table gives the waste in the various breads:

White bread	4 per cent.
Very fine wholemeal	9 "
Ordinary "	12 "
Coarse "	16 "

The coarser the wholemeal the greater the waste.

Food Value.—The value of a food is not always indicated accurately by chemical analysis. A better and more reliable method is to gauge the value by the quantity assimilated and the general action of the food on the economy.

Taking ordinary wholemeal, the results of the author's experiments may be summarised as follows:

(1) Wholemeal bread is not a perfect food, but is deficient in proteids, fat, and mineral matter; but it is more nearly a perfect food than white bread.

(2) Where the bran particles are large and coarse, the wholemeal bread is inferior to white bread as a food.

Wholemeal bread has been popularly vaunted as a safe remedy for constipation, and as a healthy stimulant to the digestive organs.

The aperient effects of wholemeal are due to the action of the indigestible bran particles on the delicate mucous membrane which lines the intestinal tract, whereby the local nervous centres and involuntary muscles are stimulated by the mechanical action of the bran ; and there can be no doubt that wholemeal bread acts vigorously in this direction. But it is a question whether such action is always desirable or beneficial, and the author has come to the conclusion that, if the action be carried too far, great harm results to the delicate absorptive surface of the intestines. Summing up, and taking Wright's Imperial Meal as a standard, we may say that *very fine* wholemeal bread is certainly a gentle aperient, and is a very valuable aid to digestion, and yields to the body a greater percentage of phosphates, proteids, and fat than white bread ; but *coarse* wholemeal is to be severely condemned as an irritating food, leading to a waste of other food, and to an abnormal condition of the inner membrane of the bowels.

It is quite a mistake to suppose that all the phosphates of the bran are extracted during the processes of digestion. As a matter of fact, only a small proportion are capable of being assimilated.

Flavour.—This is especially important to the baker in the case of wholemeal bread, as it is very difficult to produce finely flavoured brown bread. In the first place, wholemeal has a distinct flavour, quite different to white bread, and this is largely modified by the method of bread-making followed, and *the size of the bran particles.* Coarse bran entirely spoils the flavour of wholemeal bread, and therefore bakers would do wisely to use the *finest* wholemeal in the manufacture of brown bread.

Wholemeal does not readily lend itself to yeast fermentation, and many bakers find that the best loaf for texture is produced by using acid and soda, but in this case the flavour is not so good as if yeast had been used.

The author has found that good results accrue when a yeast food is employed in conjunction with quick fermentation.

CHAPTER XXI.

DECORTICATED BREAD, GERM BREADS, MALTED BREADS.

DECORTICATED Bread.—The meal employed in the manufacture of this kind of bread is milled from wheat in which the outer layers of the bran have been removed. Consequently the resulting bread is not so aperient in its effects as wholemeal, and contains less indigestible matter in the form of fibre. The following table gives an analysis of decorticated bread made from a sample of meal milled by a new process by Marshall & Son, of Great Grimsby, and may be taken as a type of what such bread should be.

	Decorticated Bread.
Water	40·25
Carbo-hydrates ...	43·74
Proteids	11·95
Fat	1·71
Fibre	1·12
Ash	1·23
	100·00

As a rule decorticated bread possesses a better flavour than the wholemeal variety.

Germ Breads.—For various reasons, chief among which are fermentive actions, and the tendency of the fat to become rancid, the germ of wheat is rejected by millers in the production of white flour, as its presence in the normal condition leads to a deterioration in the market value. The high nutritive value of the germ is shown in Chapter V. and it is important to note that the ash consists mainly of phosphates. Various successful methods are now employed whereby the ferments of the germ are destroyed, without injuring in any way the nutritive qualities, heat being generally employed as the destroying agent. The name of Mr. Richard Smith is intimately associated with the first successful attempt to treat the germ on a commercial basis, and since the advent of his patents numerous other methods have been invented.

Hovis Bread is manufactured from a special meal made by mixing one part of germ prepared according to Mr. Richard Smith's process, with three parts of flour by weight, and adding sufficient salt to obviate the necessity of the baker adding the latter ingredient. The bread is highly nutritious, and when properly made, possesses a delicious flavour. It possesses aperient qualities, without the slightest danger of irritation, the cellulose being of a very fine nature and evenly distributed through the meal.

The following is an analysis of Hovis bread compared with wholemeal and white bread:

	Hovis.	Wholemeal.	White.
Water	40·25	40·25	40·25
Proteids	13·21	10·83	7·48
Carbo-hydrates ...	41·82	43·95	50·66
Fat	2·38	1·63	·78
Fibre	·85	1·89	—
Ash	1·49	1·45	·83
	100·00	100·00	100·00

Cytos Germ Bread is made from Cytos meal prepared by Best's process. The process is a trade secret, but the distinguishing feature of the meal is that a proportion of finely ground malt is incorporated, so that not only are the nutritive qualities due to the presence of the germ obtained, but the properties of malt bread are also secured. The meal contains 25 per cent. of germ. The following is the analysis of Cytos bread compared with those of white and wholemeal:

	Cytos.	Wholemeal.	White.
Water	40·25	40·25	40·25
Proteids	13·32	10·83	7·48
Carbo-hydrates ...	41·68	43·95	50·66
Fat	2·36	1·63	·78
Fibre	·87	1·89	—
Ash	1·52	1·45	·83
	100·00	100·00	100·00

Cytos bread is characterised by a high proportion of soluble carbo-hydrates due to the presence and action of the malt.

Germ Rye Bread is a combination of germ with flour and rye prepared by a secret process, the invention of Mr. Wilkins, of Lea. It does not differ materially in composition from the analyses already given, in the proportions of the main food principles, but it possesses a characteristic flavour due to the inclusion of rye meal. All germ breads are characterised by a high nutrient ratio, and a distinct flavour, but they require to be made with great care in order to produce the best results. Bakers who make germ bread would do well to carefully follow the instructions given with the particular meal, as often the grand nutty flavour is entirely lost by variations in the method of manufacture. There can be no doubt that germ bread when properly made possesses digestive qualities far beyond those of ordinary bread, and the enormous increase of the sale of such bread during late years is sufficient evidence that the public are fully alive to these advantages.

Malted Breads.—In the manufacture of these breads malt extract or some preparation containing diastase is employed. The general character of composition of malt extracts are given in Chapter VIII. and the action of diastase in Chapter XI.; therefore it only remains to discuss here the actual effects of malt extract on the dough, and the general characters of the bread produced.

In conjunction with Jago the author made some experiments on the actual effect of diastase on panary fermentation, the final results of which are summed up below. In the experiments Montgomerie's pure malt extract was employed. Three breads were examined, made according to the following methods:

(1) By the ordinary method without the use of malt extract.

(2) By the ordinary method, with the addition of malt extract at the doughing stage.

(3) By *Montgomerie's method.*

In the latter method a *portion* of the total flour to be worked is mashed at a temperature of 140-150° F. with malt extract for some hours, and the malted mixture added to the rest of the flour at the doughing stage.

The essential differences between these various modes of bread-making are, that in the first case, *no* malt extract is used; in the second it is added to the *whole* of the dough which works at a temperature of about 80°-90° F. as a *stiff* mixture. In the third the malt extract is added to a *slack* mixture made with *part* of the flour and allowed to work at about 150° F. for some hours, and then the mass added to the dough.

The chief object was to ascertain whether the malt extract converted any of the starch into maltose by diastasic action, and if so, the general proportion.

The following is an extract from the full table, showing the amount of maltose due to conversion of the starch:

	No. I. Plain.	No. II. Malted.	No. III. Montgomerie's.
Total maltose ...	1·02	9·11	14·23
Maltose in flour and introduced in extract ...	—	7·05	7·05
Nett maltose due to diastasis ...	—	2·06	7·18

It will be observed that the greatest proportion of nett maltose was produced by Montgomerie's process. In the next table the comparative amounts are given for biscuits:

	No. II. Malted.	No. III. Montgomerie's.
Total maltose	8·61	18·46
Maltose in flour and introduced in extract	0·00	10·00
Nett maltose due to diastasis	0·00	8·46

The last results agree with those in the first table, but point to the conclusion that malt extract added as in Method II. in the doughing stage, does not work very actively until it reaches the oven, the time being limited to that occupied by the raising of the dough from 90° F. to 170° F. In the case of *bread* this period may vary from ten to twenty minutes, and therefore a certain amount of diastasis goes on in the oven, but in biscuits the time is so short that practically the diastase is destroyed before it has time to effect any change in the starch. It appears that to get the full benefit of the use of malt extract it is necessary to mash for some time in a slack mixture at a temperature at or near the gelatinisation point of wheaten starch, as in Montgomerie's method, so as to give the diastase favourable conditions under which to work.

It is probable that the slow action of malt extract in ordinary doughs is due to:

(1) The starch granules are not gelatinised.
(2) The mixture is stiff.
(3) The temperature is low.

Note.—The diastase of ordinary malt extract does not act vigorously on raw starch.

The amount of starch converted, however, depends to some extent on the quantity of diastase present, and such an extract as Fletcher's, which has a very high diastasic value, will effect a greater diastasis of starch in the oven than ordinary malt extract. Where strong extracts are used it is important for the baker to carefully watch the dough, as if too large a quantity be employed the dough runs and "falls off."

Summing up the results the author has come to the following conclusions regarding the use of malt extract for bread-making purposes:

(1) Malt extract used as described above does produce diastasis of part of the starch.
(2) That mashing under Montgomerie's process produces better results than by simply adding malt extract to the dough.
(3) The higher the diastasic power of the extract the greater the conversion of starch into maltose, but the increased conversion is not in the same ratio as the increased value on Lintner's scale.
(4) Malt extract tones down hard flour.
(5) It quickens fermentation.
(6) It influences the flavour of the bread.

The percentage of starch converted in the ordinary method of malting averages from 4 to 6 per cent., and from 14 to 18 per cent. in Montgomerie's process.

When diastase extract is used in the ordinary method, the percentage is considerably higher than the first figures quoted.

Malted bread has a higher dietetic value than ordinary bread. On account of the great proportion of assimilable bodies present it is distinctly more digestible, and if properly made possesses a better flavour.

The following table gives the composition of Montgomerie's malt bread beside bread made by the ordinary method:

	Malt Bread (Montgomerie's).	Ordinary.
Water	39·62	39·62
Proteids	9·21	9·08
Starch	29·24	41·13
Sol. Carbo-hydrates ...	18·28	6·31
Fibre	1·02	1·12
Fat	1·01	1·02
Ash	1·62	1·72
	100·00	100·00

CHAPTER XXII.

AERATED BREAD, LIMEWATER BREAD, MILK BREAD, GLUTEN BREAD, VIENNA BREAD.

AERATED Bread.—The mechanical aeration of dough was first introduced by Dr. Dauglish. The process essentially consists of preparing a solution of CO_2 in water under great pressure, and employing the solution in special receivers to make the dough. The pressure is maintained in the doughing machines, so that when the dough escapes the imprisoned gas expands and thoroughly aerates the mass.

Formerly the CO_2 was obtained by acting on limestone with sulphuric acid according to the following equation:

$CaCO_3$	+	H_2SO_4	=	$CaSO_4$	+	H_2O	+	CO_2
Lime.		Sulphuric acid.		Calcium sulphate.		Water.		Carbon di-oxide.

Lately *liquid* CO_2 stored in strong cylinders under enormous pressure has been used.

Aerated bread usually possesses a good colour and even texture, and contains slightly more proteid material than fermented bread.

The flavour however is not nearly so complex as that of fermented bread, and after standing for twenty-four hours resembles the crude taste of baked flour and water. The bread is usually sweet and the danger of the souring fermentations is reduced to a minimum. The aeration process is perhaps most successful when employed in the manufacture of wholemeal bread.

Limewater Bread.—Many bakers employ limewater in the manufacture of bread. Limewater is a solution of lime, and may be prepared by adding water to quick-lime, and allowing it to stand for some hours. The clear supernatant solution is limewater, and may be carefully drawn off for use.

The following equation gives the change:

$$\underset{\text{Quicklime.}}{CaO} + \underset{\text{Water.}}{H_2O} = \underset{\text{Limewater.}}{CaH_2O_2}$$

Usually from 4 to 6 gallons per sack are employed.

The best known process in which limewater is largely used is that patented by Mr. Hugh Black, of Rothesay, whereby part of the starch is removed from the flour, and the nitrogenous ratio thus raised in the bread.

The other effects of limewater on the dough are:

(1) It retards diastasis of starch.
(2) It stiffens the gluten.
(3) It tends to whiten the bread.
(4) It prevents sourness.

Great care must be taken that no excess of limewater is added to the dough, as carbonate of lime is formed by the action of the CO_2 on the lime as follows:

$$\underset{\text{Limewater.}}{CaH_2O_2} + \underset{\substack{\text{Carbon} \\ \text{di-oxide.}}}{CO_2} = \underset{\substack{\text{Carbonate} \\ \text{of lime.}}}{CaCO_3} + \underset{\text{Water.}}{H_2O}$$

Milk Bread.—Separated milk, or even whole milk, is often used by bakers in the preparation of bread, and sometimes sour milk is employed where powder is used to raise the bread. Usually only small batches are made, the bread being sold as a speciality. The chief effects of milk are to produce a blander flavour, and to increase the nourishing properties of the bread. As milk bread contains considerably more flesh-formers, fat and phosphates, than ordinary bread, it may be safely advertised by bakers as specially suitable for children.

Gluten Bread and Biscuits.—This variety of bread is specially manufactured for the use of individuals suffering from the disease known as diabetes mellitus.

This disease is characterised by an excretion of sugar in the urine, and is connected in some way with the glycogenic function of the liver. Most medical authorities forbid starch or sugar in any form in the diet of those suffering from the disease; hence it is important that gluten bread should be free from those food stuffs.

Gluten bread may be made as follows: Select a very hard flour and form a stiff dough with water not employing yeast. Allow the dough to stand for about a hour, and then take up a small piece, enclose in a muslin bag, and knead under water until the water ceases to be discoloured by the process. This operation removes the starch and sugar from the dough. The glutenous dough may now be shaped and baked in the ordinary way. Gluten swells enormously in the oven, therefore only *small* pieces of dough should be taken.

