U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 112.

BREAD
AND
THE PRINCIPLES OF BREAD MAKING

BY

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PREPARED UNDER THE SUPERVISION OF THE OFFICE OF EXPERIMENT STATIONS.
A. C. TRUE, Director.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., October 15, 1906.

SIR: I have the honor to transmit herewith an article on bread and the principles of bread making, prepared by Miss Helen W. Atwater, in accordance with instructions given by the Director of this Office. In preparing this bulletin Miss Atwater has consulted the available sources of information, including standard works on the subject, and has prepared the material for publication under the supervision of Director C. D. Woods, of the Maine Agricultural Experiment Station, who for some time has been immediately concerned with the investigations conducted under the auspices of this Office which have had to do with bread and bread making.

In preparing this revision of Farmers' Bulletin No. 112 the results of late investigations carried on by Professor Woods and by Prof. Harry Snyder at the Minnesota Agricultural Experiment Station have been incorporated.

Perhaps no topic connected with the subject of human food is of more general interest than bread, and this bulletin, which summarizes the most recent information on the subject, is believed to be useful and timely, and its publication as a Farmers' Bulletin is therefore respectfully recommended.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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BREAD AND THE PRINCIPLES OF BREAD MAKING.

INTRODUCTION.

There is hardly any food, except milk, which is so universally used as bread; and not only is it now known almost everywhere, but since history first began it has in some form or other made one of the staples of diet among all but the most savage peoples. In the earliest historical records it is spoken of, and the wild tribes which to-day inhabit South Africa know something of its use. Of course the bread made by the Kafir to-day, or by the American Indian three hundred years ago, is very different from our own. It would be interesting to trace the relationship between the bread-making processes of given peoples and their rank in the scale of civilization. The Kafir simply grinds his grain between two stones, makes a paste of this meal and water, and bakes it in the ashes of his camp fire; Israel, in Egypt, ate leavened bread; the ancient Greeks cultivated the yeast plant; in Pompeii an oven was found containing eighty-one loaves of bread not unlike our own; the Swiss peasant still bakes his weekly loaves in the village oven; and so on, to the mammoth bakeries and innumerable fancy breads of our own large towns. Such a classification would not be utterly absurd, for except among the lowest savages and in the extremest climates some kind of grain is recognized as a necessary food, and bread furnishes it in one of its most convenient forms—that is, a form in which it yields the greatest amount of nourishment for the least labor and cost. No wonder, then, that the more intelligent a people the better bread they make.

The reason for this importance of bread is very simple. Ever since the far-off days when our forefathers first found the wild cereals, or began to cultivate them, men have known that food prepared from them would support life and strength better than any other single food except milk. The diet of the poor in India and China often consists almost entirely of wheat or millet cakes or rice, and altho in our own land the ease with which we can get other food makes bread seem less important, there are still many districts in Europe where the people eat very little else. To a large part of mankind it is still the staff of life, and if they pray for their daily bread they mean it literally.

In regard to its ingredients, bread is one of the simplest of our cooked foods, but in regard to the changes which the raw materials must undergo to produce a finished loaf, it is one of the most complicated. Flour, water, a pinch of salt, and a little yeast—the necessary things can be counted on the fingers of one hand, yet one of the few books which describes the processes of bread making with any degree of completeness is a large volume of over 600 pages. It is the purpose of this bulletin to give a brief account of these processes—to describe the raw materials from which the bread is made, and the changes which they undergo in the preparation and baking of the dough, with the significance of each to the quality of the bread and its value as food. But before going into a detailed description of these processes it will, perhaps, be well to recall what the main steps in bread making are.

Beginning back in the flour mill, the grain is ground into powder, the coarser, outer parts of which are sifted out as bran, while the finer, interior parts constitute our flour. Once in the baker's hands, the flour is mixt with water and yeast, or something which will produce the same effect. When this paste or dough, containing yeast, is set in a warm place the yeast begins to "work," as we say, and the dough to "rise;" in other words, the yeast causes a change known as alcoholic fermentation to set in, one of the principal results of which is the production of carbon dioxid gas. If the dough has been well mixt, this gas appears all thru it, and, expanding, leavens or raises it. After the yeast has worked sufficiently the dough is shut up in a hot oven. Here the heat kills the yeast and prevents further alcoholic fermentation, causes the gas to expand and stretch open the little pockets which it forms in the dough, changes some of the water present into steam, and expands any air mechanically included, thus raising the loaf still more. Further, the heat hardens and darkens the outer layers into what we call the crust. The sum of these changes in the oven we call baking. When this has been continued long enough our bread is "done," and is ready to cool and eat.

GRAINS AND FLOURS.

Flours, as everyone knows, are made by grinding the grains of the various cereals—wheat, rye, barley, oats, maize, millet, rice, etc. Of these, wheat is the most important, partly because it can be cultivated in any temperate climate, but chiefly because it yields the flour best suited to bread making, the aim of which is to produce the most appetizing and nutritious loaf at the least expense. While the various cereals differ largely in their chemical composition, most of them are very similar in the structure of their grains, so that if we study the formation and milling of wheat, we can easily understand the production of flour from the others.

WHEAT.

Structure.—The wheat grain (fig. 1) is a small oval seed, which can be easily thrashed from the stalk on which it grows. Its five outer layers are known as the bran. Of these, the three outermost form what is called the skin of the grain, and constitute 3 per cent, by weight, of the entire seed. The two remaining layers of the bran form the envelop of the seed proper. The outer one is known as the "testa," and contains the greater part of the coloring matter of the bran. Inside it lies a thin layer of membrane. These two together form 2 per cent, by weight, of the entire grain. The layer next to the bran is called the cereal or aleurone layer. Its weight is about 8 per cent of that of the entire grain, making the total weight of the bran and aleurone layer together about 13 per cent. In milling it is exceedingly difficult to separate these three inner layers. Within lie the starchy cells which, with the aleurone, constitute the endosperm. The starchy portion comprises the larger part of the grain and consists of irregular-shaped cells containing the gluten-forming proteids and starch granules. At the lower end of the grain, almost surrounded by the endosperm, lies the germ or embryo. A portion of the embryo is called the scutellum. When the grain has thoroly ripened and has been placed in favorable conditions, this embryo will develop into a new plant. As it begins to grow it will feed upon the starch and other substances in the endosperm.

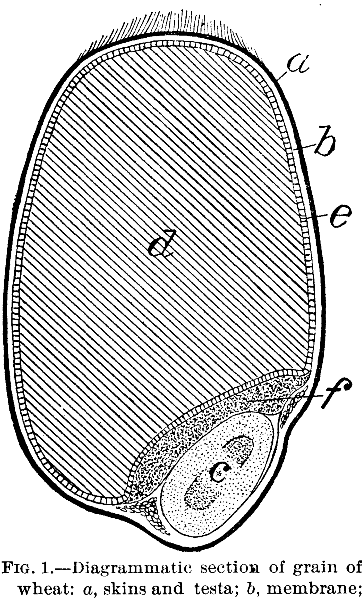

FIG. 1.—Diagrammatic section of grain of wheat: *a*, skins and testa; *b*, membrane; *c*, embryo; *d*, flour cells; *e*, cereal or aleurone layer; *f*, scutellum.

The different parts of a kernel of wheat are composed of cells varying in form and structure, but all too small to be seen except under a microscope. Figure 2 shows the cellular structure of a section of wheat cut from the surface into the endosperm, *a* and *b* being the two outer layers of the bran, *e* the rectangular cells which constitute the cereal or aleurone layer, and *f* some of the irregular cells which make up the floury portion of the endosperm. Each cell of the very large number making up the wheat berry is inclosed by a cell wall of woody fiber or cellulose, of which the thickness and character vary in different parts of the grain. Within each living cell is a network of nitrogenous material called protoplasm by the biologists, thickening toward the center of the cell into a nucleus, which is the center of cell life. Products formed by the plant, such as starch and fat, are stored in the portions of the cell not filled by this protoplasmic material. The character of the cell contents varies considerably in different parts of the wheat berry, starch being characteristic of the interior of the grain rather than the outer portions. The large rectangular cells of the cereal layer are filled with a nitrogenous material known as cerealin or aleurone. The cells of the germ, which are not shown in the diagram, contain considerable fat.

Flour is the most important product of wheat, and the character of the flour, as well as of the endosperm, is of especial interest in this connection. Figures 3 and 4 show diagrammatically the protoplasmic network (in this case gluten) of a single flour cell with its nucleus and the starch grains which would be embedded in the network. If we conceive of these figures (3 and 4) united so that the starch grains are embedded in the protoplasmic network, we have a picture of a single starch cell. The starch grains are of various sizes, and there are several hundred

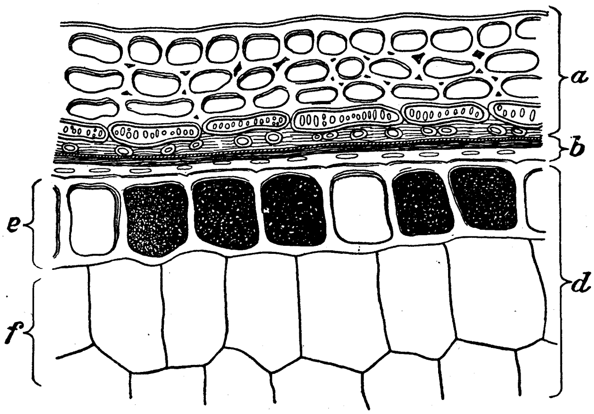

FIG. 2.—Cellular structure of a grain of wheat: *a*, skins and testa; *b*, membrane; *d*, endosperm, consisting of aleurone layer (*e*) and starch cells (*f*). (After Winton and Moeller.)

in a single cell, and from 10,000,000 to 20,000,000 in a kernel of wheat. In addition to starch, the flour cells contain mineral matter and a very small proportion of fat. These diagrams show clearly that the interior portion of the wheat berry consists of protein and starch, and not of starch only, as is sometimes claimed by popular writers.

Very interesting biological studies of individual flour cells have recently been made by N. A. Cobb in Australia[a], and the above discussion is largely based on his work.

The many changes which take place in the grain while it is stored, when it is made into flour, or when it germinates and begins to grow and form a new plant, are due primarily to changes in the cell protoplasm under different conditions. The character of the protoplasm

[a] Dept. Agr. N. S. Wales Misc. Pub. No. 539; also Jour. Dept. Agr. West. Aust., 9 (1904), p. 165.

varies in different parts of the kernel, indicating that each cell plays a different rôle in the function of the grain. Moreover, marked differences are found in the character of the cells of different varieties of wheat, and it is believed that wheats may be accurately classified according to the characteristics of their flour cells.