The best form of gluten food is the biscuit. Gluten bread and biscuits are enormously improved by the incorporation of finely-ground nuts (chestnuts are not suitable), the best being perhaps the almond, and the addition of a little fine bran thoroughly freed from starch by washing, is also desirable. Usually, however, it scarcely pays a baker to prepare gluten flour or bread just for one or two customers, especially as gluten flour and its products may be bought in the market. Messrs. Bonthron and Co., of Glasshouse Street, Regent Street, London, the well-known specialists on diabetic food, supply gluten flour, bread and biscuits of various kinds, and from personal analyses the author can say that the flour and goods are as free from starch and sugar as possible. Bakers who have their ordinary business to look after, and have, therefore, little time to spare for the preparation of gluten flour, and who do not possess special plant, cannot hope to produce so palatable and suitable diabetic food as the firm who has made it a speciality. (For fuller details the reader is referred to "The Dietetic Value of Bread," pages 273-280, and to the author's pamphlet on Diabetes.)

Vienna Bread is the term applied to rolls and bread in fancy shapes, and made from the very best flour without the aid of potatoes or ferments. Usually milk is added, and often small quantities of butter or other fat is employed to improve the general appearance and flavour. Special ovens are sometimes employed, in which arrangements are made for the admittance of steam to produce the well-known glaze characteristic of Vienna bread and rolls.

The following description and analysis will give some idea of the general properties of Vienna bread.

The bread was made with the well-known M.B.D. brand of Hungarian Patent supplied by Mr. C. Waydelin, with milk, butter and compressed yeast.

The flour gave 33·21 per cent. of moist gluten and a yield equal to 103 quarterns per sack.

The analysis gave the following results:

Water	37·21
Proteids	9·89
Carbo-hydrates	50·41
Fat	1·67
Ash	·82
	100·00

There is such a vast field for novelty in the manufacture of bread that it is not surprising that a large number of special breads are on the market, and that many bakers depart from the usual methods of breadmaking with the object of improving the quality of their goods.

CHAPTER XXIII.

DISEASES OF BREAD AND ABNORMAL CONDITIONS.

SOUR Bread is the name given by bakers to bread which has a decided sour smell and acid reaction, and must carefully be distinguished from normal *acidity*.

When broken and the nose applied, the loaf gives off a characteristic sour odour, and the flavour is unpleasant as well as distinctly acid, owing to putrefactive changes.

Acids of Sour Bread.—There is a wide divergence of opinion as to the proportions of the various acids found in sour bread. Most authorities agree that lactic, acetic, and sometimes butyric acid are present, but there is no agreement among experts as to the proportions.

Jago states that the acids are present in the following proportions:

Lactic acid...	95·0 per cent.
Acetic acid...	5·0 "
Butyric acid (rarely) ...	·05 "

Briant states that the proportions are roughly:

Lactic acid	75·0 per cent.
Acetic acid	25·0 "
Butyric acid	Traces.

The author's researches on the subject confirm the statements of Jago that lactic acid invariably forms the main bulk of the acid of sour bread, and he has never found more than 4 per cent. of acetic acid in ordinary sour bread. In many cases, *acetic acid* was found only in traces.

Formation of Acids.—The acids of sour bread are formed chiefly from the sugar by bacterial fermentation. Lactic acid is formed by the B. Lactis from dextrose, and the butyric acid by further fermentation from the lactic acid. When acetic acid appears, it is formed from the alcohol by oxidation. (See Chapter X.)

Causes of Sour Bread.—The immediate cause of sour bread is of course bacterial fermentation, and therefore anything which introduces the souring organisms into the dough may be reckoned as one of the causes of sour bread. The bacteria are introduced in the following way:

(1) By flour.—(The most important agent. Inferior flour more so than the best quality.)

(2) By the yeast.—(Unsound yeast is a fruitful cause of sour bread.)

(3) By pieces of stale dough clinging to vessels, troughs, &c., containing the souring ferments.

(4) Putrefactive organisms from air.

The mere *presence* of these ferments in the dough, however, does not necessarily imply that sour bread will result. It is the *activity* of the bacteria which determines the amount of acid produced, and therefore any *conditions* which favour the activity of these organisms may be regarded as causes of sour bread.

The chief condition favourable to the activity of the souring ferment is weak alcoholic fermentation by the yeast.

If the alcoholic fermentation be strong and vigorous the souring ferments are held in check and cannot act to any extent. If, however, the yeast ferment be weak, then the bacteria gain the ascendancy and the normal panary fermentation gives way to abnormal bacterial action. High temperature favours sour bread, inasmuch as the yeast cells work feebly, and the bacteria work strongly at such temperatures.

Long fermentations, too, also favour the production of sour bread, as towards the end the alcoholic fermentation flags, and allows the lactic organisms to gain the ascendancy.

Prevention of Sour Bread.—The precautions to be adopted to avoid the production of sour bread may be conveniently divided into two heads:

(1) *The prevention of the introduction* of the souring ferments into the dough.

(*a*) Use sound flours.
(*b*) Avoid unsound yeasts.
(*c*) See that all troughs and utensils are thoroughly clean before use.
(*d*) Keep the air pure by good ventilation, and the use of a good disinfectant like Izal in the w.c.'s, lavatories and drains. In persistent cases, the walls and floors of the bakehouse may be washed with a solution of Izal.

(2) The maintenance of a vigorous alcoholic fermentation.
(*a*) Avoid long fermentations (*Note.*—Distillers' yeast is quicker in working than brewers').
(*b*) Work at as low a temperature as is compatible with steady, strong fermentation.
(*c*) Employ when necessary a malt extract or yeast food to quicken fermentation.
(*d*) Do not work the dough too slack.

Ropy Bread is seldom seen, and is characterised by the presence in the loaf of a sticky gum-like substance closely allied to mannite. This condition is the result of bacterial activity producing what is known as a viscous fermentation, but there is some doubt as to the exact nature of the organism producing the mannite. The remarks on the prevention of sour bread are equally applicable to ropy bread.

Heavy Bread usually lacks an even texture and good vesicular structure. It is produced by insufficient fermentation or by using too little yeast or a weak yeast.

Mildew in bread is the result of the growth of a fungus known as the *Puccinia Graminis*, and develops when bread is allowed to stand for some time. A moist atmosphere is very favourable to the development of the fungus. Bread stored in a dry chamber may be kept a long time without the appearance of mildew.

Mouldy Bread is produced by the development of the acrospore stage of the *Eurotium herbariorum*, and is favoured by being stored in a damp atmosphere.

Musty Bread is somewhat similar in character to mouldy bread, but there is less green fungus to be seen, and the odour is different. It is due to the development of the *Eurotum herbariorum* and the *Mucor mucedo.* This condition is favoured by darkness and damp air.

Blood Rain in bread is marked by red patches in the bread, and is produced by an organism known as the *Micrococcus prodigiosus.*

Holes in Bread are very unsightly, and often prejudice a customer against the baker; hence it is important that they should be avoided. Holes have been attributed to :

(1) Weak fermentation.
(2) Bad and insufficient moulding.
(3) Over proving.

Should holes appear persistently in bread, the use of a steady working yeast, together with sufficient moulding, will usually get over the difficulty. Sometimes the holes are formed during the baking process, owing to over-fermentation of the dough. In this case the gluten has largely lost its tenacity, and is unable to withstand the great expansion of the gas due to the heat of the oven, so that a large number of the walls break up, forming a large cavity instead of a honey-combed mass. In such cases, the remedy lies in shortening the fermentation of the dough.

To avoid holes :

(1) Use a steady working yeast.
(2) Avoid over-fermentation.
(3) Mould evenly and well.

PART IV.

Practical Work.

CHAPTER XXIV.

THE MICROSCOPE AND ITS USE.

THE microscope may be described as an instrument which produces a magnified image of an illuminated object, the image being obtained by the use of glass lenses. A **simple** microscope is one which contains only *one* lens, while a **compound** microscope is a combination of several different kinds of lenses, in order to secure greater magnifying power and clearer definition.

Lenses made of ordinary glass are not employed in the construction of good microscopes, as they give rise to errors, owing to the dispersion of the light rays, by which some are broken up into the numerous tints which constitute the spectrum or rainbow, and which fringe the image with colour. In order to avoid this a good lens is made in two parts, one of crown, the other of flint glass, cemented together by Canada balsam, and is then known as an "achromatic lens."

Diaphragms are circular openings used to cut off the external rays of light passing through a lens. There is often a want of definition in the neighbourhood of the edges of an image due to what is termed "spherical aberration." The employment of a diaphragm reduces this, by only allowing the rays of light which pass through the central portion of the lens to reach the eye. Diaphragms are always placed in the eyepiece and body of a good microscope.

Parts of Microscope.—The compound microscope consists of the following parts:

(1) *The Body* (A Figure 52) carrying
  (*a*) The eyepiece with its lenses and diaphragm.
  (*b*) The objective.

(2) *The Stand* (B Figure 52) carrying the stage, mirror, and adjustments.

The body tube is usually made of brass blacked internally to stop reflection from the sides, and is made so that it can be moved up and down on the stand.

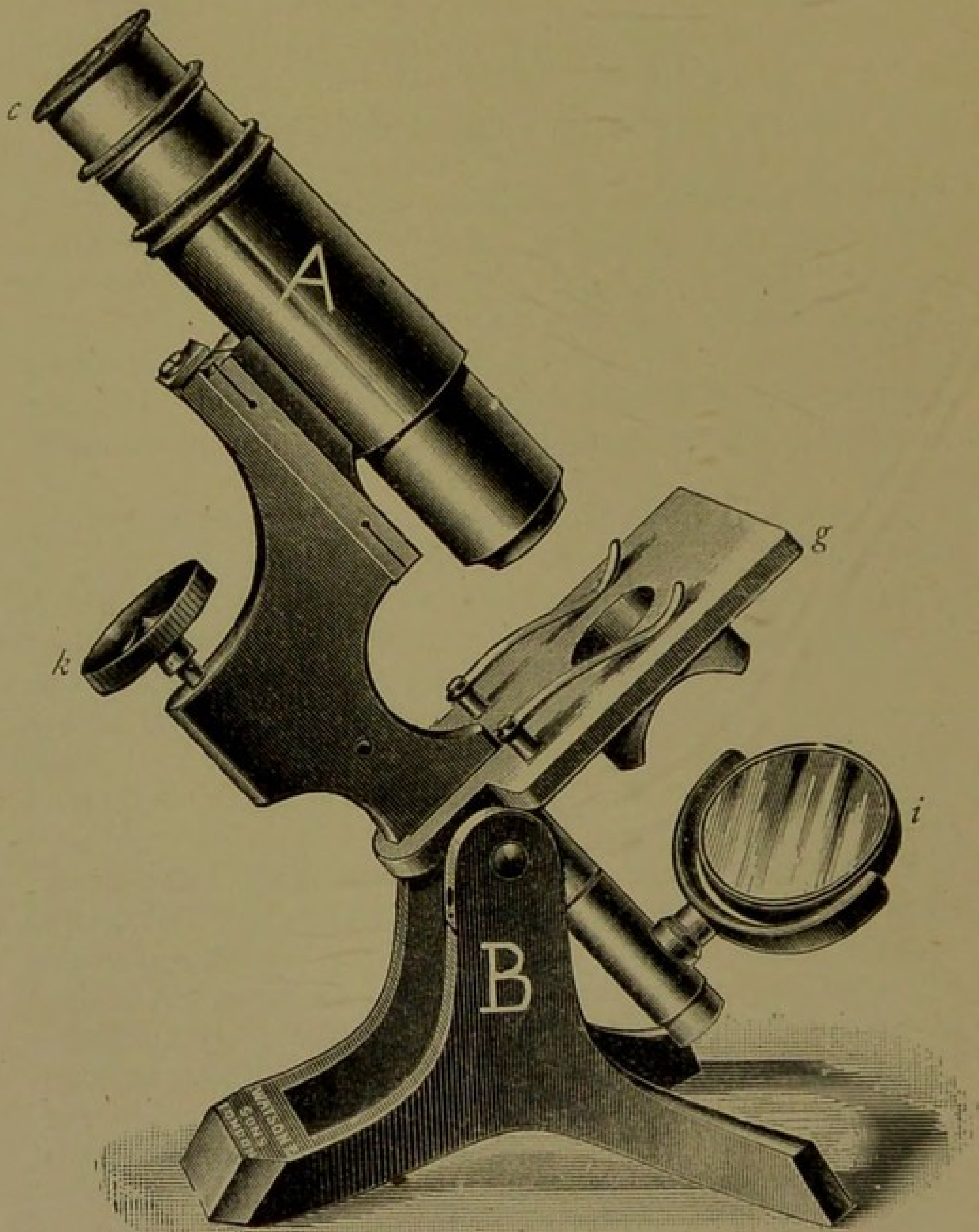


FIGURE 52.—WATSON'S HISTOLOGICAL MICROSCOPE.

A, Body; B, Stand; *c*, Eyepiece; *g*, Stage; *i*, Mirror; *k*, Fine adjustment.

The Stand of a microscope should be fairly solid, and remain firm, no matter at what angle the microscope is used.

The Eyepiece is marked *c* Figure 52. It consists of two plano-convex glasses, one termed the eyeglass being nearest to the observer and the other called the field glass placed at the further end.

A small diaphragm is placed between them to cut off the rays of light which pass through the parts of the lens near the rim. Eye-pieces are divided into three kinds: A, B and C, according to the degree of magnifying power which they effect.

The Objective.—The glass at the further end of the body and nearest to the stage *g* is termed the objective, and forms the image of the object. It is usually made of two or three achromatic lenses, mounted in a brass fitting. Objectives are termed 2″, $1\frac{1}{2}$″, 1″, $\frac{1}{2}$″, $\frac{1}{4}$″, $\frac{1}{5}$″, $\frac{1}{6}$″ $\frac{1}{8}$″, &c., which roughly corresponds to the focal distance, that is, the distance which the objective is from the object when the latter is in focus. The more powerful the objective the shorter this distance.