Composition.—The chemical composition of the protoplasmic cell network also varies in different parts of the grain, and chemists use different names to describe that in different sections. In general they speak of it as protein. That found in the inner layer of the bran is termed cerealin or aleurone, while that in the endosperm is composed of several individual proteins the chief of which are gliadin and glutenin.

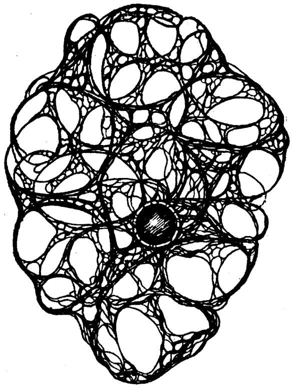

FIG. 3.—Diagram of protoplasmic structure of a flour cell. (After Cobb.)

Grain, being hygroscopic—that is, having the power of absorbing water from the atmosphere—varies with the weather in the amount of moisture which it contains; similarly, wheat grown in a wet season or a humid climate holds a larger percentage of moisture than the same kind grown under drier conditions. Thus English wheat contains on an average 3 or 4 per cent more water than American. From a comparison of many analyses the average weight of the water in the grain is found to be about 12 or 13 per cent of its total weight.

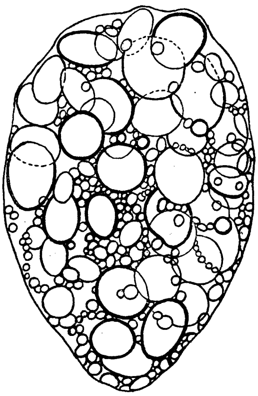

FIG. 4.—Diagram of starch grains in a flour cell. (After Cobb.)

As gluten is one of the most important factors in bread making, the baker should know the character of the gluten in the flour he uses. The so-called "hard" wheats yield a large quantity of gluten of a strong, tenacious character, while "soft" wheats yield less gluten and proportionately more starch. The gluten of hard wheat can hold large amounts of water, and produces a large loaf from a comparatively small quantity of flour. Soft wheat, on the other hand, while it does not yield so large a loaf, makes a bread containing less water and having a milder flavor.

It is useful for those interested in milling to know what parts of the grain will be most valuable both in yielding a nutritious flour and in making a well-raised loaf of good color. In considering the nutritive value of flour the principal kinds of nutrients which the body needs should be borne in mind: (1) The nitrogenous substances, called proteid compounds or proteids—typified by the white of egg and the lean of meat, and chiefly represented in wheat by the cerealin and the gluten—are the tissue-building materials of our food, tho they also furnish energy; (2) the carbohydrates, principally starch and sugars, found mainly in the endosperm, and serving the body as fuel to produce energy for warmth and muscular work; (3) the fats, occurring principally in the germ of the grain, and being valuable to the body as fuel; and (4) mineral matters found in the ash, especially that of the bran, and providing material for bones, teeth, etc. It will be remembered that it is not only the chemical composition of a substance which determines its food value, but also the amount of nourishment which the digestive organs can extract from it—in other words, its digestibility.

The abundant cellulose in the bran and the coloring matter in the testa tend, if left in the flour, to give it a coarse, dark character very detrimental to the appearance of the bread. Accordingly, until recently, that flour was quite generally considered the best which had the least of the bran in it. Lately, however, much stress has been laid on the nutritive value of the mineral matters and the cerealin of the bran; consequently a great effort has been made to get a fine flour which shall include the entire wheat grain. Such flour does not produce as white a loaf, and, what is more to the point, the bran portions are less thoroly digested by man than other parts of the wheat kernel. Moreover, the sharp, rough particles of the cellulose in the bran are said to irritate the membranes of the alimentary canal, and thus to hasten the passage of the food thru the intestines. This would tend to diminish its digestibility, altho it might be advantageous in counteracting a tendency to constipation. It would seem, then, that the value of bran in flour, as far as the nutrients are concerned, is extremely questionable. The germ, tho rich in fat and ash, is also of doubtful value in the flour, as it tends to darken the color and its fat readily grows rancid and injures the keeping quality and flavor.

The endosperm is by far the most important contributor to the flour. In it are found the starch and the gluten, the chief nutritive ingredients of bread. The gluten, the principal nitrogenous constituent of wheat, when mixt with water forms a tenacious, elastic body, which, together with the starch, produces what is called the dough that expands under the pressure of the gas and inclosed air until it is full of gas-filled holes; the tough gluten of their walls does not allow the gas to escape, and thus makes the dough light and porous. The more gluten a flour yields the more water it can be made to take up in dough, and the greater will be the yield in bread from a given amount of flour. Hence flours are classified as "strong" or "weak" according to the proportion and quality of the gluten and their consequent ability to yield bread. Gluten has also a high nutritive value as an easily digested proteid substance.

Milling.—When people first began to grind their grain they did so simply by crushing it between any two stones which happened to be handy; a little later they kept two flat ones especially for the purpose, one of which they soon learned to keep stationary while the other was turned about on it. At first each woman ground the meal for her own family on her own stone; but after treadmills, windmills, and, later, water wheels came into use all the grinding was done by the professional miller in the village mill. In feudal days the lord forced his tenants to have their grain ground in his mill, even to bake their bread in his oven, and charged a good round toll for the use of each. Various devices for grinding and sifting the grain have gradually been invented, until to-day we have mills covering acres of ground and doing apparently impossible things with the grain. In Hungary the old Roman system of cylinder milling, similar in principal to an ordinary coffee mill, has been developed, but elsewhere the systems which are known as high and low milling are more common. Here we have the original system of crushing between two stones or rollers, but so elaborated as to be almost unrecognizable. In low milling the grain is ground in one process between two crushers placed as near together as possible. Graham flour is commonly produced in this way. This milling product, invented by an American physician, Dr. Sylvester Graham, is really wheat meal containing all of the grain; it is made by simply washing and cleaning the grain and then grinding it between two stones or rollers, whose surfaces are so cut as to insure a complete crushing of the grain. In high roller milling the grain is washt and tempered. After removal of the bran, the stock is run thru five or even more pairs of rollers, each successive pair being set a little nearer together than the last pair. After each grinding, or "break," as the miller terms it, the fine flour is sifted out, and the leavings of each sifting, called "middlings," are themselves ground and sifted several times. In a mill where the grain goes thru a series of 6 straight breaks there are as many as 80 direct milling products, varying in quality from the finest white flour to pure ground bran. Careful millers always try to grind as near the aleurone layer as possible, and to leave as much of the germ in the flour as is consistent with a good color. To make sure that each product is up to the standard set up for it in the mill, samples of it are frequently tested and the milling is regulated accordingly.

The so-called "straight grade," "patent," "standard," and "household" flours, etc., found on the market are made by blending different milling products in such a way as to give the flour the desired characteristics. The modern roller milling retains a much larger proportion of the wheat berry, and gives a much smaller proportion of bran and other offal products, than the older methods of milling. Entire wheat flour is produced by high roller milling, and differs from ordinary flours mainly in that the inner sections of the skin, with the aleurone layer, are included.

The accompanying table shows the chemical composition of various milling products and American wheat flours. Such data might vary for different kinds of wheat, or for the same wheat grown in different regions, or in the same region in different seasons. But the analyses here shown are those for the given products all milled from the same lot of Minnesota hard spring wheat, hence they are all strictly comparable with one another.

Analyses of wheat and the products of roller milling.

Milling product.	Water.	Protein (N×5.7).	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
First patent flour	10.55	11.08	1.15	76.85	0.37
Second patent flour	10.49	11.14	1.20	76.75	.42
Straight or standard patent flour	10.54	11.99	1.61	75.36	50
First-clear grade flour	10.13	13.74	2.20	73.13	.80
Second clear grade flour	10.08	15.03	3.77	69.37	1.75
"Red dog" flour	9.17	18.98	7.00	61.37	3.48
Shorts	8.73	14.87	6.37	65.47	4.56
Bran	9.99	14.02	4.39	65.54	6.06
Entire-wheat flour	10.81	12.26	2.24	73.67	1.02
Graham flour	8.61	12.65	2.44	74.58	1.72
Wheat ground in laboratory	8.50	12.65	2.36	74.69	1.80
Gluten flour	8.57	16.36	3.15	70.63	1.29

If, as often happens, it is desirable to blend two kinds of wheat in order to obtain a flour with the average of their qualities, the grains are usually mixt before milling. Sometimes the miller, or even the baker, mixes two kinds of flour, but such a proceeding is less reliable.

Very complicated chemical tests are necessary to determine the exact quality of a flour, but there are certain general rules by which a good bread flour may be judged offhand. Its color should be white with a faint yellow tinge; after being prest in the hand it should fall loosely apart; if it stays in lumps it has too much moisture in it; when rubbed between the fingers it should not feel too smooth and powdery, but its individual particles should be vaguely distinguishable; when put between the teeth it should "crunch" a little; its taste should be sweet and nutty without a suspicion of acidity.

Impurities and falsifications of wheat flour.—Wheat flour is in general very carefully made. The impurities which may accidentally slip into a bag of grain, or even into the flour made from it, consist chiefly of the seeds of other plants, and of blighted or molded wheat. When flour is well milled they are entirely removed. The foreign seeds most to be dreaded are perhaps cockles and darnel, and both should be carefully guarded against—cockles because they injure the color of flour and bread, and darnel because it is commonly regarded as poisonous. Other foreign seeds may not be equally dangerous, but they should be removed with equal care, as they lessen the nutritive value and the strength of the flour. Molds and other fungus growths often give a musty odor and taste to grain or flour which has been kept in a damp place. Both these classes of impurities are easily and generally avoided by careful milling and storing, and are not so much to be feared as the foreign substances which may be added to the flour to cheapen its cost or improve its appearance. Those which have been used to cheapen the cost are usually rye flour, corn (maize) flour, rice meal, potato starch, and meals from various leguminous plants, such as peas or beans. They are not harmful in the food and sometimes improve the color of the bread; nevertheless they are fraudulent because they lower the quality of the flour without harming its appearance. When such a mixture is sold as flour the purchaser secures an adulterated article under a false name, and often at the same price as pure goods. Mineral substances, such as alum, borax, chalk, carbonate of magnesia, bone, etc., are occasionally put into the flour to whiten it or to neutralize its acidity, but as these are more often used by the baker than by the miller their effect will be discust later.