The Stage (*g*) is the part intended for the reception of the object to be examined, and is provided with spring clips to keep the object in position. There is a circular hole in the stage through which the light from the mirror (*i*) passes to the object.

This opening may be made smaller by the use of a revolving plate beneath, which successively brings different sized holes to the centre. The smaller diaphragms or openings are employed for the highest powers.

The Mirror (*i*) is employed to reflect light *through* the object. Generally it is silvered on both sides, one being a plane surface and the other concave, the latter being used for the higher powers. The mirror is so fitted that it can be placed at any angle.

Adjustments.—There are two adjustments to a good microscope, one coarse and the other fine (*k*). The former moves the body through comparatively great distances very rapidly, while the latter moves either the objective or body through very small space. The coarse adjustment is used to get the objective near the focus, and the fine to obtain the exact focus. For low objectives, say up to ½″, it is usually unnecessary to use the fine adjustment. In some microscopes the coarse adjustment is simply obtained by sliding the body through the fitting of the stand.

Transmitted light is used to examine the majority of objects under the microscope, therefore it is necessary to render the objects transparent and mount them on glass.

Opaque bodies are studied by reflected light, the objects being illuminated by the rays from a bulls-eye or condenser.

Use of the Microscope.—The microscope has been of the utmost value in the elucidation of many problems of the greatest importance to the trade, and though, perhaps, it may not be a necessary instrument to the baker, yet a brief description of the method of working and the mode of preparing the object will be of use to those who are entering the trade and studying for the examinations of the City and Guilds Institute and the National Association of Master Bakers.

The microscope may be applied :

(1) To the study of the structure of the wheat grain.
(2) To the examination of flour for foreign starches.
(3) To the examination of yeast.

Preparation of a Section of Wheat.—The structure of the wheat plant may be made out by transmitted light, hence the sections should be mounted on glass slides. For this purpose, glass slips are sold with ground edges measuring 3 in. by 1 in., and small thin circular discs of glass, termed cover glasses, are used to cover the object.

The materials and reagents required are :

(1) Section cutter.
(2) Razor.
(3) Glass slips.
(4) Cover glasses.
(5) Watch glasses.
(6) Glycerine.
(7) Canada balsam.
(8) Absolute alcohol.
(9) *Oil* of turpentine.
(10) Paraffin wax.
(11) Needles and forceps.
(12) Benzole.

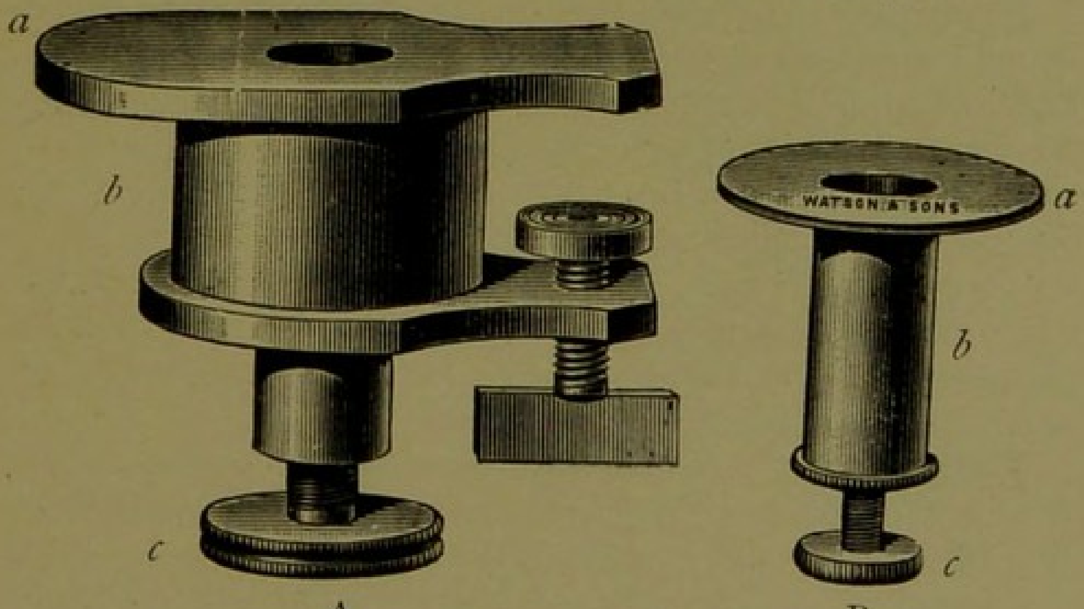
The preparation consists of the following operations:

Preliminary preparation.—The grain should be soaked in glycerine and water until fairly soft; about three hours is usually sufficient. Before cutting, the grains should be dried by the use of blotting paper.

Cutting a Section.—For this purpose an instrument, termed the section cutter, is employed. A general idea of its appearance will be obtained from Figure 53. A shows one adapted for clamping to a table, while B is intended for holding in the hand.

The principal parts are:

(1) Perfectly level brass plate (*a*).
(2) A central hole communicating with a tube (*b*).
(3) A screw arrangement by which a plug may be moved up or down tube at will (*c*).



A B

FIGURE 53.—WATSON'S SECTION CUTTERS.

To cut a section the plug is moved up to within ¾ in. of the surface of brass plate. Melted paraffin wax is then poured into the well until well filled; as the wax cools a hollow will be left in the centre, which must be filled up with fresh wax. Just before the wax solidifies, the grain is introduced into the centre of the mass in the desired position, care being taken to place the grain *below* the level of the surface of the brass plate. More wax is then poured on until it flows partly over the plate. When cool, a sharp razor is placed flat on the plate and firmly passed over, thus bringing the wax in the well flush with the cutting plate. If the screw (*c*) be now turned slightly the plug moves *upwards*, pushing the cylinder of wax with the grain *above* the cutting plate. The razor is passed over again and a thin disc of wax is cut off. This process is continued until the grain is exposed, when a continuous series of sections may be cut, each embedded in a thin disc of wax.

The thickness of the section depends on the space through which the milled head is turned. The razor should be wetted with a mixture of alcohol and water each time it is used, and the sections should be placed into a watch glass containing the same solution.

The sections may be released from the wax by careful manipulation with needles in alcohol and water.

Staining.—The use of certain stains brings out in many cases details which would otherwise escape notice, but in the case of the wheat grain, the main features may be made out in the plain section. Should stains be used it would be advisable to get them ready made up from a firm of microscope makers.

To stain a section, remove it from the wax to a watch glass containing the stain, and allow to remain from three to ten minutes according to the strength, and then wash lightly in alcohol and water.

Dehydration.—It is next necessary to remove water from the section. To effect this, immerse the section for five minutes in absolute alcohol in a watch glass.

Clearing.—To render the section transparent remove it to a watch-glass containing oil of turpentine, and allow it to remain about two minutes.

Mounting.—Remove the excess of oil of turpentine from the section with the edge of a piece of blotting-paper. Clean a glass slip and cover glass, and place a drop or two of Canada balsam on the slip. Gently immerse the section in the balsam and carefully place the cover glass on by means of the forceps. Gently press the cover glass down. The object of mounting in Canada balsam is to preserve the section. Should the Canada balsam be too thick, a little benzole will thin it.

Drying.—The section should be allowed to dry and harden, when it is ready for examination.

Cleaning.—When thoroughly dry the excess of balsam which has exuded from underneath the cover glass may be carefully scraped off by means of a penknife, and the slip left clean.

Ringing.—The section may be further preserved by surrounding the edge of the cover glass with cement. For this purpose liquid preparations are sold which harden on exposure to the air. The cement is laid on by a brush, and the rings made true by the use of an ingenious contrivance termed the turn-table.

The cover glass is centred by the help of the painted rings

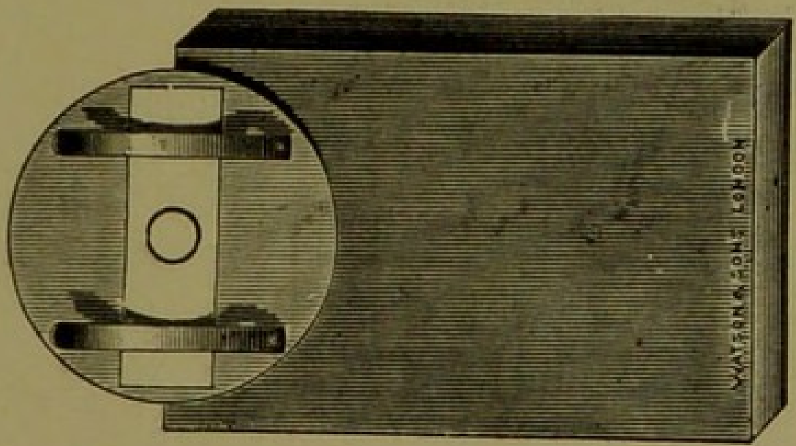


FIGURE 54.—WATSON'S TURN-TABLE.

on the table, and the glass slip secured by the clips. The table is then set rapidly rotating, and the cement laid on carefully from the tip of the brush.

Labelling.—A neat label should be put on each slide bearing

(1) Name and direction of section.
(2) What mounted in.
(3) Name of preparer.
(4) Date.

Slides prepared in this way last for an indefinite period.

Preparation in Glycerine.—Another method may be adopted for rapid examination of a section, in which the sections are mounted in glycerine.

All that need be done is to remove the section to a mixture of two parts of glycerine to one of water, and allow it to soak for about ten minutes, and mount on the glass slip in pure glycerine. These sections do not keep, however, for any length of time.

The necessary reagents and apparatus may be conveniently kept in a cabinet.

Sections of the wheat grain may be examined with all the powers fitted to the microscope, low as well as high.

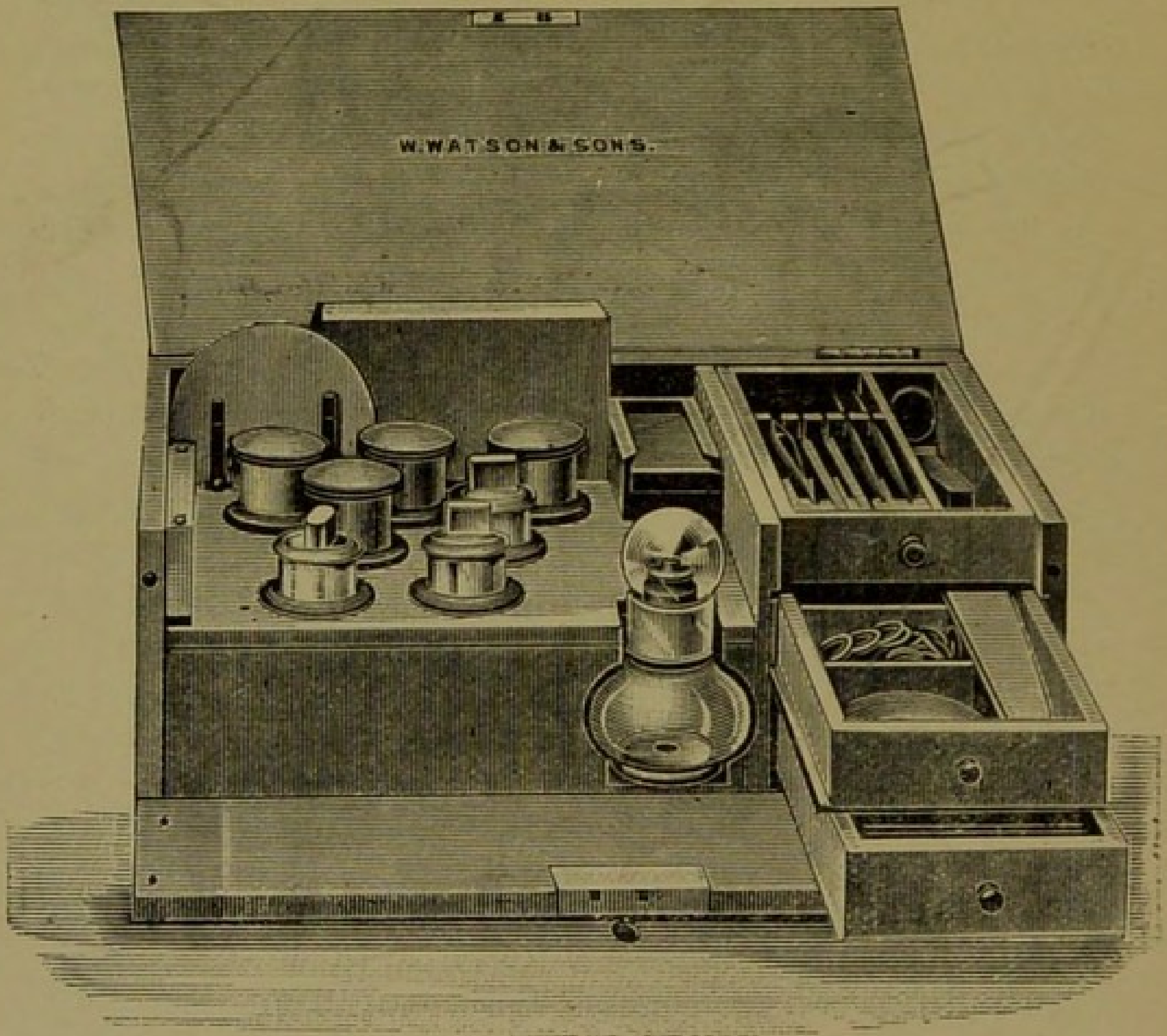


FIGURE 55.—WATSON'S CABINET OF MOUNTING MATERIALS.

Examination of Flour.—Stir a little flour into a mixture of two parts of glycerine and one of water in a watch glass. When evenly distributed remove a drop to a slip and place a cover glass on and examine with a high power.

The presence of foreign starches may be detected by the aid of diagrams in Chapter III.

Examination of Yeast.—To examine pressed yeast a small portion may be taken and broken up in a watch-glass containing distilled water. When the mass is thoroughly mixed a small drop should be removed to a glass slip, and a cover glass put on with a hair beneath to prevent the yeast cells from being crushed. Examine with a high power. The main characteristics of a yeast cell may be readily made out, and the freedom or otherwise from foreign ferments may be ascertained.

Considerable experience is necessary before any safe deductions can be drawn from the microscopic examination of yeast, but it may be stated generally that the fewer the foreign organisms the better the yeast for bread-making purposes. Foreign organisms may be recognised by their appearance as minute rods, the yeast cells being all more or less round, but the student is advised to purposely obtain a sample of a badly prepared yeast and carefully study its appearance under the microscope, and compare it carefully with a yeast of known purity like the N. G. and S. F.

Starch may be easily recognised by the characteristic shape of the granules.

Good Pure Yeast is known by the following points:

(1) Absence of starch.
(2) The presence of few foreign ferments.
(3) Cells of uniform size and fairly free.
(4) Cells well filled but containing a few vacuoles.
(5) Cell walls of medium thickness.

Inferior yeast is indicated by

(1) Presence of foreign ferments in large proportions.
(2) Shrunken cells.
(3) Very thick or very thin cell walls.

Kind of Microscope Suitable.—A plain simple microscope is best suited for the bakehouse; and the author has used with great success the form shown in Figure 52, a model manufactured by Watson & Son, 313, Holborn, London, of whom all the accessories and re-agents mentioned in this chapter may be obtained. In any case a *good* body and stand should be obtained, as accessories to the microscope may be conveniently added afterwards. For working purposes a 1 in. and $\frac{1}{6}$ in. or $\frac{1}{8}$ in. will be found sufficient to do all ordinary work.

Hints on the Use of Microscope.

(1) Place the microscope at a convenient angle. If working by daylight the window should be on the left hand and the microscope nearly upright.

(2) Place slide on the stage with object in centre of the opening.

(3) If working by artificial light place light to the left.

(4) Manipulate mirror until the light illuminates the object from below.

(5) Begin examination with *lowest* powers and finish with the highest.

(6) In focussing move the body down until the objective nearly touches the cover glass, and then focus by *moving body* upwards. If this rule be not adopted, valuable objectives may be ruined in the beginner's hands by being forced down on the glass slip.

(7) Use the eyes alternately.

(8) Try and make rough sketches of what is seen.

(9) Always remove objectives after use and place them in their cases.

(10) Thoroughly dust instrument after use and place under a glass case or in a box.

For fuller information on mounting the reader is referred to the author's work on "Practical Physiology" (co-author, Dr. Pilley) and for a full description of the microscope itself to Hogg's work on "The Microscope."

CHAPTER XXV.

GENERAL APPARATUS, MATERIALS, AND REAGENTS REQUIRED FOR PRACTICAL WORK.

BEFORE passing to the practical tests it will be necessary to describe a few of the more common pieces of apparatus and reagents which are required. In the following list due regard has been paid to usefulness and economy, and, with a little care, most of the preliminary work and tests possible in an ordinary bakery can be efficiently performed by the aid of the apparatus and reagents mentioned.

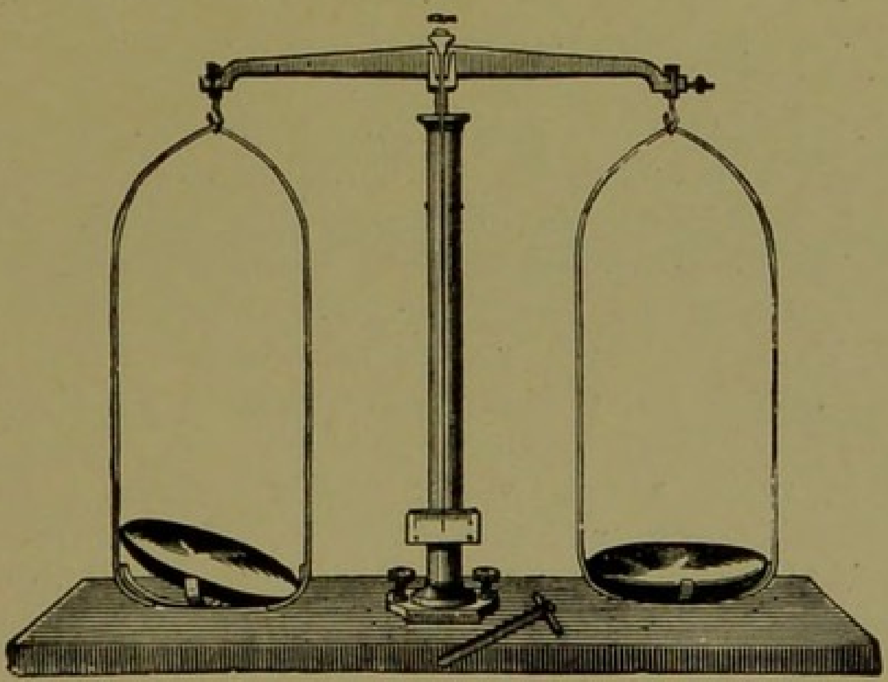


FIGURE 56.—BECKER'S PRECISION BALANCE.

The Balance.—In many of the experiments to be described in the next chapter, definite weights of the material to be tested must be taken. It is therefore necessary to possess a good balance and to learn how to manipulate it properly. A very delicate balance is necessary for laboratory work, but the type shown in Figure 56 is sufficiently accurate for bakehouse purposes.

It is mounted on a mahogany board and is made to carry 100 grammes (about 3½ ozs). It is so constructed that, when not in use, the razor edges are released from their supports by turning the handle to the left. The beam is provided with a pendulum needle moving over an ivory indicator, and when the pans are properly balanced it swings the same number of divisions on each side. The balance may be adjusted by means of the screw nut on the right-hand side of the beam.

The following rules should be observed in weighing:

(1) See that the balance is accurately adjusted before use. If wrong, put right by means of the screw nut on right-hand side of beam.

(2) Put weights in right hand pan, and the substance to be weighed in left.

(3) Never put in weights while the pans are swinging. Always bring the balance to a state of rest by means of the handle, and then put in or take out the weights.

(4) In taking the weight, allow the pans to swing slightly, and judge from the moving index over the plate whether the weight is correct. When the needle moves over the same number of divisions on each side the weight is correct. Usually a slight waving movement of the hand over the pan containing the weights is sufficient to set the beam moving slightly.

(5) Move the weights with a pair of forceps. Do not touch them with the hand.

(6) When weighing flour, baking powder, &c., do not put the substance into the naked pan, but take two papers, one for each pan, and counterpoise them before the weighing operations. This can easily be done by cutting the surplus from the heavier paper.

(7) Keep the balance in a clean dry place.

Weights.—It would be advisable to get both English and French sets. Figure 57 shows convenient ounce weights, and Figure 58, a set of weights on the metric system, ranging from 200 grammes to 1 milli-gramme.

In using the English weights the smallest weight required in the following tests is ¼ oz. but in taking moistures the finer of the French weights may be required. The balance illustrated above can only be depended on to five milligrammes, but this will furnish sufficiently accurate results for the general purposes of the baker.

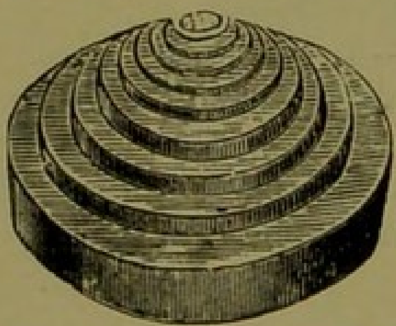


FIGURE 57.—ENGLISH WEIGHTS.

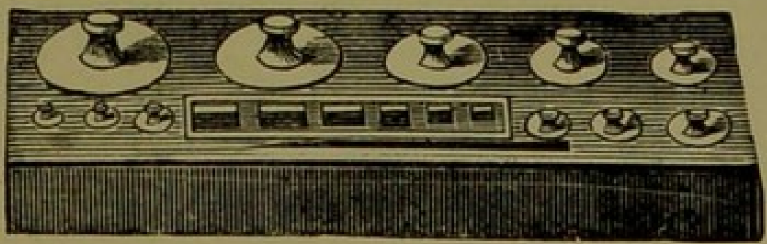


FIGURE 58.—FRENCH WEIGHTS.

The cylindrical brass weights in the box are marked in grammes coming down from 200 to 1 while the flat weights are marked in fractions of a gramme thus :

·5	grammes	=	500	milligrammes
·3	,,	=	300	,,
·2	,,	=	200	,,
·1	,,	=	100	,,
·05	,,	=	50	,,
·03	,,	=	30	,,
·02	,,	=	20	,,
·01	,,	=	10	,,
·005	,,	=	5	,,

In weighing it is best to commence with a weight just *above* the weight of the body to be weighed, and then to work downwards. In totalling results by the help of the table above, put down the result in grammes and fractions of a gramme.

A Bunsen Burner is an arrangement whereby air is admitted at the bottom of the vertical tube, and so mixes with the gas before it ignites at the aperture. By this means, a perfect combustion is secured. By means of a revolving ring, the aperture may be closed converting the flame into the ordinary illuminating variety.

Water Oven.—In order to thoroughly dry bodies it is necessary to subject them to a temperature approaching 212° F. for twelve hours. For this purpose a water oven is employed. The outside jacket is filled with water, a Bunsen placed underneath, and the water kept boiling for twelve hours. From time to time the water in the jacket must be replenished. The materials to be dried are placed in dishes or on stiff paper on the shelves inside.

The Tripod is an arrangement for the reception of bodies to be heated by the flame of a spirit lamp or Bunsen burner.

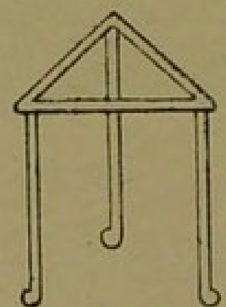


FIGURE 59.—TRIPOD STAND.

Sand Bath.—This is a small metal saucer for the reception of silver sand, and designed for placing on the tripod stand. Dishes containing liquids to be heated are placed on the sand, to protect them from the naked flame and to evenly distribute the heat.

Test Tubes of various sizes are required for the reception of liquids to be tested, and a test tube holder is desirable to prevent scalding and burning of the fingers. Test tubes may be cleaned by the aid of a test tube brush.

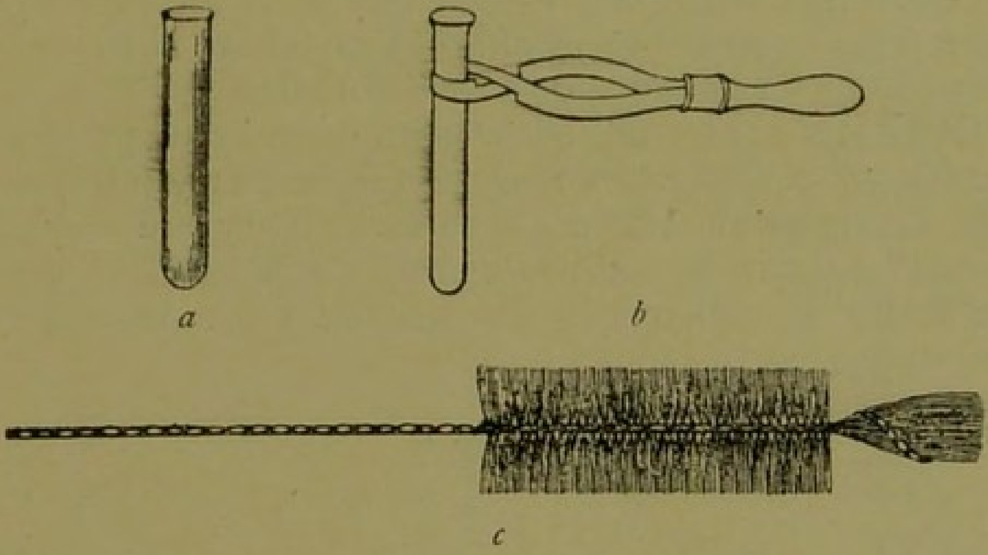


FIGURE 60.—(*a*) TEST TUBE; (*b*) TEST TUBE AND HOLDER; (*c*) TEST TUBE CLEANER.

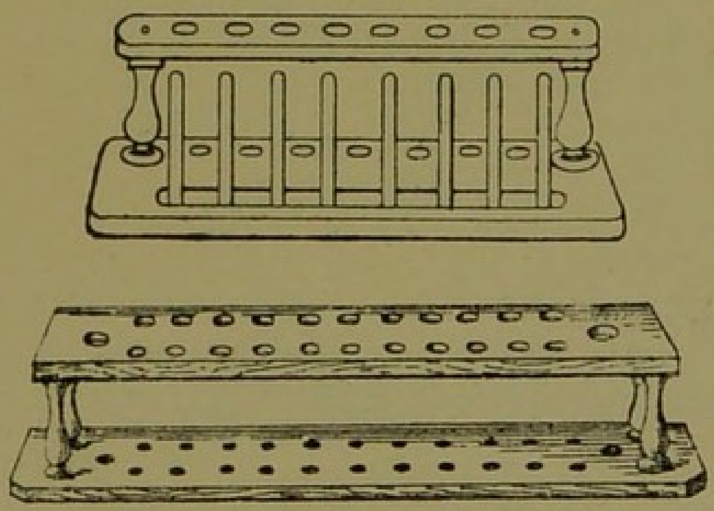


FIGURE 61.—TEST TUBE STANDS.

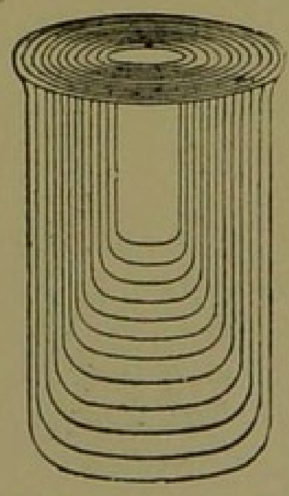


FIGURE 62.—NEST OF BEAKERS.

Test Tube Stands are necessary to hold the empty tubes and to receive them after the tests have been made. Convenient forms are shown in Figure 61.

Beakers are small flasks with or without spouts for the reception of filtrates and the preparation of reagents and for general testing purposes. They are sold in "nests" containing twelve different sizes.

Flasks of different kinds and sizes are wanted for various purposes.

FIGURE 63.—FLASK.