The Bureau of Chemistry[a] of this Department states that at the present time flour sold in the United States is almost never adulterated and that alum is not used by bakers to whiten bread. National legislation requires that all mixt or blended flours be marked and tared. However, it is stated that some adulteration is practised with special kinds of flour. For instance, untreated wheat flour is frequently sold for gluten flour, and indeed much of the so-called gluten flour on the market is not what it purports to be. Buckwheat flour and other special articles of a similar nature are also frequently adulterated with cheaper cereal products. As prepared in modern roller mills wheat flour is also one of the cleanest of human foods.

RYE.

The grain of rye is darker in color than that of wheat, but is otherwise similar in appearance. It differs, however, in one important particular—its gluten has not the same elastic, tenacious quality and does not yield so light and well-raised a loaf. Altho this fact and its dark color make it less desirable than wheat flour, it is second in importance as a breadstuff. It is more easily cultivated than wheat, especially in cold countries, and consequently costs less. In many

[a] U. S. Dept. Agr., Bureau of Chemistry Bul. 100, p. 19.

parts of Europe it practically replaces wheat among the poor, and in the rations furnished the army. When it is milled entire, as it usually is, it contains more protein than wheat flour, but is probably less completely digested. Wheat and rye flour are often used together in bread.

BARLEY AND OATS.

These cereals are so seldom used in bread that a short description of them will suffice. In general structure their grains are not unlike those of wheat and rye, but their composition differs noticeably. In barley the bran makes up about 21 per cent of the entire grain; in oats, about 44 per cent. Both contain much less moisture than wheat. They do not contain any true gluten (which appears only in wheat and rye), and altho their other nitrogenous ingredients make them comparatively rich in proteid nutrients, they do not yield a light, attractive loaf. Bread made from them also contains a large amount of indigestible cellulose.

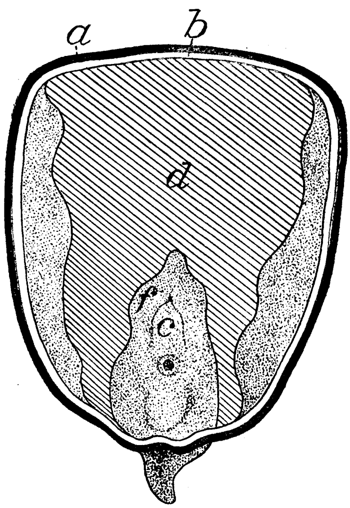

FIG. 5.—Diagrammatic section of grain of corn: *a*, skin and testa; *b*, membrane; *c*, embryo; *d*, endosperm, *f*, scutellum.

CORN, OR MAIZE.

This cereal, commonly known to us as Indian corn, and on the continent of Europe as maize or Turkish wheat, is a native of America. It is commonly grown in North and South America, northern Africa, India, and southern Europe, especially Italy and the Balkan regions, and is slowly being introduced into other European countries. The hull of the kernel is thin and tender, the endosperm abundant, white, and mealy, the germ comparatively large. The diagrammatic drawing of a section of a kernel of corn (fig. 5) shows the distribution of the several parts and the relative proportion of each. Figure 6 shows the character of the cells making up the skin and testa, membrane, and endosperm. Each cell has an outer wall of cellulose varying somewhat in thickness and character in the different parts of the grain. Within the cell is a proteid network and the cell nucleus, starch and other products of cell activity being embedded in this protoplasmic material. The character of the cell contents varies in different parts of the grain, the cells in the endosperm being characterized by the presence of large amounts of starch and those in the germ by fat. The kernels are generally white or yellow. Compared with wheat, maize is rich in fat, poorer in cellulose and protein, and about equal in carbohydrates, mineral matters, and moisture. Most of its fat is in the embryo or germ, which in milling is often removed to prevent the flour or meal becoming rancid. Maize flour makes very nutritious and appetizing unleavened bread, hoecake, johnnycake, etc., but this dries so quickly it must be eaten fresh. Since maize flour contains no tenacious, gluten-forming proteins it can not be used alone to produce a good loaf raised with yeast. Much corn bread and other foods made from corn meal are eaten in the United States. In Italy corn-meal mush, or "polenta," as it is called, forms the principal article of diet

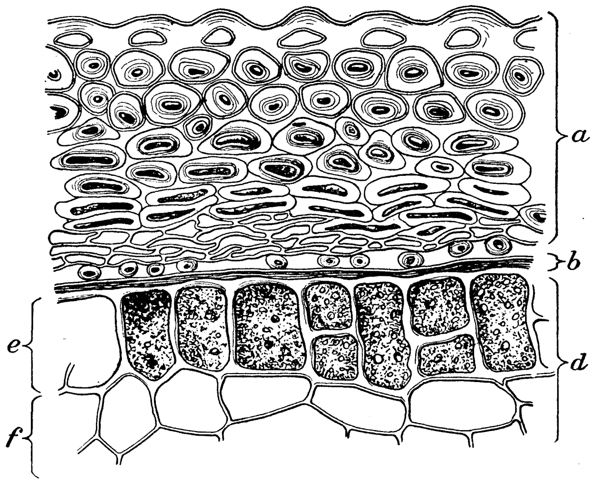

FIG. 6.—Cellular structure of a grain of corn: *a*, skin and testa; *b*, membrane; *d*, endosperm consisting of aleurone cells (*e*), and starch cells (*f*). (After Winton and Moeller.)

of the peasants, in large districts thruout a considerable part of the year. In Servia the unripe corn is eaten much as we use it, and corn-meal bread and mush are staple articles of diet.

RICE, MILLET, BUCKWHEAT, ETC.

Rice is a very important cereal in China, Japan, and other oriental countries; much millet is eaten in China, India, and Russia; sesame is also largely used by the native races of India, and in the United States buckwheat is often made into batter cakes; but none of these as a rule takes the place of bread to any extent except in some oriental countries. In some regions of Russia, however, buckwheat porridge is the principal cereal food. Kafir corn is used in the United States to a limited extent for batter cakes, etc., but in its native land it is the principal cereal of large numbers of Abyssinians, Kafirs, and other races.

The following table gives figures by which the chemical composition of our most common cereals may be easily compared:

Composition of cereals.

	Water.	Protein.	Fat.	Carbohydrates.		Ash.
				Starch, etc.	Crude fiber.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Barley	10.9	12.4	1.8	69.8	2.7	2.4
Buckwheat	12.6	10.0	2.2	64.5	8.7	2.0
Corn (maize)	9.3	9.9	2.8	74.9	1.4	1.5
Kafir corn	16.8	6.6	3.8	69.5	1.1	2.2
Oats	11.0	11.8	5.0	59.7	9.5	3.0
Rice	12.4	7.4	.4	79.2	.2	.4
Rye	11.6	10.6	1.7	72.0	1.7	1.9
Wheat:						
Spring varieties	10.4	12.5	2.2	71.2	1.8	1.9
Winter varieties	10.5	11.8	2.1	72.0	1.8	1.8

YEAST AND OTHER LEAVENING AGENCIES.

THE THEORY OF FERMENTATION.

When, in beer making, a little yeast is put into a vat of warm, sweet liquid, bubbles gradually appear until the whole mass seems to be boiling. If the liquid is analyzed after the yeast has so worked in it for a time it will be found to contain less sugar than at first; the amount of yeast will have increased, and alcohol and carbon dioxid will appear in considerable quantities. The explanation is this: The yeast, which is really a mass of tiny plants, has reproduced again and again, and in this growth has fed upon the sugar of the liquid and given off alcohol and carbon dioxid. Such a phenomenon is called alcoholic fermentation, and is essentially the same as that which "raises" a loaf of bread. Such fermentation is by no means the only kind which occurs in common life. The souring of cider into vinegar, for instance, is due to another kind. In that case a variety of microscopic plant develops in large numbers in the cider, and in so doing produces, first, alcohol, and then acetic acid, which gives vinegar its characteristic taste. This latter process is called acetic fermentation. Similarly, if another variety of bacteria gets a chance to develop in sweet milk they give rise to lactic fermentation, during which is produced the lactic acid which turns the milk sour. Rancidity of butter is due to the so-called butyric fermentation. Here the bacteria yield butyric acid, which gives such butter its disagreeable taste and odor.

These microscopic plants and many others are widely distributed in the air, and often find their way accidentally into different materials, where they grow and multiply, causing fermentation, just as thistle seeds, for instance, are blown about in the air until they lodge in some favorable spot and grow. At other times special forms of ferments in so-called "pure cultures" are purposely added to some material, just as seeds of larger plants are purposely sown in the garden. Thus pure cultures of certain microscopic organisms are added to cream to improve the flavor of butter and make it uniform in quality. This insures a special fermentation instead of the accidental fermentation which would otherwise occur. The term "fermentation" was first applied to the action of yeast plants on sugar with the formation of carbon dioxid and alcohol. There is another class of chemical changes to which the term "fermentation" is applied. Such changes are produced by chemical substances called enzyms, which are not living organisms, but which are produced by living organisms. Ferments are therefore divided into two classes, (1) the organized ferments, such as yeast, bacteria, etc., and (2) unorganized ferments, or enzyms. Human saliva contains an enzym called ptyalin. When mixt with food in the mouth it changes starch into a form of sugar, which is more easily digested than starch. In grain there exists an enzym called diastase, capable of producing a similar effect on starch. The pepsin and trypsin of the digestive juices are also enzyms.

It is a peculiar feature of fermentation that the microscopic plants which cause it affect a much larger amount of the material on which they feed than goes to their own development, and this in spite of the rapidity with which they multiply. Thus yeast converts much more sugar into alcohol and carbon dioxid than it consumes in its own growth and reproduction. When the fermentation ceases the yeast plant remains; in other words, the fermentation has been produced without changing the nature of the agent producing it. In the same way the enzyms cause fermentation without being themselves changed. Tho so much has been learned in recent years concerning fermentation, there still remain many things to be explained. We know what changes take place and under what conditions, but just why they take place is not so clear. It is a remarkable fact concerning ferments that in time the substances they produce put a stop to their activity. Thus the alcohol produced by the yeast is in time sufficient to hinder the growth of the yeast plant and ultimately to kill it. If, however, the products of this activity are removed, the ferments resume work, even tho the yeast itself is killed.

YEAST.

Keeping the above facts in mind, it is easy to understand the leavening effect of yeast in dough. The yeast, "working" in the warm water and flour, feeds on sugar[a] originally present or else produced from the

[a] The sugar upon which yeast is said to feed in its growth is not necessarily such sugar as we ordinarily use to sweeten our food. The word sugar is here used in its broader, scientific sense. All starches and sugars, it will be remembered, are grouped together by chemists under the name of carbohydrates. They are chemical compounds of carbon, oxygen, and hydrogen, and differ from each other in the proportion of oxygen and hydrogen to carbon which they contain. For a more extended discussion of sugar see U. S. Dept. Agr., Farmers' Bul. 93.