Porcelain dishes for evaporating purposes and general work are required. They are often employed in conjunction with the sand bath to boil liquids in.

FIGURE 64.—PORCELAIN DISHES.

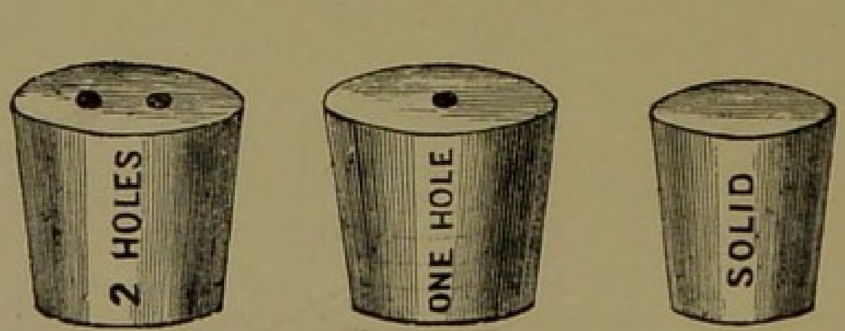


FIGURE 65.—INDIARUBBER CORKS.

Corks of various sizes with holes are necessary for fitting up various kinds of apparatus. The best are made of Indiarubber, but by means of a set of cork borers, ordinary corks may be used with success.

Retort Stand.—This is used for the reception of flasks undergoing the process of being heated, but it may also be employed as a funnel stand.

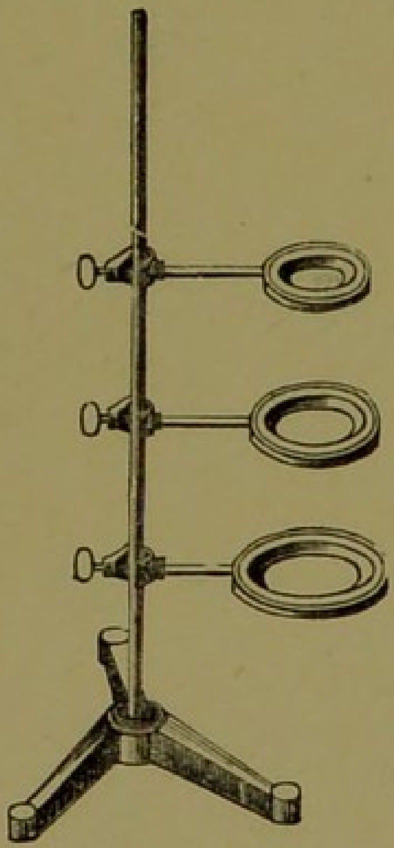


FIGURE 66.—RETORT AND FUNNEL STAND.

Funnels are employed for the purpose of receiving filter papers, and are used in the process of filtration.

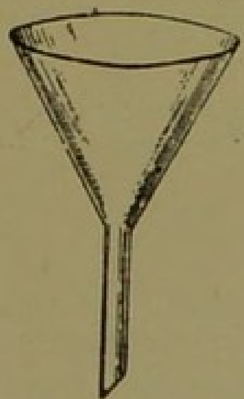


FIGURE 67.—FUNNEL.

Measuring Jars and vessels of various descriptions are very handy, and save much time in making actual tests. The most useful is shown in (*a*) Figure 68. It is a tall cylindrical glass graduated in cubic centimetres (c.c.) to 100. A measuring glass graduated in ounces is shown at (*b*), while a plain jar for use in conjunction with the hydrometer is illustrated at (*c*).

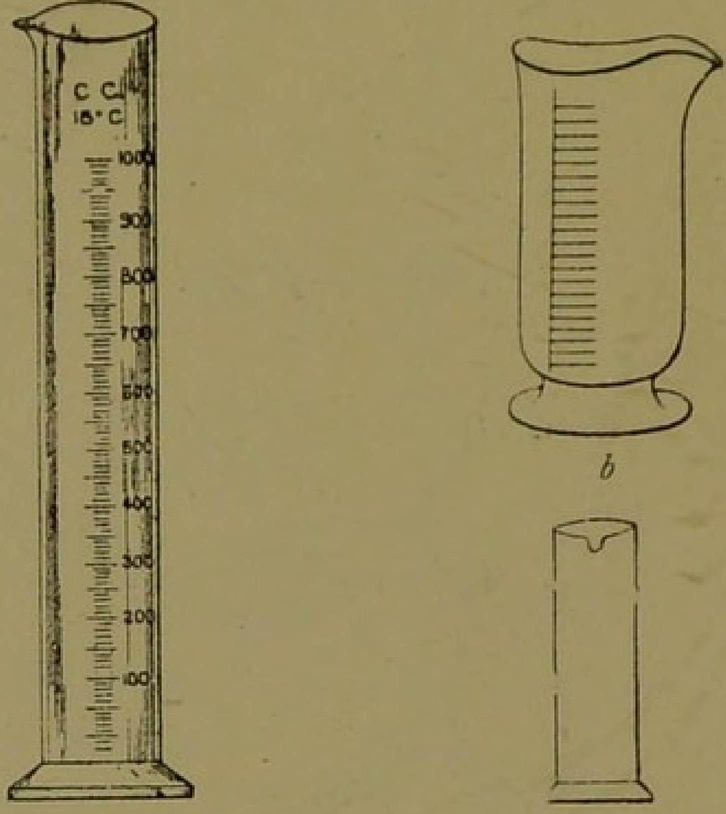


FIGURE 68.—MEASURING JARS.

Pipettes.—These pieces of apparatus are used for measuring liquids. They are marked in drachms and ounces or cubic centimetres. When full, the outflow is regulated by the first finger.

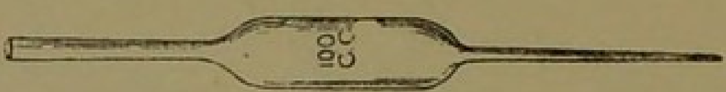


FIGURE 69.—PIPETTE.

Burettes.—A burette is also employed to measure liquids, but the outflow is regulated by means of a spring clip or glass tap. They are usually marked to deliver cubic centimetres and parts of cubic centimetres.

The Hydrometer is a very useful instrument to the baker, as by its means the specific gravity of liquids may be taken. Specific gravity is the weight of a body when compared with the weight of an *equal volume* of pure water at the same temperature. In the ordinary hydrometer 1000 is the standard for water at 60° F. That is to say, when floated in pure water at 60° F. the mark 1000 on the stem will be level with the surface of the

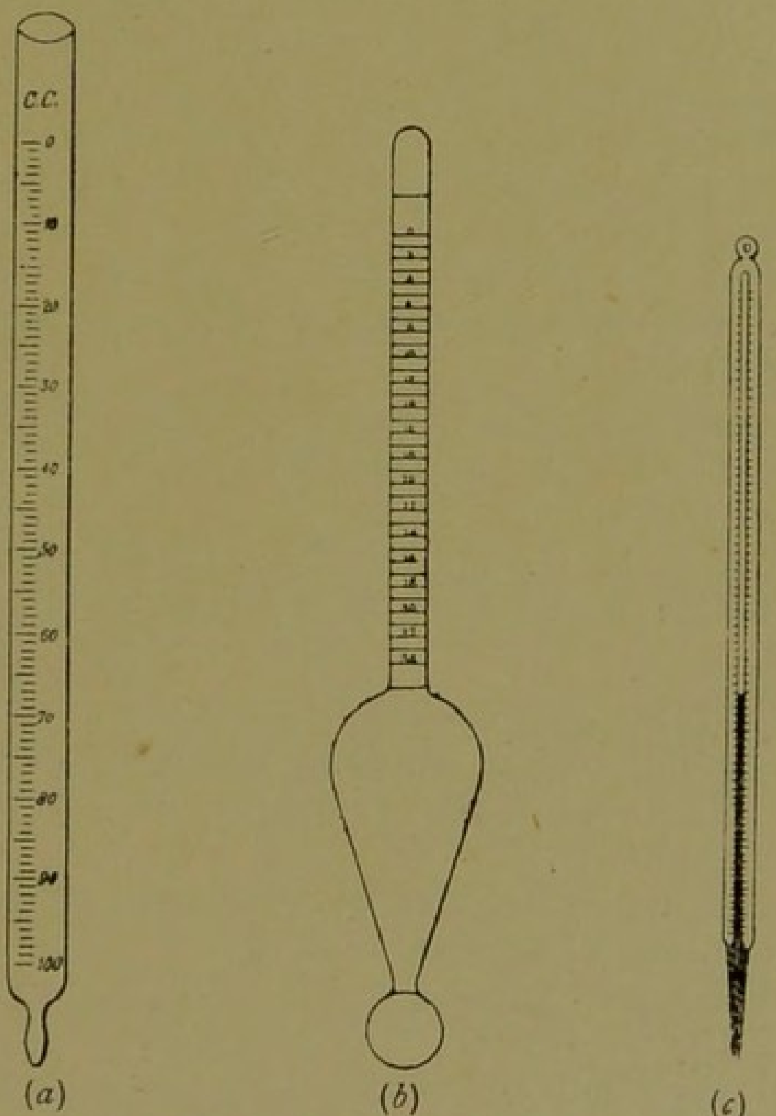


FIGURE 70.—(*a*) BURETTE; (*b*) HYDROMETER; (*c*) THERMOMETER.

water. In heavier liquids the stem rises, while in lighter bodies the stem sinks. The hydrometer designed by Twaddell is a very convenient form of instrument, and is used chiefly for liquids heavier than water. It is shown in Figure 70 (*b*). The stem is graduated in equal divisions from near the top to 34 near the bulb. When floated in pure water at 60° F. the stem sinks to 0. In liquids heavier than water the stem rises. To take a specific gravity it is only necessary to immerse the hydrometer in the liquid (which should be contained in a tall vessel at 60° F.) and to allow the stem to come to a state of rest. Observe the number level with the surface of the water, and by the aid of the following table at once read off the specific gravity.

No.		Sp. gr.	No.		Sp. gr.
0	—	1000	7	—	1035
1	—	1005	8	—	1040
2	—	1010	9	—	1045
3	—	1015	10	—	1050
4	—	1020	20	—	1100
5	—	1025	30	—	1150
6	—	1030			

In other words every division on the stem is equal to 5° specific gravity.

Thermometer.—It is very useful to have an unmounted thermometer, as it is easily cleaned. Figure 70 (*c*) illustrates a convenient form.

In addition to the apparatus mentioned above, glass tubing, india-rubber tubing, filter papers, and files will be required.

The following reagents will be necessary:

(1) Iodine solution made by dissolving iodine in a solution of iodide of potash.
(2) Chloroform.
(3) A saturated solution of ammonium carbonate.
(4) Solution of logwood in alcohol.
(5) Fehling's solution.
(6) Litmus solution.
(7) Hydrochloric acid.
(8) Sulphuric acid.
(9) Nitric acid.
(10) Ammonium hydrate.
(11) Sodium hydrate.
(12) Pure calcium carbonate (powdered).

The solutions may be made by the directions in the appendix, but it would be advisable for the baker to obtain them ready-made from a chemist's shop.

GENERAL HINTS.

How To Cut Glass Tubing.—Hold the glass tube in the left hand and place part to be cut perfectly level on a flat surface (table or bench). With a triangular file make a firm scratch by a double movement—to and from you. Break tube with the two hands. Before use, smooth the rough edges by fusing in the Bunsen flame.

To Bend Glass Tubing.—Glass tubing is best bent in the ordinary gas flame. Hold the tube so that at least three inches are subjected to the action of the *upper* part of gas flame. In a minute or so the tube will become red hot, and may be readily bent. On no account *force* the tube, but allow it to fall gently by force of gravitation. In this way the calibre of the tube is not interfered with. If forced the bend is flat and the bore is narrowed.

In boring corks turn both borer and cork, the former from you, the latter to you. Smooth hole by rat-tail file.

To Fold Filter Paper.—Halve it as in figure 71. Then quarter it. Separate the parts to form a cone. Insert in funnel and moisten with water.

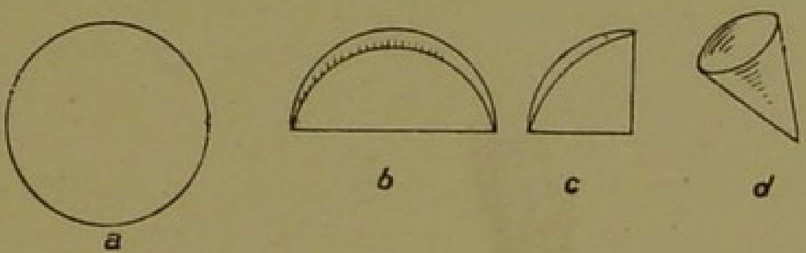


FIGURE 71.—FOLDING A FILTER PAPER.

To Work a Pipette.—Draw the liquid into pipette by suction at the end with mouth. Quickly and firmly close upper aperture with first finger of right hand before drawing pipette from liquid. On withdrawing pipette no liquid will escape while the upper aperture is closed by finger. By reducing the pressure of finger on aperture so as to allow air to flow in, the liquid is allowed to flow out, and the amount passing out is regulated by the degree to which the finger is removed from the tube.

Always clean test tubes and apparatus after use, and keep the reagents in definite places on a separate shelf.

All the apparatus and reagents mentioned in this chapter may be obtained of Messrs. Becker & Co., 33–37, Hatton Wall, London.

CHAPTER XXVI.

GENERAL TESTS.

IT will be advisable for the baker to familiarise himself with one or two common reactions and phenomena before passing on to the examination of flour, yeast, and other bakers' material.

Starch.

(1.) *Microscopic Examination.*—To examine the appearance of various starches proceed as follows :

Grind the particular cereal the starch of which you wish to examine into a fine powder. Inclose a portion in fine muslin and gently wash in a running stream of water, catching the flow in a tall jar. Allow the vessel to stand until a sediment sinks to the bottom. Pour off the supernatant liquid. (The sediment consists largely of starch grains.) Clean a glass slip and cover glass, and place a few drops of glycerine on the slip. With a pointed glass rod remove a small portion of the sediment to the glycerine and gently disperse. Place the cover glass on and examine with the highest power.