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starch by diastase, grows and spreads thruout the dough, at the same time giving off carbon dioxid gas, which forces its way between the tenacious particles of gluten and lightens the dough.

Scientifically speaking, yeast is a minute fungus of the genus Saccharomyces. A single plant is a round or oval one-celled microscopic body (fig. 7), which reproduces in two ways—either by sending out buds which break off as new plants, or by forming spores which will grow into new plants under favorable conditions. It grows only in the presence of moisture, heat, and nutritive material. If the moisture is not abundant the surrounding substances absorb that which already exists in the yeast cells and so prevent them from performing their functions. Yeast develops best at a temperature of 77°–95° F. (25°–35° C.). We have already seen how yeast uses up sugar in its growth. It is also believed that some nitrogen is necessary for the best development of yeast, and that such development is most complete in the presence of free oxygen, but why these things are so is not yet clearly understood.

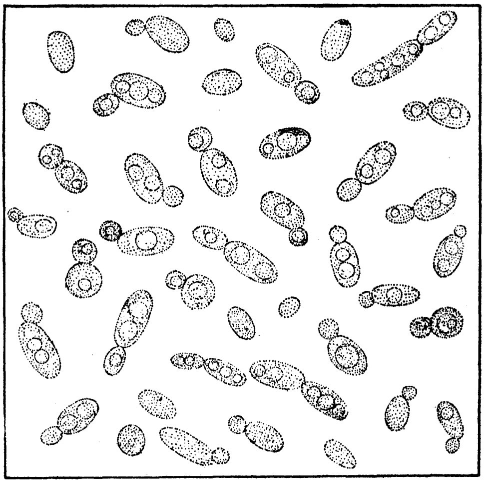

FIG. 7.—Yeast plant highly magnified.

Yeast is literally as old as the hills. It must be present in the atmosphere, for if a dish of malt extract, originally free from yeast, be exposed to the air, alcoholic fermentation, such as could be produced only by yeast, will soon set in. Such yeast is known as "wild yeast," and all our yeasts have been cultivated from it. The oldest method of growing yeast is perhaps that used by the Egyptians. A little wild yeast was obtained and set in dough, a portion of which was saved from the baking; there it went on developing as long as materials held out, and thus the bit of dough or "leaven" contained so much yeast that a little of it would leaven the whole loaf. It was such leaven as this which the Israelites had not time to put into their bread when they were brought out of the land of Egypt. A microscopical examination was recently made of some bread over four thousand four hundred years old, found in Egypt, with other remains of a long-vanished people. It was made of barley, and the dead yeast cells were plainly visible. A similar process of raising bread with "leaven" is still carried on in some regions of Europe. The "wet" or "potato yeast," so common in this country before the days of yeast cakes, was made by a similar method. Wild yeast was cultivated in a decoction of hops or potato and water, and some of the material thus obtained was mixt with the dough. The "barms" so much used in Scotland are made by letting yeast grow in malt extract and flour (p. 23). Brewers' and distillers' yeasts are taken from the vats in which malt extract has been fermenting. Comprest and dry yeasts are made by growing yeast plants in some sweet liquid, then drying the material to check their growth, and pressing it. Sometimes a little starch is added to make the little cakes keep their shape. Flour, meal, or some similar material is also added to the dry yeast to absorb moisture and form a cake which can be dried in convenient form. The comprest yeast is moist when marketed. The dry yeast contains no visible moisture, as it has been dried to prevent molding, etc. The strength of any yeast depends on the care with which it is made and preserved. Ordinary brewers' yeasts are likely to be full of the bacteria which set up lactic or other fermentations in the bread and give it a disagreeable taste and odor. They are very susceptible to changes in the weather, and can not be always relied on. Comprest and dry yeasts, if carefully made, are more uniform in strength and composition than liquid yeast. Usually a few of the microscopic plants or bacteria other than yeast are allowed to remain in all kinds of yeast, as the slight acid taste they give to the bread is considered an advantage.

SUBSTITUTES FOR YEAST.

Partly because yeast is uncertain in its workings, partly, too, because it uses up some of the nutritive ingredients of the bread by feeding upon them, attempts have been made to find some substitute for it. Various chemicals have been used to produce carbon dioxid gas in the dough. The first noteworthy attempts were made about fifty years ago at Harvard University and in Germany. Yeast powder, as the American preparation was called, was a mixture of an acid and an alkaline powder—the former calcium phosphate and the latter bicarbonate of soda. When duly mixt with the dough these were supposed to give off carbon dioxid as effectively as yeast. Liebig, who calculated that in Germany the daily loss of material by the growth of the yeast plant was, if saved, sufficient to supply 400,000 persons with bread, made a great effort to introduce a similar preparation into Germany, but with little success. Numerous baking powders made from various chemicals are in the market now. The self-raising flour used in the United States Army is a flour ready mixt with such a preparation. The chief objections to such yeast substitutes are that, unless carefully prepared, they may be inefficient or harmful, that they are easily adulterated, and that bread made from them is usually rather tasteless, lacking the flavor and aroma which good yeast imparts. Soda, cream of tartar, or saleratus biscuits are made on the same principle with other leavening agents.

The "aerated bread" so popular in London is made by a different method, invented by the English physician Dauglish in 1856. According to this method, the water used for wetting the dough is directly charged with the requisite amount of carbon dioxid gas and then mixt with the flour in a specially constructed machine. Sometimes a little fermented barley infusion or "wort," as it is called, from a brewery is put into the water. This aids it in absorbing the gas, renders the gluten more elastic, and improves the flavor of the bread.

The so-called "salt-rising" bread is interesting as an illustration of self-raised bread. In it the ferments originally present or acquired from the air produce the fermentation which leavens it. To make it, warm milk and corn meal are mixt together into a stiff batter, which is left at blood heat until the whole mass is sour—that is, until the ferments present have produced fermentation thruout. Next, a thick sponge is made of wheat flour and hot water, in which a little salt has been dissolved. This sponge and the sour batter are thoroly kneaded together and set in a warm place for several hours. The leavening action started in the batter spreads thru the dough and produces a light, porous loaf, which many persons consider very palatable. Such a bread is free from acidity, as the presence of the salt prevents undesirable acid fermentation.

RAISED BREAD.

Ordinarily a baker mixes his dough with water, and most of the experiments and analyses quoted here have been made with such bread. Sometimes, especially in private families, milk is used in the place of water. Such dough is slower in rising, but makes an equally light loaf. Milk bread naturally contains a larger percentage of proteids and fats than water bread and is equally digestible. Its use is by all means to be advocated, especially on farms where skim milk is abundant.[a] When water is used, it should, of course, be free from any dirt or contamination. Its hardness or softness makes little difference in the quality of the bread, tho perhaps the softer water is to be preferred. Salt is used in bread because it imparts a flavor without which bread is usually considered insipid, and because it exerts a retarding influence on the chemical process by which starch is converted into sugar and on fermentation.

[a]See articles on the digestibility of bread in Maine Sta. Rpt. 1898. Also U. S. Dept. Agr., Office of Experiment Stations Bul. No. 85.

PREPARATION OF THE DOUGH.

There are various methods of mixing dough, but certain general rules apply to them all. As yeast develops best at a moderately high temperature (77° to 95° F.), the materials of the dough should be at least lukewarm, and the mixing and the raising should be done in a warm place, as free as possible from drafts. On the other hand, too high temperatures must also be avoided, as they kill the yeast. If all portions of the dough are to be equally aerated by the gas from the growing yeast, the latter must be thoroly mixt with the flour and water; moreover, as the presence of oxygen aids the growth of the yeast, all parts of the dough should be exposed to the air. Both these results are accomplished by the kneading. Too little yeast will, of course, yield a badly raised loaf, but too much yeast is just as objectionable, as the bubbles formed in the gluten of the flour, unable to resist the pressure of the excessive amount of gas, break open, the gas escapes, and the dough becomes heavy and soggy. Too much yeast also gives an unpleasant "yeasty" taste to the bread, due partly to the presence of superfluous yeast cells, but more especially to other microscopic growth-producing fermentations. Even when used in small quantities, yeast has a decided influence on the flavor of the bread. The amount of yeast which should be used depends on the strength of the flour. A flour in which the gluten is abundant and tenacious can resist a much stronger pressure of gas than one with scant or weak gluten, which, if it does not fall entirely, is likely to make a loaf with large holes and heavy, badly raised masses between. Similarly, the proportion of water which should be used varies with the strength of the flour. The standard cookbooks suggest an average of about three parts of flour to one of water, the ratios changing with the quality of the flour. In general, nothing but practical experience with his materials can teach a baker the exact quantities which he should mix. Salt, as has been said, tends to retard fermentation, and consequently should be added toward the end of the mixing; then it is useful because it checks lactic or butyric fermentations, such as often follow the alcoholic fermentation.

It seems almost unnecessary to say that the greatest cleanliness should be observed in kneading bread. Many household cooks maintain that it is impossible to mix dough as evenly with a knife or spoon as with the hands, tho expert cooks insist that perfect mixing may be obtained by the use of a knife. Perhaps, where bread is made in small quantities and every precaution is taken to insure cleanliness, this use of the hands may be tolerated, but not in wholesale bakeries where dough is mixt in such large quantities that the kneading is violent physical exercise and the worker is unable to take his hands from the dough long enough to wipe his dripping forehead. In such establishments the modern kneading machines, in which revolving metal blades do the work of the hands, are surely to be advocated, and in general those breads are to be recommended which are made with the aid of machinery so arranged that none of the materials need be touched by hand from the time they enter the bakery until the finished loaves are taken from the oven. Every utensil used for bread making should be scrupulously clean, not only on principles of general decency, but because otherwise bacteria may get into the dough and produce harmful fermentation.

The ways of mixing dough most used in this country by bakers are probably those known as "straight dough" and "sponge dough."

Straight dough, or "offhand" dough, as it is sometimes called, is made by mixing all the materials at one time, and then setting the mass in a warm place to rise for ten hours or more before baking. It requires more yeast and stronger flour than other methods in which the yeast is allowed to grow in an especially favorable medium before being mixt with the main dough, and needs a longer time to rise, but, on the other hand, gives an unusually large yield in bread. It is convenient in family bread making, especially when strong, comprest yeast is used, as the dough can be mixt overnight and baked in the morning. Some wholesale bakers dislike it because the dough is stiff and hard to knead, because the large quantities of materials used at one time require extensive kneading apparatus, and because the bread is usually coarse in texture, with a raw, grainy taste, due to the strong flours used.

Sponge dough.—This method is best adapted to fancy working, and makes equally good crusty loaves or light biscuit. To make the "sponge," as the bread mixture is commonly called, the yeast is allowed to work for eight or ten hours in a portion of the flour or water. This is then mixt with the remaining materials and left to rise a few hours before baking. The sponge is "slacker"—that is, contains more water than offhand dough—and thus gives the yeast a better chance to work. Bakers usually set their sponge with a strong flour, which gives it a light, elastic quality; a little salt is put into it to prevent lactic fermentation. A weaker flour may be used in the second mixing, as the greater part of the gas has already been given off in the sponge, and no great pressure will come on the newly added gluten. If strong flour be used instead, the bread yield will be greater, but the mild, sweet flavor imparted by the weaker kinds will be replaced by the harsh taste noticed in bread made from offhand doughs. Great care must be taken to mix in the second lot of flour thoroly, or the bread will be full of hard lumps on which the yeast has had no effect. Sponge-made bread usually rises evenly and well, and can be worked into almost any shape. It has the further advantage of keeping well. It requires longer labor than the method described before;

still the difference is really that between two short kneadings in soft dough and one long one in stiff. Like offhand dough, it can be started the night before it is baked.

After mixing his dough in the way he considers most desirable, the baker sets it in a warm place (77° to 95° F.) to rise. Here the yeast continues to work and the gas given off stretches the spaces between the particles of dough. If the gas is allowed to go on increasing until its pressure is greater than the elasticity of the gluten can resist, the latter breaks apart, leaving large holes thruout the dough. If such "overproved" dough is kneaded a little before it is put into the oven the excessive gas will be forced out and the holes will be more regular.

Besides the methods of bread making previously noted, there are others occasionally used. Jago [a] describes those employed by bakers in England and Scotland. The following statements are based on his description:

Ferment, sponge, and dough method.—As the name implies, this is a combination of the two methods last described. The ferment is mixt with the sponge, then, after this has stood for several hours, the rest of the flour and water are mixt in the sponge and dough fashion. There is, perhaps, a slight economy of yeast by this method, but it is very complicated, and therefore less certain.

A similar proceeding is sometimes practised in the southern part of the United States, and is known as a "bleaching process," because the long rising is supposed to whiten the dough. This, of course, has nothing to do with the "bleaching" of flour.

Scotch barm method.—This is not unlike the ferment, sponge, and dough system, "barm" taking the place of the other ferments. Barm is literally the foamy scum which rises to the top when beer, etc., is made. This may be used to ferment other materials. A variety of yeast is also called barm. To make barm in the household malt is crusht in warm water, hops and boiling water are poured over it, then flour is added, and the mixture is allowed to stand until the starch granules from the flour have been burst open by the hot water and the starch thus freed has been changed into sugar by the diastase of the malt. A sweet liquid is drained off from this and mixt with flour and water, the resulting sticky mass being subjected to the action of yeast, either acquired spontaneously by exposure to the air (virgin barm) or added in the form of a little old barm or ordinary yeast (Parisian barm). The fermentation thus started is allowed to continue several days and then the barm is ready for use in the sponge. A strong flour is needed for both the barm and the dough, and consequently the bread yield is large. In Scotland, where this method is

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[a] The Science and Art of Breadmaking. William Jago, London, 1895.

almost universal, bakers consider it most economical, because there is practically no yeast to be bought and the flour used in the barm goes into the bread. These arguments seem hardly tenable, however. The cost of labor in preparing the barm must be considerable and at least a portion of the flour in the barm is lost in the form of alcohol and carbon dioxid. Moreover, while the barm is exposed to the air in making, it takes in a great many bacteria which start lactic and other fermentations and give a decidedly sour taste to the bread. To be sure, persons accustomed to such bread find an ordinary sweet loaf insipid. Still, such a flavor would, it is probable, hardly be acceptable to the average American palate.

BREAD MADE WITH LEAVEN.

According to Boutroux,[a] the leaven used in France is easily prepared. A little of the dough ready for baking is saved and mixt with an equal amount of flour and water and is allowed to stand four or five hours. This operation is repeated three or four times before the leaven is ready to be mixt into the actual dough. This gradual mixing of the leaven is preferred, because in this way the yeast is allowed to act on one lot of flour only for a short time, then before it has become exhausted and other fermentations set in new yeast food is added, and thus a large number of yeast cells is supposed to be produced along with relatively few lactic and butyric bacteria. In spite of this precaution bread made with leaven has a much more acid taste than that made with yeast, especially if the leaven has been kept some time. Anyone who has eaten the bread ordinarily made by the poor country people of France or Switzerland will willingly testify to this. More leaven is required in winter than in summer, because the yeast develops less quickly in cold weather, but on the average the leaven should form one-third of the entire dough. Bread made with leaven has large, irregular holes in its crumb. This is attributed to the fact that the bacteria in the leaven give rise to a ferment (diastase) and acids, which tend to soften the gluten.

Boutroux considers bread made with leaven more healthful than that made with yeast, because the acids it contains aid in its digestion. He also maintains that leaven is more reliable than the yeasts ordinarily found in the French market, but probably the majority of experts in this country would hold that the best of our commercial yeasts are more reliable and much more convenient. Whatever its practical value nowadays, bread made from leaven is interesting from the historical point of view, as it represents the way in which almost all the world made its bread from the time of the Pharaohs down to our own century.

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[a] Le Pain et la panification. L. Boutroux, Paris, 1897.

SPECIAL BREADS.

Besides the ordinary white breads described in the last section, there are innumerable fancy white breads, breads made from other flours than wheat, and unleavened breads on the market. So few analyses of them have been made, however, that they can be hardly more than enumerated here.

FANCY LEAVENED BREADS.

Most like the ordinary white bread are of course the fancy white ones, Vienna and French rolls, milk breads, etc. These usually differ chiefly in the use of milk, sugar, butter, lard, etc., in the dough. Entire wheat, graham, rye, barley, or oatmeal flours are made into bread in essentially the same way, and vary in texture and nutritive value according to their original composition. Soda, cream-of-tartar, or baking-powder biscuits, shortcakes, etc., are intrinsically the same thing as ordinary white bread, except that the baking powder or its substitute does the work of yeast. Such breads do not require to be kneaded or set to rise, and bake very quickly; hence are very convenient when yeast is unobtainable or time is short. They never become so light and porous as yeast-made bread, however, and dry very quickly.

UNLEAVENED BREADS.

The most interesting of these is perhaps the Passover bread, which has been used during Passover week by orthodox Jews from the time of Moses until now. It is simply a mixture of flour and water, baked in small round cakes until it is dry and hard, and is not unlike plain water crackers. Pilot bread, or ship's biscuit, is another simple preparation of flour and water so cooked that it can be kept for any length of time. Crackers, or biscuits, as they are often called, especially in England, are also a variety, or, more correctly, innumerable varieties, of unleavened breads. Milk, butter, lard, spices, dried fruits—anything or everything desired to give them a particular consistency, color, or flavor—is mixt with the flour and water, and the dough is then past thru very ingenious cutting machines and quickly baked in a hot oven. Such crackers are dry and fairly dense, and therefore a concentrated form of nourishment.

The original graham bread, made without yeast from graham meal according to the receipt of its inventor, and not to be confounded with raised graham bread, is made by kneading the flour and water thoroly and allowing the dough to stand several hours before baking. It is heavier than ordinary yeast bread, but still has a few "holes" in it, due probably to fermentation started by bacteria accidentally present in the flour or the air. It is sweet and by no means unpalatable, but probably the nutritive value of its protein is lower than Doctor Graham supposed.

So-called raw wheat breads are on the market which are apparently made by pressing the cleaned and macerated grains into small cakes. Such foods, it is claimed, tend to counteract a tendency to constipation.

Gluten bread, as its name implies, contains the gluten of the flour from which more or less of the starch has been removed. To make it, strong flour and water are made into dough, which is prest and strained under a stream of water until the starch has been worked out; it is then kneaded again and baked. It makes a light, elastic loaf, frequently prescribed for diabetic patients from whose diet it is considered desirable to exclude starch. Unfortunately not all the so-called "gluten flours" on the market have as much of the starch removed as their names or descriptions imply, and diabetics should be guided by the advice of an experienced physician or analyst in their choice of brands.

Altho macaroni, spaghetti, and other wheat pastes occupy a very different place in our bills of fare, they are so similar to unleavened breads in their ingredients that they may fittingly be mentioned here. They are made by mixing hard wheat flour and hot water into a stiff paste, which is then molded and dried. The wheats most suitable for their manufacture—viz, the "Durum" wheats—were formerly grown mainly in eastern Russia, the Mediterranean countries, and South America, but recently have been successfully cultivated in certain sections of the United States, so that domestic pastes are likely to become more and more common in our markets. Noodles, which are only slowly coming into general use in this country, tho they have long been popular in Europe, differ from macaroni and the other flour-and-water pastes in having eggs mixt in, and are therefore lighter and richer in protein.

HOUSEHOLD METHODS OF BREAD MAKING.

In preceding paragraphs attention has been called to the methods of bread making followed by bakers. These differ from the household methods more in the quantities used than in the principles followed. Thus, a baker uses a large amount of flour and finds that mixing the dough and kneading it is much facilitated by machinery of different sorts. With the small quantities used in the household special machines for kneading, etc., have not until recently been commonly used. Within a few years, however, household "bread machines" have become more and more popular, and several kinds are found on the market, each having its advocates. In one of these a peculiarly bent rod, turned by means of a crank, mixes the dough thoroly and perhaps more evenly and quickly than the ordinary kneading. In another form the dough is mixt by revolving knife-like devices. It is claimed by expert cooks that bread may be evenly and thoroly mixt without contact with the hands if a large flexible knife is used. The method of manipulating the dough with the knife can be readily learned with a little practise.

In different regions somewhat different ways of making bread in the household are popular, and, indeed, each bread maker is apt to believe she has some especially valuable way of mixing, kneading, etc. These differences are not as important as is sometimes supposed, and, as has been said, the general principles followed in bread making at home are the same as in bakeries. What are perhaps the two most popular ways of making bread at home are sometimes called the "quick-raising method" and the "slow-raising" method.

Quick-raising method.—A stiff dough is made of the flour, water, and yeast. It is thoroly kneaded and is then allowed to rise until it doubles its bulk, when it is again kneaded thoroly. After rising a second time it is baked. In the quick-raising process a large quantity of yeast is used, and the time of fermentation is only about two and a half hours. The baking is completed in about four or five hours after the bread is first started to rise.