Carefully note the appearance and size of the starch granules. By mixing different flours together, and proceeding as above, several kinds of starch grains may be obtained on *one* slip and their general character and sizes compared. Typical starches may, however, be bought already mounted at Watson & Sons.

(2) *Gelatinisation.*—Stir a little powdered starch into a beaker of water, until it assumes a milky appearance. Note that the starch is insoluble in water.

Place the beaker in a larger vessel containing water, and apply heat to the outer vessel by a Bunsen burner or spirit lamp. Notice the slow change of appearance of the mixture of starch and water, and that it gradually loses its white milky appearance, and assumes a pellucid, jelly-like consistency. With a thermometer in the inner beaker, take and note the temperature at which the mixture begins to clear, and when it is complete.

(3) *Soluble Starch.*—Add a little starch powder to a test tube half full of water. Boil and filter. The filtrate when tested will be found to contain starch.

(4) *Test for Starch.*—Take a little of the filtrate from (3) and when cool add a little iodine solution. Note the deep indigo blue colouration; boil. The colour disappears, but returns as the liquid cools.

(*Note.*—If the starch be present in considerable quantity the mixture appears black, but the blue colour is apparent on dilution with water.)

(5) *Inversion of Starch.*—Digest a little gelatinised starch with strong sulphuric acid in a beaker standing in boiling water, for a few hours. Cool, and carefully add powdered calcium carbonate until all effervescence ceases. Filter.

To a portion of the filtrate add a little sodium hydrate, and then sufficient Fehling's solution to make the liquid a rich blue. Boil and note the red precipitate indicating the presence of sugar.

To another portion of filtrate add a little iodine solution. No blue colouration is obtained, showing the absence of starch. The starch has been converted into sugar by the action of the sulphuric acid.

Dextrin.

(1) Add a little dextrin (British gum) to water in a beaker and stir. Note that it is soluble.

(2) To a small portion of the solution add absolute alcohol. Note that the dextrin is precipitated.

(3) To a small portion of the solution add iodine solution, and note the rich red colour obtained. Boil. The colour disappears and does *not* reappear on cooling.

Starch and Dextrin.

Measure 5 c.c. of a starch solution into a test tube (*a*) and 5 c.c. of dextrin solution into a separate similar test tube (*b*). Into a third tube (*c*) measure 5 c.c. of the starch solution, and 5 c.c. of the dextrin solution and thoroughly mix. Add equal volumes of iodine solution to all three. Note carefully the differences in colour:

(*a*) Indigo blue of starch.

(*b*) Deep violet of the mixed colours, indigo and red.

(*c*) Red colour of dextrin.

Boil all three and allow to cool. Note in

(*a*) Indigo blue of starch.

(*b*) Indigo blue of starch.

(*c*) Absence of the red colour of dextrin.

In order to make the comparison of greater value add to (*a*) and (*c*) 5 c.c. of water.

In this way it is possible to distinguish the presence of dextrin when mixed with soluble starch.

Suppose, for instance, a solution gives a purple colour with iodine. The inference is that starch and dextrin are both present. On boiling and allowing to cool, the colour changes to indigo blue; the presence of dextrin with the starch is confirmed.

Dextrose and Maltose.

(1) Note that they are very soluble in water and give no colouration with iodine.

(2) Take a little of a solution of dextrose and add sufficient Fehling to make a deep blue mixture; boil. Note the bright red precipitate of cuprous oxide.

(3) Perform a similar experiment with maltose, and note that the same result is obtained as in the case of dextrose.

Cane Sugar.

(1) Note that cane sugar is exceedingly soluble in water.

(2) To a little of the solution add absolute alcohol. Note that the cane sugar is precipitated.

(3) Note that no colouration is produced by the addition of iodine solution.

(4) To a little of the solution add Fehling's solution. Boil. Note that *no* red precipitate is produced.

Invert Sugar.—To a weak solution of cane sugar add a little strong hydrochloric acid and digest in boiling water for half-an-hour. When cool add powdered calcium carbonate until all effervescence ceases. Filter.

To a portion of the filtrate add a *little* sodium hydrate and then Fehling's solution. Boil. Note the red precipitate which is formed showing presence of dextrose.

Proteids.

The albumin of an egg will serve for many of the reactions. Break an egg and allow the *white only* to fall into a jar; add a large bulk of water and cover the jar with a glass plate. Shake vigorously and allow to stand. After a while the membranes will form a scum on the top of the liquid. Break the scum through and pour off the clear liquid into another vessel. The liquid is a solution of native albumin in water, and may be used for the following tests:

(1) *Coagulation.*—Half fill a small beaker with the solution and place in water inside a larger beaker. Apply heat to the external vessel, and by means of a thermometer in the inner beaker, note the temperature at which the albumin coagulates. By coagulation is meant the change by which the albumin becomes insoluble and opaque.

(2) To a small portion of the solution add a little strong nitric acid. Note that a white precipitate is formed. Boil. Part dissolves. When cool, add a little ammonium hydrate; a deep yellow colour is obtained. This test is very characteristic and delicate, and is known as the Xanthoproteic reaction.

This reaction may be applied to all proteids except peptones. In the case of *insoluble* proteids, like gluten, they must be first dissolved by the aid of strong potassium hydrate. The solution is best effected by grinding the body with a strong solution of caustic potash in a mortar by means of a pestle. The mixture is then filtered, and the filtrate tested as directed above. In these cases a larger quantity of the strong nitric is required than if a neutral solution had been employed.

CHAPTER XXVII.

FLOUR TESTING.

THE following simple tests will be found useful in determining the value of a flour:

Colour.—The colour should be examined dry and wet by Pekar's test. In order that this preliminary examination may be of service it is necessary to have some means of comparison, and in the absence of the tintometer there is no better plan than to select the *best* brand of a good milling firm and use that as a standard. The examination of a *single* flour by the naked eye conveys very little accurate information as to the exact colour, but when two flours are placed side by side there is usually little difficulty in determining which is the better of the two.

Suppose there are three flours to be examined for colour. Proceed as follows:—Procure a smooth piece of wood about 6 in. long and 3 in. wide. With a spatula place side by side a small portion of each flour, and finally the flour you have taken as a standard of comparison. These portions of flour should nearly touch one another. With the spatula smooth the flours with a firm movement from the middle of the board to the edge. The flour should now present the appearance of a beautifully smooth mass on the board, the different samples touching one another. Examine the flours in a good white light, and note the differences in colour, placing the flours in order of merit in a note-book, the lightest first, down to the darkest. It is best now to put the flours again on a clean board in the proper order, beginning with the lightest and ending with the darkest, and to examine them again. A better idea will thus be gained of the relative differences.

Starchy flours, poor in gluten, are indicated by a dull white colour.

The best quality flours are characterised by a *bright*, slightly yellowish-white tinge.

Lower grades are indicated by darkness in colour.

Pekar's Test.—By this method the colours of the flours may be examined dry *after having been wetted*, and, therefore, some idea may be obtained of the colour of the dough. In making the test, smooth the flours as in the second dry test (that is, in order of colour) and then carefully immerse in water by allowing the board to enter the water at the edge, and then describing an arc under water. In immersing it is important to keep the board perfectly level. The flours are allowed to dry in a dark place, and then examined.

Another method is to make up small pieces of dough of standard consistency, and to place each mass on a clean glass slide and then to press another glass on top, flattening out the dough into a sheet between the two glass plates. The colour may be then compared. In comparing doughs it is necessary to proceed as above with glass plates, as surface dough, under the action of the air, darkens considerably.

The value of the colour test depends on comparison, and it is very necessary for the operator to have great experience of various flours, or a definite standard to which he can refer all flours he examines. Lovibond's tintometer gives a method of absolute comparison, but the limits of this work will not allow a detailed description.

Strength is the quantity of water which a flour will absorb to make a dough of standard consistency, and usually a fair idea may be obtained of the likely yield by ascertaining how much water a given weight of flour will absorb. Here again, every baker forms his own standard, and he will naturally judge all flours by that standard.

Thoms' Method.—Mr. Thoms, F.R.M.S., of Alyth, has devised a method whereby an approximate estimate may be made of the number of quarts of water a sack of a given flour will require, and the yield of bread.

The things required are :—A vessel to make the dough, Thoms' pipette, and table. The pipette is graduated to drams.

The test is made as follows:—Weigh out 1¼ ozs. of flour, and place in the doughing vessel. Now make the dough of standard consistency, *measuring* the water used from the pipette. When the dough is ready note the number of drams of water used from the pipette, and by reference to the table read off the number of quarts per sack and yield of bread. It is necessary to be very careful not to make the dough too stiff or slack, and it is best to allow the dough to stand for an hour to ascertain whether with the water absorbed it gives too much. The yield given in the table is nett, allowance having been made for loss during baking operations.

FIGURE 72.—THOMS' PIPETTE.

The pipette and table may be obtained from Mr. Thoms at a moderate price.

Jago's Method.—Jago uses a burette which is graduated in such a way as to give quarts per sack when 1½ ozs. of flour are used.

Figure 73 shews the burette fitted with a reservoir, from which the burette may be filled up to the mark *o* by simply squeezing the spring clip (*a*). (*Note*—It is necessary for the reservoir to be *above* the top of burette.) To make the test, weigh out 1½ ozs. of flour, and fill burette up to *o* mark. Next proceed to make a dough of the desired consistency, by allowing the water to run out of the burette. When the dough has been made, read off the number of divisions from *o* to the surface of the water in the burette. The number gives the *quarts per sack* which the flour requires. In this

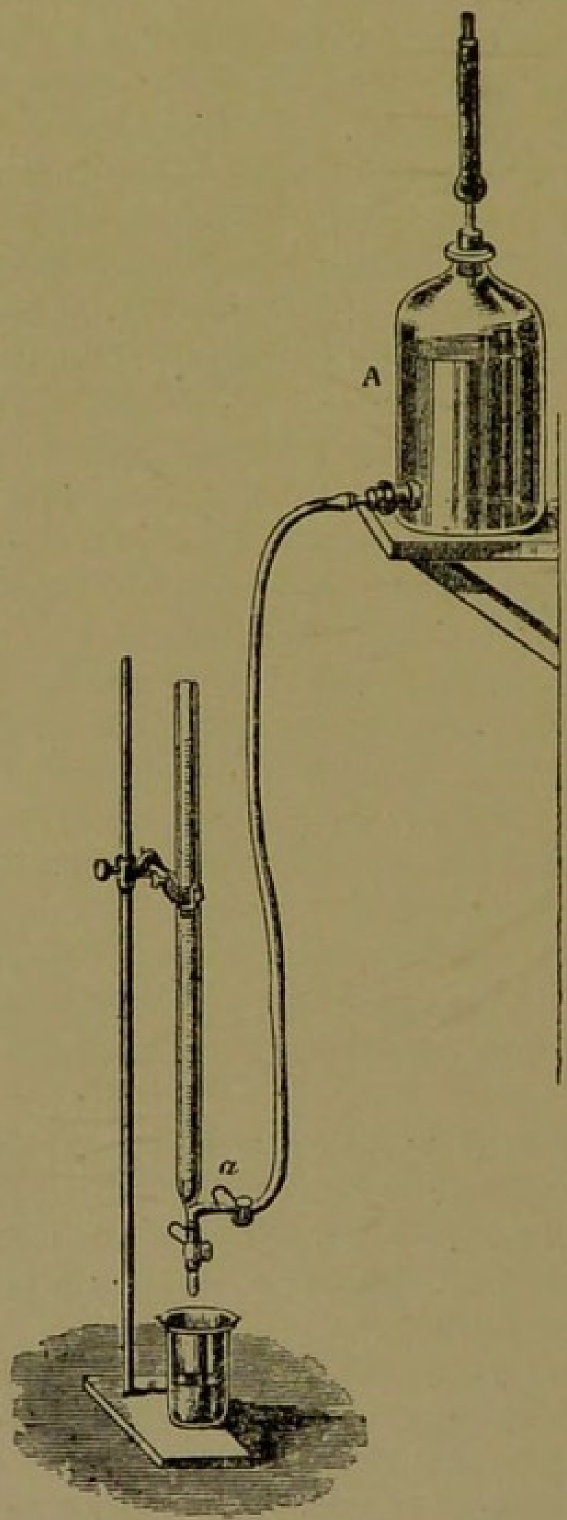


FIGURE 73.—JAGO'S BURETTE.

method every difference of a quart of water between two flours represents a half quartern loaf.

The burette may be obtained of Mr. Jago, F.I.C., F.C.S., 32, Clarendon Villas, Brighton.

The word "strength" is used by Mr. Jago to indicate "the capacity of a flour for producing a bold, volumed, well-risen loaf," and confines the property of mere absorption to the term "Water absorption capacity." "Strength" in this light depends largely on the quality of the gluten, and is somewhat difficult to measure. If the plan be followed of allowing the doughs to stand for an hour before deciding the water-absorbing capacity, and reducing the quantity of water should they fall off, the indication of this capacity for yield and boldness is sufficiently accurate for the purposes of this little work.

Stability is the name given to the resistance which a dough gives to softening influences. The simplest test for stability is to make doughs of standard consistency, and allow them to stand for six or eight hours, under cover, and then notice their condition. The most stable flour will remain the stiffest and most tenacious, while the comparatively unstable (soft) flours will be found to have considerably softened, and to have lost much of their tenacity. Another method is to roll the doughs into balls, and to notice how far each mass spreads. The least stable flour spreads the most.

By comparative tests the baker may easily place a number of flours in order of merit with regard to stability, and will thus be in a position to judge as to which flours to use in the sponge, and which in the dough, and also the proportions to use in blending. Jago's viscometer and Hogarth's machine are special instruments for measuring the stability of doughs after standing for given times, but a detailed description of them does not fall within the province of an elementary text-book.

Gluten Determination.—A good deal of useful information may be obtained about the quality of the gluten by separating it out from the other constituents of the flour. Proceed as follows :—Weigh out 20 grammes of flour, and place in a suitable vessel to make a dough.

Make a dough of a stiff consistency and allow it to stand for an hour. Enclose the dough in a piece of fine bolted silk and gently wash under the tap, taking care that no small pieces of gluten escape. The water carries away the starch, sugar, and soluble albuminoids, leaving the gluten behind as a tough mass. The mass should be gently kneaded every now and again. When the water runs away perfectly clear, stop the washing process and remove the gluten from the silk. Wash carefully again in the naked hand, and then squeeze all the water possible from the mass.

Dry the outside and weigh carefully. Multiply the weight by five, and that gives the percentage of wet gluten.

Example :

20 grammes of flour taken.
Weight of wet gluten = 7·56 grammes.
7·56 × 5.

$$\begin{array}{r} 7{\cdot}56 \\ 5 \\ \hline 37{\cdot}80 \end{array}$$

The sample (Bowyer & Priestley's Patent) contained 37·8 per cent. of wet gluten.

Examine the gluten so obtained to see whether it is very elastic and tenacious, and note whether the gluten breaks off easily. Mould into a little ball and allow to stand on a glass for twelve hours. Note if the ball has lost much of its shape and whether it has spread. Hard flours are characterised by tenacious gluten, hard to break, and by the fact that the gluten does not spread much when allowed to stand in the form of a ball. Gluten which runs much, and is easily broken, indicates a soft flour.

To ascertain the weight of dry gluten, place the gluten with the glass plate in the water oven, and allow it to remain there for twelve hours, the water in the oven boiling all the time. Remove, and when cool, rapidly weigh. Multiply the weight by five, and the result will give the percentage of dry gluten.

Thus in example quoted above the weight of dry gluten was 2·43 grammes.

2·43 × 5

$$\begin{array}{r} 5 \\ \hline 12{\cdot}15 \end{array}$$

The flour contained 12·15 per cent. of dry gluten.

By dividing the wet gluten by three a rough estimate is obtained of the dry gluten.

Miniature Baking Tests.—Though the tests described above give a good deal of information about the flour, yet the best plan is to make a small baking trial, using the oven under ordinary baking conditions.

A convenient quantity to take is 3½ lbs. of flour, and proceed in the method to be followed in larger batches. Care must be taken to ascertain the *weight* of water used in ounces, and that may be conveniently done by using the ounce measure or a burette graduated to ounces.

The dough having been got ready, is moulded up into loaves and scaled in the usual way, and after baking the yield, colour, texture, boldness, and flavour may be noted. In the operations the way in which the flour works in the sponge or dough should be noted.

The following table gives the equivalent per sack when 3½ ozs. are used:

OUNCES OF WATER.		QUARTS PER SACK.	OUNCES OF WATER.		QUARTS PER SACK.
24	...	48	30½	...	61
24½	...	49	31	...	62
25	...	50	31½	...	63
25½	...	51	32	...	64
26	...	52	32½	...	65
26½	...	53	33	...	66
27	...	54	33½	...	67
27½	...	55	34	...	68
28	...	56	34½	...	69
28½	...	57	35	...	70
29	...	58	35½	...	71
29½	...	59	36	...	72
30	...	60			

Example.—Suppose a flour takes up altogether 32½ ozs. of water. By table, 32½ ozs. of water equal 65 quarts per sack.

To estimate yield weigh the total bread produced when cold. Reduce this to pounds and multiply by 80. Then divide by four, and the result will be the number of *nett* quarterns which a sack will give.

Example.—3½ lbs. of flour in a small baking test produced 4·8 lbs. of bread.

Then multiply 4·8 lbs. by 80 :

$$\begin{array}{r} 4{\cdot}8 \times 80 \\ 80 \\ \hline 384{\cdot}0 \end{array}$$

Cross off the 0 on right for the decimal place.
This gives 384 lbs. of bread per sack.
Divide 384 by 4 :

$$\begin{array}{r} 4)384 \div 4 \\ \hline 96 \end{array}$$

The flour yields 96 nett quarterns, and, of course, 192 2-lb. loaves.

CHAPTER XXVIII.

YEAST, BAKING POWDER, SUGAR, MILK, MALT EXTRACT, ALUM, WATER.

YEAST.—The microscopical examination of yeast has already been dealt with. But there are two tests which may be conveniently applied—one for starch and the other for gas-producing power.

Test for Starch.—Place a small portion of compressed yeast in a large test tube, and add a little water. Thoroughly break it up in the water and boil for a few minutes. Filter until a fairly clear filtrate is obtained. To a *cool* portion of the filtrate add iodine solution. A bluish colour, which disappears on boiling, indicates presence of starch.

(*Note.*—The indigo blue is not always well marked, as sometimes other bodies come through, which give *brown* reactions with iodine. But any marked *lightening* of the dirty colour on boiling certainly indicates starch).

Gas-producing Power.—This is ascertained by measuring the quantity of gas which a given weight of yeast will produce from a known volume of a suitable yeast food. The author has found the following mixture to answer all ordinary purposes:

9 grammes best cane sugar.
½ gramme phosphate of potassium
½ gramme phosphate of ammonium.
100 c.c. of distilled water.

For every test 50 c.c. of the mixture should be taken.

The apparatus required is shown in Figure 74, and may be easily fitted up from ordinary flasks, glass tubing and corks.

A is a block of wood which receives the part of the apparatus marked K.

B is a tripod stand carrying a vessel D containing water.

C is a Bunsen burner to heat the water.

E is a glass flask of 100 c.c. capacity, fitted with an india-rubber cork carrying a bent delivery tube F.

G is a small piece of india-rubber tubing joining the tube F to H.

H is a bent delivery tube passing through the cork of the jar K.

K is a glass jar containing two apertures, one at the neck and the other near the bottom. Both openings should be fitted with single hole india-rubber corks. The capacity should be at least 500 c.c. The form of jar known as a small aspirator will do admirably.

L is a glass tube, bent so as to fit the hole of the cork at one end, and to form a spout at the other. This tube should fit perfectly, and be capable of moving up and down.

M is a jar to catch the water which drops from L.

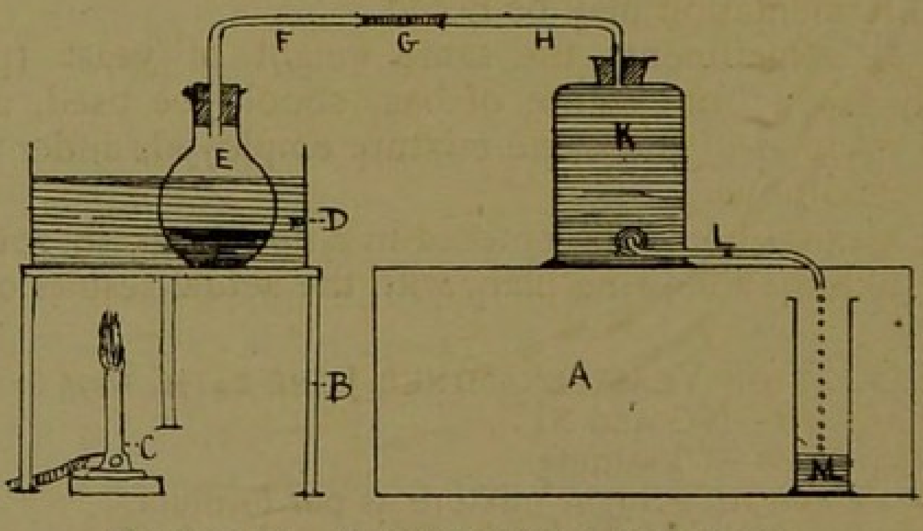


FIGURE 74.—YEAST-TESTING APPARATUS.

The test is made as follows :—Push up the tube L until the spout is above the neck of the bottle K. Fill K with water, and fit in the cork and delivery tube H. Fit on delivery tube F (which should carry the cork of flask E at the end) by means of piece G. Introduce into flask E standing in vessel D 50 c.c. of sugar solution and 1 gramme of yeast (previous to the introduction of yeast break it up carefully in a little distilled water), and immediately firmly insert the cork. Lower the glass tube L, and place jar M under spout. A little water escapes at first, but if the apparatus is accurately fitted none flows out after the first few drops. If there should be any continuous escape from the first there is a leak somewhere in the joints. It is necessary that the whole apparatus should be air-tight, for reliable results to be secured.

The water in the vessel D should be near a temperature of 85°F., and a little experience will soon enable the operator to regulate the gas flame, so as to keep the temperature of water constant.

Soon fermentation begins, and CO_2 is evolved, which gradually forces the water from the vessel K through tube L into jar M. The action should be allowed to go on for six hours.

The quantity of gas given off may be roughly ascertained by *measuring* the water in the jar M. Suppose the jar contains 450 c.c. of water, then 450 c.c. of gas has been given off. By measuring hourly the *regularity* of the fermentation may be noted.

In all experiments the same weight of yeast (preferably taken from centre of bag) should be used, and equal volumes of the same mixture employed, under the same conditions.

All results should be entered in a note-book in something like the following plan, with the actual results of a test:

SAMPLE OF YEAST EXAMINED JUNE 24TH, 1895:

Name of yeast—NG and SF.
Quantity taken—1 gramme.
Mixture employed—Sugar mixture as per formula.
Temperature of bath—Maintained from 85° to 87°F.
Gas in c.c. per hour, as measured by the water in the jar:

1st hour	69 c.c.
2nd hour......	88 c.c.
3rd hour	91 c.c.
4th hour	98 c.c.
5th hour	99 c.c.
6th hour	84 c.c.
Total gas in six hours ...	529 c.c.

Examination for starch—None.
Microscopical examination—Cells well defined, healthy looking, and free from each other. No shrunken cells observable. Very few bacteria present.

Remarks--A sound healthy yeast, free from starch and foreign ferments, of great strength and regularity of action.

The value of the tests for gas-producing power is chiefly for comparative purposes.

Baking Powders.—The chief point of interest to the baker is the gas-producing power of the powder.

Gas Producing Power.—The apparatus shown in Figure 75 will be required.

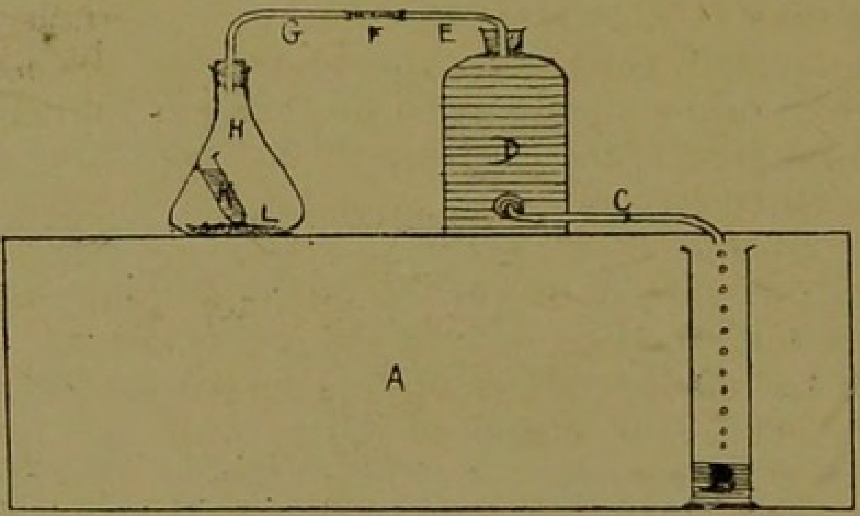


FIGURE 75.—APPARATUS FOR TESTING BAKING POWDER.

A is a block of wood to receive apparatus.

B is a jar to receive water from the vessel D.

C is a delivery tube made in the same form as the one marked L in Figure 74 previously described.

D is a small jar the same size as that recommended for use in Figure 74.

E is a delivery tube bent at right angles.

F is a piece of indiarubber tubing joining G to E.

G is the delivery tube of flask H bent at right angles.

K is a small test tube of such a size that it will stand in the flask H without falling. The diagram shows it filled with water ready for the test.

L is the baking powder at bottom of flask H.

The test is made as follows. Raise the tube C until it is perpendicular. Fill jar D with water. Fit in the cork and delivery tube E. Weigh out one gramme of baking powder, and introduce into flask H. Nearly fill small test tube K with boiling water. Introduce the tube K full of water into flask H, *without spilling any of the contents*, and rest the tube against the side of flask as shewn in

Figure 74. Carefully fit in cork carrying the delivery tube G. Join G to E by indiarubber tube F. In all these operations care must be taken not to upset tube K. Push down tube C, and when the water ceases to run, place jar B under spout. Now tilt jar H, until the water runs out and covers the powder L, and allow the apparatus to stand for one hour. The moment the hot water comes in contact with the powder, the gas is given off and drives the water from D into the jar B. When all action has ceased the volume of water gives approximately the volume of gas given off by 1 gramme of the baking powder under the conditions of the experiment.

If desired *cold* water may be used, but the results are not so reliable.

All tests should be carried out under the same conditions and noted as follows, the results given being an actual test made with Cerebos baking powder and sodium bicarbonate and cream of tartar with the apparatus described above.

COMPARATIVE TEST MADE ON JUNE 21ST, 1895.

Name of Powder—Cerebos baking powder.

What Tested against—Ordinary mixture of sodium bicarbonate and cream of tartar.

Temperature of Water—60° F.

Weight of Powder—1 gramme.

Length of Time allowed—One hour.

Volume of CO_2 *as* measured by water in jar—80 c.c.

TEST WITH THE MIXTURE OF BICARBONATE OF SODIUM AND CREAM OF TARTAR UNDER THE SAME CONDITIONS.

Volume of CO_2 *as* measured by water in jar—58 c.c.

Value of Cerebos Baking Powder over Mixture equals 22 c.c. per gramme.

As in the case of yeast these results are only of value when used comparatively.

Cane Sugar.—The chief points of importance are the percentage of moisture, the presence of mineral matter, and the adulteration with glucose. It is important on the score of economy that the sugar should not contain too much water, and all other things being equal, the sugar which contains the least moisture is the best. The presence of mineral matter shows an inferior grade of sugar, and the addition of glucose lowers the sweetening power.

Moisture.—Weigh out 10 grammes of the sugar. Dry for twelve hours in a water oven. Weigh again. The loss of weight equals the water in 10 grammes. Multiply by ten, and the percentage is found. The percentage in good sugars varies from 2 to 5 per cent.