Slow-raising method.—A batter is made of the flour, yeast, and water, which is allowed to ferment ten or fifteen hours, usually over-night. More flour is then added, the dough is kneaded until smooth, and then allowed to rise and is treated in the same way as in the first method. In the slow-raising method less yeast is used than in the short process, and the fermentation is carried on for a longer time. The usual temperature at which the fermentation thus takes place is perhaps not far from 70°.

Various forms of "raised biscuits," "hot bread," etc., are made in the household by adding shortening, milk, eggs, etc., to the dough, or by modifying in some way the process followed. Sometimes baking powder of some sort is used as a leavening agent instead of yeast, and the form of bread called "baking-powder biscuit," or by some similar name, is the result. An interesting variety of bread made without leavening is known as "Maryland" or "beaten" biscuit. A rather stiff dough is made from flour and water, or milk, with shortening and salt added. It is kneaded and then beaten or pounded, being frequently turned over and over until it looks light and puffy. The biscuits are then formed and baked. The folding and pounding of the dough incloses small quantities of air in numberless little blisters. These expand in baking and make the biscuit light and porous. The different kinds of bread from other grains than wheat, as "corn bread," "brown bread," "rye bread," "gems," etc., which are made in many households, vary somewhat in different regions, but they all follow the same principles which govern the bread making from wheat flour—that is, the flour or meal is mixt to a dough with water or milk, and some leavening substance is generally added to make the dough porous. Eggs, sugar, shortening, etc., may be added, giving rise to the numerous varieties with which we are all familiar.

BAKING AND COOLING.

In the earliest days of bread making the dough was simply put into the ashes of the fire or on hot stones to bake; then came the ovens heated by a fire within, which are still used to some extent, and finally the elaborately constructed ovens which can be heated or cooled to any temperature by means of furnaces and ventilating devices around them. But whatever the structure of the oven, the changes which the bread undergoes while in it are essentially the same. It goes in a heavy, uniform mass and comes out a light body of increased volume with a crisp, dark exterior—the crust—and a firm, spongy interior—the crumb. Let us first see what happens in the crumb. This, of course, heats more slowly than the outside; indeed, the moisture which it contains prevents its temperature from rising much above the boiling point of water (212° F.). When first put into the oven the yeast continues working, but a temperature of 158° F. kills it. The gas in the dough, however, still expands and, forcing its way outward, enlarges the loaf and gives it a spongy appearance. The gluten becomes stiffened by the heat, so that even after the gas in the bubble-like pores has escaped the walls still retain their shape. The starch granules and perhaps the protein compounds undergo certain chemical changes which are believed to render them more digestible. Meanwhile the crust is becoming hard and dark; the heat changes its starch into stiff gum and sugar and dries out the moisture; the brown color is due to chemical changes known as "caramelization." Of course the proportion of crust to crumb varies with the size of the loaf. The accompanying table[a] gives the relative percentages by weight in loaves of different weight of German bread:

Comparative weight of crust and crumb in bread.

	Weight of loaf.	Crumb in loaf.	Crust in loaf.
	Grams.	*Per cent.*	*Per cent.*
Bread No. 1	398	55.2	44.8
Bread No. 2	880	59.7	40.3
Bread No. 3	1,783	64.3	35.7
Bread No. 4	1,998	71.2	28.8

The heat in the oven should not be too great, especially at first, or the outside of the bread will harden too quickly and the interior will not be done before the crust is thick and dark; further, the gas expanding in the crumb will be unable to escape thru the crust and

[a] Arranged from Birnbaum's Das Brotbacken. Braunschweig, 1878, p. 255.

will lift up the latter, leaving great holes beneath it. To prevent too rapid formation of the crust, bakers often moisten the tops of their loaves before putting them into the oven or have devices for passing steam over them during the baking. The steam also changes some of the starch into a sort of gum on the top of the loaf and gives it the shiny look so often seen in Vienna bread. The same effect can be produced by moistening the top of the loaf just before it is taken from the oven. If his oven is not equally heated thruout, a baker usually puts his small loaves into the hottest part at first, as the crumb of these bakes more quickly and is in less danger of being underdone. When these are baked the larger loaves, whose crumb has baked gradually in the cooler parts, are moved into the warmer place and their crust is quickly hardened. In some large ovens the temperature is gradually raised during the baking; especially is this the case in the aerated bread factories. Aerated dough is mixt with cold water, and if it were immediately subjected to a high temperature the crust would form before the interior was more than warmed thru. Accordingly, a peculiar oven is used, one end of which is heated much hotter than the other. Two cylinders, one at either end of the oven, are connected by an endless chain, on which the bread plates are hung; the dough is placed on the latter at the cooler end, and then is gradually swung over to the warmer end, the speed being regulated by the time needed for baking. This insures a thoro baking of the crumb, while the extreme heat at the last gives a good, crisp crust.

The temperature of an oven and the time required for baking depend upon the size of the loaves. Small biscuits or rolls can stand a much hotter oven and quicker baking than large loaves, which must be heated slowly and long. For ordinary purposes a baker heats his oven to 400° or 500° F. and lets a pound loaf bake an hour or an hour and a quarter; small rolls perhaps half an hour. An experienced cook can tell when the oven is hot enough by putting the hand in, but a pyrometer, as a thermometer for measuring high temperature is called, makes a much safer guide for an ordinary person.

On being taken from the oven bread should be placed on slats or sieves so that the air can circulate about it until it is thoroly cooled. By that time all the gas and steam which are likely to escape have done so, and the bread may be put away. Some housekeepers wrap their hot bread in cloths, but this is not advisable, not only because it makes the bread "taste of the cloth," but also because it shuts the steam up in the loaf and makes it damp and clammy—an excellent medium for cultivating mold.

Of course as great cleanliness should be observed in handling and marketing bread as in making it. In some bakeries it is kept where the dust and dirt from the street can get to it, or sometimes bread is delivered in dirty baskets or carts. In this way disease germs and dirt may readily be brought into the home. In Germany this is sometimes avoided by slipping the loaves into parchment-paper bags as soon as they are taken from the oven. Some American bakers adopt similar plans; a frequent one is that of wrapping the bread in paraffin paper, which serves the double purpose of keeping out dirt and preventing the bread from drying.

STALE BREAD.

Good fresh bread has a crisp crust which breaks with a snap and an elastic crumb which springs back into shape after being prest with the finger. Before bread is a day old, however, its texture has changed; its crust has become softer and tougher, while the inside seems dry and crumbly—the bread is "growing stale," as we say. This was formerly supposed to be due simply to the drying of the bread, but as the loss of water is found by experiment to be comparatively slight some other explanation is necessary. Various explanations have been offered, of which the most interesting seems that given by Boutroux in the work already quoted. He maintains that the apparent dryness is due to a shifting of the moisture from the crumb to the crust. When first taken from the oven the dry crust cools quickly, but the moist crumb retains its heat much longer. As gradually, however, its temperature falls to that of the surrounding atmosphere its moisture tends to distil outward, leaving a comparatively dry crumb and moist crust. Common experience shows that if stale bread is put into the oven for a few minutes it regains something of its fresh consistency—a crisp crust and moist crumb. This fact would be explained by the reverse of Professor Boutroux's proposition—that is, the moisture is driven back into the crumb. Such warmed-over bread lacks the elasticity of the fresh loaf, and its interior crumbles as easily as before it was reheated. Recent investigations indicate that this is due to chemical changes in the starch, which tends to go back into less soluble form as the bread grows old.

In this connection the well-known household plan of putting a piece of bread in the cake box to keep the cake moist may be mentioned. This is accomplished probably because the bread gives off moisture more rapidly than the cake and keeps the air in the box too damp to allow the cake to lose much of its moisture. While cake thus kept does not dry as fast as it otherwise would, it loses its fresh taste, probably on account of chemical changes corresponding to those in aging bread.

IMPERFECTIONS AND IMPURITIES IN BREAD.

One of the most common and dangerous faults in bread is heaviness and sogginess. As we have seen, this may be caused by the use of flours poor in gluten which can not absorb all the water put into the dough, or, to state it in another way, by the use of too much water in proportion to the flour; by too little or by too poor yeast; or by insufficient kneading, rising, or baking. Heavy bread is popularly considered to be very productive of digestive disturbances. When chewed it rolls itself into solid lumps, which might readily hinder the action of the saliva and gastric juices.

Occasionally the crumb of fresh bread breaks when cut, instead of separating cleanly under the knife. According to Jago[a] harsh, dry flours, not sufficiently fermented, may be the cause of this, or the dough may have lost its tenacity by being overworked.

Another common fault in bread, especially in baker's bread, is a crumb full of large, irregular holes instead of the small, even pores which it should show. These occur in overkneaded or overraised dough; or, if they are found just below the crust, they mean that the oven was too hot and that the crust formed before the carbon dioxid had finished expanding.

Sometimes bread makers are troubled by what is known as "sticky" or "slimy" bread. In such cases bread three or four days old takes on a light-brown color and a peculiar taste and odor. Gradually, too, it becomes sticky or slimy until it may be pulled into strings, sometimes several feet in length. The trouble appears to be caused by the common potato bacillus (*Bacillus mesentericus vulgatus*), a minute organism which finds its way into the materials of the dough, survives the baking, and, growing in the bread, causes it to decompose. Experiments made at the Wisconsin Experiment Station[b] show that the bacilli enter the bread with the yeast, which in the cases investigated was a variety of the comprest yeasts ordinarily on the market. It was also proved that the bacilli will survive the heat of baking. Accordingly, if yeasts are not carefully made such trouble may occur at any time, but especially when the weather is warm and favorable to the growth of the bacilli. The best safeguards are to keep the bread in a cool place and to bake only as much as can be consumed within a day or two.

Not infrequently, especially in damp weather, mold forms on the outside, or even in the inside of bread. Mold, like yeast, is a minute plant whose spores (or seeds) are floating about everywhere in the air, ready to settle down and grow wherever they find a moist, suitable home for themselves. The best practical way to protect bread from them is to keep it in a dry, air-tight box.

But all these faults seem insignificant compared to that dread of all bakers, sour bread. This is due to lactic, or, in the worst cases, butyric, acid given off by undesirable bacteria in their growth. A little acid is not necessarily harmful, as was seen in the discussion of

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[a] The Science and Art of Breadmaking. William Jago, London, 1895.

[b] Wisconsin Sta. Rpt. 1898, p. 110.

bread made with leaven and barm; but when the acidity is very pronounced or even accompanied by putrefaction (developed in company with butyric acid) then something is radically wrong. Possibly the vessels in which the bread was made were not thoroly cleaned after the last using and some of the undesirable bacteria got into the dough from them; or perhaps the yeast contained an undue proportion of these bacteria; or, if the latter were found only in normal quantities, possibly the yeast itself was weak and was quickly exhausted. The trouble may be due to the fact that the dough was allowed to stand too long after mixing, the yeast ceased working, and the dangerous bacteria which grow best in the presence of acetic acid, such as occurs after alcoholic fermentation has ceased, had gotten the upper hand. If none of these things are at fault, the undesirable bacteria may have come from the flour itself. Such cases are, fortunately, very rare, and if a baker guards against all the other dangers he is pretty sure to make sweet bread. If bread grows sour with age it has probably caught the undesirable bacteria from the air, just as it catches mold. Very rarely, however, bread perfectly sweet at first grows sour before the bacteria in the air have had a chance to get at it. The only possible explanation for this is that the bacteria have managed to survive the baking and are growing luxuriantly in undisputed possession of the good things in the bread.

Besides these acid-producing bacteria, various others occur in bread, mostly harmless, but some of them very curious in their effects. Most striking among these is the *Micrococcus prodigiosus*, a minute organism which makes blood-red spots in the dough and whose presence gave rise to many interesting superstitions during the middle ages.

Aside from the adulterants mentioned in the section on flour, those most commonly met with in bread are mineral salts which have been mixt into the dough for the purpose of producing a good-looking loaf from poor flour. Alum is the most common of these. It tends to check the action of the diastase and permits a weak flour to absorb more water than usual. It also improves the color of the bread. Many reliable bakers use it under the impression that it does good and not harm; but besides producing a bread whose nutritive value is not so great as appearances indicate it is, under some conditions in which it is used, really injurious to the digestive system and must be ranked at least as a questionable ingredient. Alum tests are usually made by soaking a sample of the suspected bread in a solution of tincture of logwood and ammonium carbonate, in which alum betrays itself by a bluish color. Copper sulfate is occasionally used to produce an effect similar to that of alum in bread, but is believed to be more dangerous. Lime exerts practically the same influence and does no particular harm. Its use is reprehensible only because it gives poor bread the appearance of good bread. (See p. 13.)

Soda is often used in bread to prevent souring, and as it does not lessen the value can hardly be called an adulterant. In breads made from special flours which contain no true gluten—oatmeal, barley, etc.—it is convenient in the production of a sweet, well-raised loaf.

NUTRITIVE VALUE AND COST OF BREAD.

If we wish to know which of several foods furnishes the most actual nourishment for the least cost, we must know not only the actual price and the nutritive ingredients of each, but also their relative digestibility. The one which is found to furnish the greatest amount of digestible nutrients for a given sum will be the cheapest.

CHEMICAL COMPOSITION.

The chemical composition of the finished loaf differs somewhat from that of the original ingredients. The following table, which gives the results of analyses of patent wheat flour and several sorts of bread made from it, illustrates this point:

Composition of flour and of bread made from it in different ways.

Material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Flour	10.11	12.47	0.86	76.09	0.47
Bread from flour and water	36.12	9.46	.40	53.70	.32
Bread from flour, water, and lard	37.70	9.27	1.02	51.70	.31
Bread from flour and skim milk	36.02	10.57	.48	52.63	.30

The increase of water in the bread hardly needs explanation, since it is evidently due to the water added in making the dough. The apparent decrease in protein and carbohydrates also is due to the increased proportion of water. It has been estimated that the alcohol generated by the yeast plant is equivalent to about 1 per cent of the total weight of the bread. Earlier investigators reported a small percentage of alcohol (less than 0.5 per cent) in the bread, but according to Snyder's investigations no appreciable amount of the alcohol remains after baking. The bacteria and other microscopic plants which accompanied the yeast in their growth doubtless used up some of the protein and carbohydrates also, returning a part in the form of the characteristic acids and other bodies which they produce. Part of the starch in the crust has been changed into dextrin, and that in the crumb has become gelatinous or partly soluble. The gluten, as we have seen, has taken definite shape. This really means that it has coagulated very much, as the white of an egg does in boiling. The decrease in fat in bread made from flour and water is doubtless caused by its oxidation during baking. Its increase in bread made with lard is of course due to the latter ingredient and the increase of protein in skim-milk bread of course comes from the protein in the milk.

COMPOSITION OF BREADS AS COMPARED WITH SOME OTHER FOODS.

To show the difference in the proportions of the different food ingredients in various foods it may be well to compare the analyses of bread and other foods as given in the following table. The samples of wheat bread here represented are grouped together according to the kinds of flour used; that is, all those given under Minnesota hard wheat were made in exactly the same way from flours specially milled from the same lot of wheat, and the differences between them are due only to the differences in the milling processes. The Oregon and Oklahoma flours were likewise specially ground and the breads made in the same way as those from the Minnesota flours. Thus, if we compare these figures for entire wheat bread from these three classes of flours, the differences may be accounted for entirely by differences in the original grain and not at all by differences in milling and baking. It should be remembered, however, that grains grown in the same locality may vary considerably in composition from year to year, so that the figures here quoted might not always be strictly accurate. They do, however, represent correctly the general differences between the breads from various types of wheat.

Composition of various sorts of bread and some other food materials.

	Number of analyses.	Refuse.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Wheat bread:							
From hard Scotch Fife spring wheat, Minnesota—		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Graham flour			47.20	7.76	1.27	42.82	0.95
Entire-wheat flour			49.16	7.45	1.14	41.73	.52
Standard patent flour			44.13	7.75	.90	46.90	.32
Second patent flour			42.10	7.75	.72	49.16	.27
First patent flour			44.40	7.48	.71	47.14	.27
From Oregon soft winter wheat—							
Graham flour			38.55	6.11	1.12	52.68	1.54
Entire-wheat flour			39.95	5.70	1.09	52.39	.87
Straight grade flour			34.95	5.41	.89	57.85	.90
From Oklahoma hard winter wheat—							
Graham flour			42.20	10.65	1.12	44.58	1.45
Entire-wheat flour			41.31	10.60	1.04	46.11	.94
Straight grade flour			37.65	10.13	.64	51.14	.44
Straight grade flour with 14 per cent bran			43.20	9.50	.84	45.55	.91
Straight grade flour with 7 per cent germ			38.00	11.07	1.13	49.12	.68
From miscellaneous flours—							
High grade patent			32.9	8.7	1.4	56.5	.5
Standard grade patent			34.1	9.0	1.3	54.9	.7
Medium grade patent			39.1	10.6	1.2	48.3	.9
Low grade patent			40.7	12.6	1.1	44.3	1.3
White bread, average	198		35.3	9.2	1.3	53.1	1.1
Rolls	20		35.7	8.9	1.8	52.1	1.5
Crackers	71		6.8	10.7	8.8	71.9	1.8
Macaroni	11		10.3	13.4	.9	74.1	1.3
Corn bread (johnnycake)	5		38.9	7.9	4.7	46.3	2.2
Rye bread	21		35.7	9.0	.6	53.2	1.5
Rye-and-wheat bread	1		35.3	11.9	.3	51.5	1.0
Beef, ribs:							
Edible portion	15		55.5	17.5	26.6		.9
As purchased	8	16.8	39.6	12.7	30.6		.6
Veal, leg:							
Edible portion	19		71.7	20.7	6.7		1.1
As purchased	18	11.7	63.4	18.3	5.8		1.0
Mutton, leg:							
Edible portion	15		63.2	18.7	17.5		1.0
As purchased	15	17.7	51.9	15.4	14.5		.8

Composition of various sorts of bread and some other food materials—Continued.

	Number of analyses.	Refuse.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cod steaks:							
Edible portion	1	....	79.7	18.7	0.5	....	1.2
As purchased	1	9.2	72.4	17.0	.5	....	1.0
Hens' eggs:							
Edible portion	60	....	73.7	13.4	10.5	....	1.0
As purchased	....	11.2	65.5	11.9	9.3	....	.9
Butter	....	....	11.0	1.0	85.0	....	3.0
Milk, whole	....	....	87.0	3.3	4.0	5.0	.7
Potatoes:							
Edible portion	136	....	78.3	2.2	.1	18.4	1.0
As purchased	....	20.0	62.6	1.8	.1	14.7	.8
Apples:							
Edible portion	29	....	84.6	.4	.5	14.2	.3
As purchased	....	25.0	63.3	.3	.3	10.8	.3
Chocolate, as purchased	2	....	5.9	12.9	48.7	30.3	2.2

From various dietary studies it is reckoned that the average man at moderately active work requires about a quarter of a pound of protein and so much of fats and of carbohydrates in his daily food that the available energy of all together will equal 3,400 calories. The harder he works the more food he will need. Milk contains the three classes of nutrients, but not in the proper proportion for adults in health. The large quantities of milk which a man would have to drink in order to obtain the necessary amount of nourishment make it inconvenient for exclusive use. Meats and cheese are rich in protein and fat. Vegetables are especially rich in carbohydrates. Bread contains both protein and carbohydrates, but in order to get the requisite amount of protein from it one would have to take more carbohydrates than is otherwise necessary. The combination of bread with such material as meat or cheese, which is rich in protein, makes a much better balanced ration.

Turning again to the bread analyses, it will be seen that while the breads made from graham, entire-wheat, and lower grade patent flours contain slightly more protein than the finer grades the difference is often extremely small, and differences between the original composition of the grains used are more important. Thus graham flour made from Oregon soft winter wheat produced bread containing 0.7 per cent more protein than straight grade flour from the same grain; but straight grade flour from Oklahoma hard wheat yielded bread with almost two-thirds again as much protein as the Oregon graham flour. Evidently, then, the ordinary housekeeper who buys flour under a brand name which tells little or nothing of its origin is about as likely to get as high a percentage of protein in a patent as in a graham or an entire-wheat flour. Fortunately the differences are likely to be very small in any case.

In considering the differences in the composition of bread made from various flours, it should not be forgotten that the amount of water which a loaf contains affects the percentage of nutrients present. The quality of its gluten allows Oklahoma hard wheat flour to absorb and retain more moisture in bread made from it than Oregon soft wheat, for instance, and the percentage of protein and other nutrients contained in the former is proportionately smaller. Similarly the percentage of protein, etc., in bread made from patent flours is relatively smaller than that in graham bread, because the former absorbs more water.