Mineral Matter.—A simple test is the following:—Dissolve 20 grammes of the sugar in 80 c.c. of distilled water, and pour into a tall conical glass. Allow to stand undisturbed for twelve hours. Any insoluble mineral matter will sink to the bottom of the glass, and may be readily distinguished.

Glucose.—Weigh out 2 grammes of sugar and dissolve in 8 c.c. of water. Filter the solution. To a portion of the filtrate add a little Fehling's solution and boil. A red precipitate shows the presence of glucose.

The most extensive fraud practised is, however, the substitution of the inferior products of the refinery for the better qualities of sugar. These lower products are usually light in colour, and the crystals are very small. They have a high percentage of moisture, and possess far less sweetening power than pure cane sugar.

The following test is a very useful one: Weigh out 50 grammes of the sugar. Dissolve in 500 c.c. of water. Raise the solution to about 70° F. and pour into a tall glass jar. When the solution has cooled to 60° F., test with the hydrometer. The nearer the specific gravity is to 1040, the better the quality of the sugar, supposing it to be free from glucose.

In Twaddell's hydrometer the specific gravity of 1040 is shown when the stems stand at No. 8.

Milk.—Whole milk may be tested roughly as follows:

Cream.—Thoroughly stir the milk and pour into the measuring glass (illustrated in Fig. 68A.) until the milk stands level with 100 cc. Allow to stand for twenty-four hours in a moderately warm place. During this period the cream rises, and should at least occupy 12½ divisions of the glass. Special glasses are sold for this purpose, known as Creamometers. If the cream occupies less than twelve divisions out of the hundred, the milk has probably been robbed of part of its cream.

Addition of Water.—This may be sometimes detected by the hydrometer. Good milk varies from 1028 to 1032 at 60° F in specific gravity. The addition of water to whole milk lowers the specific gravity.

To make the test pour the milk into a tall glass and raise to 60° F. Float the hydrometer and note the number. If the specific gravity falls below 1026 water may have been added. Special hydrometers for milk are sold under the name of lactometers.

Another test is to weigh out 10 grammes of milk into a porcelain dish, the weight of which is known, and to dry for twenty-four hours in the hot-water oven.

When cool weigh again and the loss of weight multiplied by ten, gives the percentage of water. In good milk this varies from 85 to 86 per cent.

If the percentage rises above 88, water has been added.

Example:

Weight of dish ...	49·216	grammes
Weight of dish and milk	59·216	,,
Weight after drying for 24 hours in oven	50·595	,,
Loss of weight ...	8·621	,,

8·621 multiplied by 10

$$\begin{array}{r} 8{\cdot}621 \\ 10 \\ \hline 86.21 \end{array}$$

The milk contains 86·21 per cent. of water.

When the creamometer and hydrometer are used the following data will be found useful:

Creamometer above 12 Hydrometer above 1026		Pure milk.
Creamometer below 12 Hydrometer above 1032		Cream abstracted; no water added.
Creamometer below 12 Hydrometer below 1026		Water added.

Alum.—For the detection of alum in flour the following test may be employed:

Weigh out ¼ oz. flour and measure ½ oz. water into a white porcelain dish. Add 10 c.c. of the logwood preparation and 10 c.c. of the ammonium carbonate solution. Thoroughly mix the four ingredients, and smooth with a spatula. Place dish in the hot water oven for two hours. When cool note the colour. Pink shows pure flour. Blue or deep violet shows the presence of alum.

Alum in Bread may be tested for as follows:

Cut a *very thin* slice of bread and place in a shallow vessel. Measure out 10 c.c. of the logwood and 10 c.c. of the ammonium carbonate and rapidly mix, adding 180 c.c. of water, and immediately pour over the slice of bread, seeing that it is thoroughly saturated. Allow the bread to soak for a few moments and then pour off the liquid, and dry in the oven for two hours. A violet, lavender, or blue tint shows the presence of alum.

Alum is more likely to be present in self-raising flours and in baking powders. It is important therefore for those who extensively use these to occasionally test the bread produced in the manner described.

Diastase.—The following test has been found by the author to be a reliable qualitative test for the presence of diastasic bodies in extracts. Prepare a little starch solution, and dilute the extract down to a workable degree. Take three test tubes of the same size and add to each 10 c.c. of the diluted extract and label *a*, *b*, *c*, respectively. Boil *a* for a few minutes, to destroy diastase. When cool add to *a* and *b* 10 c.c. of starch solution. To *c* add 10 c.c. of water. Stand all three tubes for four hours in warm water. (Temperature should be kept at 150° F.) When cool add to each 5 c.c. of iodine solution and compare the colours carefully.

In *a* you have the colour of *unaltered* starch and the extract when acted on with iodine. In *c* you have the colour of the extract alone when acted on with iodine.

It is clear that if the extract contains diastasic bodies the starch in *b* will be converted into sugar, and will therefore not give the characteristic blue of iodide of starch, but the contents of the tube will approximate to *c* in colour, and be quite unlike *a*. Should the extract, however, not contain diastasic agents, the starch will remain *unaltered*, and will therefore give a bluish tinge to the solution, and the colour will be identical with the tube *a*.

In this test it is necessary that the temperature should not rise above 150° F. while the starch is being acted on by the extract.

Water.—The following tests may be applied to ascertain the comparative purity of water:

Odour.—Pure water should give off no appreciable odour. To test the smell of water, proceed as follows:—Pour a little water into a glass flask, add a little caustic potash, cork up tightly and gently heat for a few minutes, and uncork quickly, applying the nose to the mouth of the flask. An unpleasant odour indicates impure water.

Colour.—Fill a tall jar with water, and place on a white piece of paper. Look *down* at the paper through the water. A decided greenish-brown hue may indicate impure water.

Ammonia.—To a little of the water add a few drops of Nessler's reagent. If a yellowish or reddish precipitate appears within an hour the water has been probably contaminated.

Organic Matter.—In a large porcelain dish measure out 50 c.c. of water, and evaporate in the oven. When reduced to about 10 c.c. add another 50 c.c., and evaporate to dryness. Place the dry dish on the sand bath and heat by means of a Bunsen. If a brown colour appears on the dish organic matter is present, and the water is impure.

Another test may be made as follows:—Thoroughly clean two glass vessels of the same size. Prepare a solution of permanganate of potash by dissolving the crystals in distilled water. The colour should be a very dark magenta. Nearly fill one of the vessels (*a*) with water known to be pure, like distilled water from a chemist's, and the other (*b*) with the same volume of the water to be tested. Add to the pure water sufficient permanganate solution to make the whole a light ruby colour. To the other add exactly the *same quantity* of the permanganate solution. Add to each 5 c.c. of sulphuric acid, cover the vessels, and allow to stand for a week. Compare the colour of the flasks every day by placing a piece of white paper behind. In *a* there will be no appreciable loss of colour, and it thus forms a standard of comparison. The purity of the sample under examination may be roughly gauged by the rapidity with which the colour disappears. If the water is fairly pure there will only be a slight loss of colour in a week. But should the colour disappear to any extent before that period the water is impure. If the red tinge entirely disappears in a week the water is very impure. Should the colour go in twenty-four hours the water is highly charged with impurities. This test should not be applied to water which is known to contain iron.

APPENDIX I.

ANALYSES OF ROLLER MILL PRODUCTS.

From the Albert Bridge Mills, Battersea, London, S.W.
(Messrs. Marriage, Neave & Co.)

	Moisture.	Gluten.	Fat.	Fibre.	Ash.	Sol. Albuminoids.	Carbo Hydrates.
Uncleaned wheat ...	11·92	11·89	1·64	2·75	1·71	1·82	68·27
Cleaned wheat ...	11·24	12·02	1·73	2·21	1·49	1·93	69·38
Throughs—							
1st Break... ...	11·62	6·21	1·42	3·82	1·14	1·92	73·87
2nd and 3rd Breaks	11·82	7·24	1·23	3·21	1·02	·83	74·65
4th and 5th „	12·02	8·02	1·02	1·81	·85	1·08	75·20
6th Break ...	12·01	4·21	1·52	2·91	1·23	1·23	76·89
Tailings—							
1st Break ...	11·48	6·21	1·42	3·21	1·58	1·38	74·72
2nd „	11·34	6·82	1·62	4·52	1·70	1·32	72·68
3rd „	11·21	7·82	1·35	4·89	1·82	1·48	71·43
4th „	11·32	7·94	1·56	6·73	2·35	1·98	68·12
5th „	11·21	4·82	1·29	8·58	3·89	1·93	68·28
6th „	11·42	Trace	1·95	11·73	4·52	2·08	68·30
Semolina	12·02	9·21	·87	1·98	1·31	1·02	73·59
Flours—							
1st Break... ...	10·81	5·02	1·12	1·38	·82	1·63	79·22
2nd „	10·72	6·21	1·02	·89	·68	1·38	79·10
3rd „	10·69	6·89	1·02	·82	·71	1·02	78·85
4th „	10·52	7·21	1·21	·78	·68	1·32	78·28
5th „	10·58	7·38	1·08	·76	·69	1·58	77·93
6th „	10·98	7·92	1·21	·76	·62	1·03	77·48
Patent Grade ...	11·82	10·21	1·31	·21	·48	1·28	74·69
Bakers	11·04	12·45	1·98	·43	·72	1·58	71·80
Low	11·78	4·21	2·46	1·04	2·01	1·98	76·52
Pollard	12·18	Trace	1·65	17·21	6·42	1·42	61·12
Bran	12·21	Trace	1·89	19·89	7·62	1·68	56·71
Germ	13·21	None	12·82	2·82	4·21	10·58	56·36

APPENDIX II.

COMPOSITION OF VARIOUS BREADS.

Bread.	Water.	Carbo-hydrates.	Proteids.	Fat.	Fibre.	Ash.
White Bread	40·25	50·19	7·48	·78	·47	·83
Wholemeal Bread	40·25	42·93	11·85	1·63	1·89	1·45
Decorticated Bread	40·25	43·74	11·95	1·71	1·12	1·23
Hovis Bread	40·25	41·82	13·21	2·38	·85	1·49
Cytos Bread	40·25	41·68	13·32	2·36	·87	1·52
Malted Bread (Montgomerie's)	40 25	29·34 (insol.) 17·79 (sol.)	9·07	1·01	1·01	1·53
Milk Bread	40·25	48·25	8·95	1·03	·48	1·04
Limewater Bread (Black's) ...	40·25	45·25	12·21	·82	·45	1·02
Rye Bread	40·25	49·74	7·78	·52	·46	1·25
Triticumina Bread	40·25	32·25 (insol.) 13·21 (sol.)	10·21	1·62	1·14	1·32
Diastase Bread (Fletcher's) ...	40·25	35·59 (insol.) 14·58 (sol.)	7·46	·79	·48	·85

APPENDIX III.

PREPARATION OF REAGENTS AND MATERIALS.

Embedding Mixture for section cutting :

Solid Paraffin	...	4 parts.
Lard ...	...	1 part.

Carefully melt and thoroughly mix at a low temperature, and store in a gallipot for use.

Iodine Solution.—Dissolve 1 gramme of iodide of potassium in 100 c.c. of water, and dissolve sufficient iodine crystals in the solution to make the whole a dark sherry colour.

Ammonium Carbonate.—To make a saturated solution of ammonium carbonate dissolve the solid in distilled water until no more will dissolve, taking care to leave about half-an-inch of undissolved crystals at the bottom of bottle.

Logwood Solution.—Place some logwood chips in beaker, add a little good methylated spirit, and stand the mixture in hot water. When the spirit is coloured a dark yellow brown, filter off the liquid, and allow to cool. Keep in a stoppered bottle for use as required.

Fehling's Solution.—Prepare the following three solutions :

Copper solution.—Dissolve 34·64 grammes of pure copper sulphate in 500 c.c. of water and store in a stoppered bottle.

Tartrate solution.—Dissolve 173 grammes of sodium potassium tartrate (Rochelle salt) in 500 c.c. of water.

Alkaline solution.—Dissolve 125 grammes of solid potassium hydrate in 500 c.c. of water and filter till clear.

Add the alkaline solution to the tartrate solution, store in a stoppered bottle, and label "Alkaline tartrate solution."

To make Fehling's solution mix equal volumes of the alkaline tartrate solution and the copper solution.

Litmus.—To make litmus solution dissolve the solid blue material in water. Acids turn the solution red. To prepare *red* litmus, add a little hydrochloric acid to a solution of blue litmus. Litmus paper may be prepared by cutting out oblong strips of filter paper, soaking in red or blue litmus, and carefully drying. When litmus papers are used they should be previously moistened.

Stain for Microscopic sections:

Logwood.—Prepare a solution of logwood by digesting logwood chips in hot water. Take 2 c.c. of logwood solution and add 8 c.c. of a solution of alum. This mixture forms the stain.

APPENDIX IV.

USEFUL DATA.

1 lb. avoirdupois ...	=	7,000 grains.
1 oz. " ...	=	437·5 "
1 gallon of water weighs		10 lbs.
1 gramme	=	15·43 grains.
1 gramme	=	·03527 ozs.
1 litre	=	1,000 c.c. or 1·76 pints.
1 litre	=	61·0270 cubic inches.
1 pint	=	34·65923 " "
1 c.c. of water weighs		1 gramme.

THERMOMETER SCALE.

Centigrade.		Fahrenheit.	Centigrade.		Fahrenheit.
0°	=	32°	105°	=	221°
5	"	41	110	"	230
10	"	50	115	"	239
15	"	59	120	"	248
20	"	68	125	"	257
25	"	77	130	"	266
30	"	86	135	"	275
35	"	95	140	"	284
40	"	104	145	"	293
45	"	113	150	"	302
50	"	122	155	"	311
55	"	131	160	"	320
60	"	140	165	"	329
65	"	149	170	"	338
70	"	158	175	"	347
75	"	167	180	"	356
80	"	176	185	"	365
85	"	185	190	"	374
90	"	194	195	"	383
95	"	203	200	"	392
100	"	212	205	"	401

GENERAL INDEX.

INDEX TO ILLUSTRATIONS.