The figures given for the average composition of many samples of bread, rolls, crackers, and macaroni are interesting, because they represent better than the others, perhaps, the average of such goods as found in our open markets. The average composition of 198 samples of white bread is just about the average composition of the breads prepared from special flours in the first part of the table. The reason why crackers and macaroni seem to be richer in nutrients than bread is of course that they contain less water. Corn bread, like corn meal, contains less protein and more fat than wheat bread and flour. Of course the amount of fat in any kind of bread varies with the amount of shortening used. Judged by their composition, all breads are nutritious foods, and too great stress should not be laid on the variations in composition between the different kinds.

DIGESTIBILITY OF DIFFERENT KINDS OF BREAD.

The next question is, What kind of bread furnishes the greatest amount of digestible nutrients? Among the earliest and most famous experiments made to test this question are those conducted by Meyer and Voit, of Munich, about thirty years ago. They used different kinds of rye and wheat bread, and reached the conclusion, which all later work has verified, that the digestibility of bread depends largely upon its lightness. The work done during ten years at the Maine and Minnesota experiment stations throws much light on the comparative value of different kinds of bread.[a] Many experiments were made to learn how graham, entire-wheat, and patent flours compare in digestibility. The flours used in these comparisons were milled from the same lots of wheat, and mixt and baked in the same way. The results all show that patent flour yields to the body a larger proportion of its nutrients than the kinds which include more or less of the bran. Of the protein in bread made from standard patent flour, 88.6 per cent was found to be actually utilized by the body, as against 82 per cent from entire wheat and 74.9 from graham. Of the carbohydrates, 97.7 per cent from the standard patent, 93.5 per cent from the entire wheat, and 89.2 per cent from graham was utilized. The amount of fat in the bread was so small that it was impossible accurately to test its digestibility. Usually, however, the fat in bread is of comparatively little importance in the diet, since this nutrient is supplied by

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 85, 101, 126, 143, 156.

butter and other fatty foods. Apparently, then, as regards the digestibility of the more important nutrients, the patent flours are superior to those containing bran. It is interesting to notice that the digestibility of these three kinds of bread varies in the same order as the lightness of the loaves. The patent flour makes the most porous loaf, next comes the entire-wheat, and last of all the graham.

These differences in lightness and digestibility are not large, and many persons maintain that the larger amounts of protein supplied with the bran offsets the loss from the undigested material. The amount of nutrients which a given weight of bread will actually yield to the body may be found by multiplying the weight of its nutritive ingredients by their percentages of digestibility. Let us thus determine the amount of protein furnished by, say, the breads made from Oklahoma flours. The table of composition on page 34 shows that 100 grams of such graham bread contains 10.65 grams of protein; the same amount of entire-wheat bread, 10.60 grams; of patent-flour bread, 10.13 grams. Multiplying these amounts by the percentages of digestibility we get: For graham bread (10.65×0.749), 7.98 grams; for entire-wheat bread (10.60×0.82), 8.69 grams; and for patent-flour bread (10.13×0.886), 8.98 grams. Apparently, then, the greater amount of protein does not compensate for the lower digestibility of the bran-containing flours, and the amount of that nutrient actually available to the body is greatest from patent flour and least from graham flour.

As regards the claim that the bran-containing flours furnish valuable mineral matters, it should be stated that as yet very few experiments have been made to test the digestibility and nutritive value of the different phosphorus compounds and other ash constituents of foods, and until that is done nothing positive can be said on either side, nor should too much stress be laid on the importance of the extra amount of phosphates and other ash constituents of bran. It should be remembered that fine flour also contains these ash constituents, and it is not unlikely that they are in forms which are more available or useful than those in the bran, even if finely ground. These mineral substances are of undoubted value, but there is little experimental data to show the amount of different ash constituents necessary for maintaining the body in health. It is doubtless safe to say that the ordinary mixt diet of children and adults furnishes an abundance of mineral matter. The coarser flours, owing to the particles of bran or some other property, often increase the peristaltic action of the intestine and thus tend to prevent constipation. They may at times otherwise aid digestion; hence for persons in need of a laxative bread made from such flours may often be preferable to white flour, but for a healthy person its claim of superiority on the basis of nutritive value is not warranted. Certainly no plea can be made for them on the ground of economy, for entire-wheat and graham flours are not cheaper than white flour. On the other hand, it must not be forgotten that all flours are wholesome and palatable, and that variety in our bread is just as pleasing as variety in our meats, vegetables, and puddings. The housekeeper may therefore wisely use all the different kinds of flours here discust to give variety to the diet and please the taste of different members of her family. As has been said, well-made bread of any kind is a very nutritious food, and the differences between the various kinds are too small to be of practical importance to persons of healthy digestions and comfortable circumstances.

Experiments similar to those with the flours just discust have been made with different grades of patent flours. It was found that the percentages of digestibility differed very little, and that as far as nutritive value is concerned the cheaper grades are fully as good as the more expensive. The bread made from them is as light as that from the finer flours, but not quite so white and appetizing. Where rigid economy is necessary the cheaper grades can safely be used.

Crackers, macaroni, and various sweet cakes made from white flour have also been tested at the Minnesota Experiment Station, and it has been found that their digestibility was practically the same as that of white bread. Of course all these experiments were made with healthy normal persons, and the results should not be applied too closely to invalids or others of delicate digestion. Moreover, nothing has yet been learned about the ease and quickness with which these foods are digested. Bearing these limitations in mind, however, we may safely say that simple, well-made crackers and cakes, at least when eaten in moderate quantities, are digested by persons in health with much the same thoroness as bread.

Statements of a popular nature are frequently met with regarding the unwholesomeness of hot bread. The fact that bread is hot has doubtless little to do with the matter. New bread, especially that from a large loaf, may be readily comprest into more or less solid masses, and it is possible that such bread would be much less finely masticated than crumbly, stale bread, and that, therefore, it might offer more resistance to the digestive juices of the stomach. However, when such hot bread as rolls, biscuit, or other forms is eaten in which the crust is very large in proportion to the crumb this objection has much less force. There is then little difficulty in masticating the crumb, and it is doubtless usually finely divided. The advantage of toast for invalids is often said to lie in the fact that the carbohydrates have been changed into more soluble form by the extra heating. Only the outer layers are thus changed, however, unless the bread is dried and browned thruout. If there is any advantage it probably comes from the more appetizing flavor of the toasted bread and the fact that it is more likely to be thoroly masticated.

MARKET VALUE OF BREAD.

In many European cities there are regulations which govern the weight of loaves of bread to be sold for a given sum. In old colonial days in Massachusetts the authorities set up similar standards and obliged each baker to stamp his initials on his wares. Such supervision, however, is almost unheard of at present, and when we consider the current market prices of bread, we find they bear little relation to the nutritive ingredients or even to the cost of the materials. Experiments made at New Brunswick, N. J., and Pittsburg, Pa.,[a] tend to show that bakers in those sections set their prices by the size and trade name of the bread. Thus in New Brunswick, where fifty analyses were made, the bread containing the highest amount of nutrients and that containing the lowest were sold at exactly the same price per pound, 4.1 cents. In New Jersey it appeared that the larger the loaf the higher the cost per pound tended to rise. The average cost of bread seems to vary in different localities. Thus while the investigations just referred to were being carried on, it averaged from 5 to 6 cents a pound in Middletown, Conn., from 3.8 to 4.9 in different cities in New Jersey, and 3.25 in Pittsburg.

When the selling price of bread and the cost of its ingredients are compared, the results are still more striking. In two experiments made in New Jersey it was found that two lots of bread made from materials costing, respectively, $2.28 and $2.56 were sold for $5.86 and $6.08. This represents a profit of 116.5 per cent over the cost of the materials, or, to put it in dollars and cents, the baker received $216.50 for bread the materials of which cost him $100. In Pittsburg the average increase in price over the original cost was 110 per cent. Even subtracting from this the cost of labor, rent, fuel, etc., the profits of the baker were so high that, to quote from the Pittsburg report:

> It would seem that in the case of very poor families * * * an important pecuniary saving would result if bread were made at home. To the man in ordinary circumstances it must always be more a question of convenience and taste than of cost. In short, each family can best determine for itself whether it is desirable to pay the baker for the trouble of making the bread and delivering it, or whether the labor of making and the extra fuel for baking can best be provided at home.

SUMMARY.

Cereals of one kind or another have always made an important item of human food, and of all the forms in which they have been used bread has proved the most satisfactory, palatable, and convenient. To prepare the grain for bread making it is usually cleansed, crusht, and sifted into a fine soft powder, which we call flour. Among various

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 35 and 52.

flours the preference should of course be given to the one which yields the most nutritious loaf for the least money, if strict economy must be practised, but all kinds of bread are wholesome if of good quality, and the use of several kinds is an easy way to secure variety in the diet.

The nutritive value of bread depends not only on its chemical composition, but also on its digestibility, and digestibility in its turn seems to depend largely on the lightness of the loaf. It is the gluten in a dough which gives it the power of stretching and rising as the gas from the yeast expands within it, and hence of making a light loaf. Rye has less gluten proteids than wheat, while barley, oats, and maize have none, so that they do not make a light, porous loaf like wheat. It is possible that of the various kinds of wheat flour those containing a large part of the bran—entire-wheat and graham flours—furnish the body with more mineral matters than fine white flour, but it is not certain that the extra amount of mineral matter furnished is of the same value as that from the interior portion of the grain. They do not yield more digestible protein than the white flours, as was for a time supposed. It seems safe to say that, as far as we yet know, for a given amount of money, white flour yields the most actual nourishment with the various food ingredients in the best proportion.

The raising or leavening of bread is usually brought about by letting yeast develop in it. These minute plants feed upon sugar in the dough and in their growth give off alcohol and carbon dioxid gas, which (particularly the carbon dioxid), expanding with the heat, force their way thru the dough and thus lighten it. In order to give the yeast a better chance to work, the dough is usually "set to rise" for some hours before it is put into the oven.

There are many methods of growing yeast at home or in the bakery, but the dry and the comprest yeasts now in the market seem to give equally good results with so much less labor that their use, in the United States at least, is becoming practically universal.

The lightness and sweetness of bread depend as much on the way in which it is made as on the materials used. The greatest care should be used in preparing and baking the dough and in cooking and keeping the finished bread. Heavy, badly raised bread is a very dangerous food, and unfortunately very common, and probably more indigestion has been caused by it than by all other badly cooked foods.

As compared with most meats and vegetables, bread has practically no waste and is very completely digested. It is usually too poor in protein to be fittingly used alone, but when eaten with due quantities of other foods it is invaluable, and well deserves its title of "the staff of life."

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