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BREAD AND 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., January 31, 1910.

Sir: I have the honor to transmit herewith an article on Bread and 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, as well as the reports of investigations relating to bread and bread making which have been conducted under the auspices of this Office, especially those carried on under the supervision of Director C. D. Woods, of the Maine Agricultural Experiment Station, and by Prof. Harry Snyder, at the Minnesota Agricultural Experiment Station.

Perhaps no topic connected with the subject of human food is of more general interest than bread, and no crops are more important to the farmer than the bread-yielding cereals. This bulletin, which summarizes the most recent information on the use of cereals for bread making, is believed to be useful and timely, and its publication as a Farmers' Bulletin is therefore recommended. It is designed to supersede Farmers' Bulletin No. 112, bearing a similar title and issued in 1900.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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BREAD AND BREAD MAKING.

INTRODUCTION.

Probably no food, unless it is milk, is more generally used than bread, nor is there any food that constitutes a larger part of the diet of the average person. 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 that with which we are familiar. 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 loaves of bread not unlike that of the present day, many European peasants still bake their weekly loaves in the village oven, and so on, to the mammoth bakeries and innumerable fancy breads of modern times. The reason for this importance of bread is very simple. Ever since the far-off days when the wild cereals were first found or cultivated men have known that food prepared from them would support life and strength better than any other single food except milk. Although in this country the ease with which other foods can be obtained makes bread seem less important, there are many districts of Europe and Asia where it is still the "staff of life," and where if people pray for their daily bread they mean it literally.

Even in the United States it probably plays a more important part than many realize. Statistical investigations which have been conducted by the Government indicate that at present the annual per capita consumption of wheat in the United States is about 4½ bushels, which represents not far from a barrel of flour, and there are reasons to suppose that this amount is increasing. In the course of the 400 dietary studies made by the Office of Experiment Stations under a large variety of conditions, it has been discovered that wheat flour and other wheat products supply 20 per cent of the total food materials used by the average American family in the United States, 30 per cent of the total proteids, 5 per cent of the total fats, and 42 per cent of the total carbohydrates. If only patent flours and the bread made from them are considered they are found to supply 18 per cent of the total food, 20 per cent of the protein, 3 per cent of the fat, and 38 per cent of the total carbohydrates.

Because of the very general and extensive use of this article of food it seems desirable that the housekeepers in country and town and others who are interested should be given the means of understanding its composition, its nutritive value, and the best means of preparing it for use. For this reason the present bulletin has been prepared.

In regard to its ingredients, bread is one of the simplest of 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 the books which describe the processes of bread making with any degree of completeness are often large volumes. In this bulletin it is proposed to give a brief account of these processes—to describe the raw materials from which 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 not only what the main steps in bread making are, but also what characteristics food must have in order to be of greatest nutritive value to the human body.

In the flour mill, where the initial steps in bread making may be said to be taken, the grain is ground into powder, the coarser outer parts being sifted out as bran, while the finer interior parts constitute flour. Once in the baker's hands, the flour is mixed 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," 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 mixed, this gas appears all through it, and, expanding, leavens or raises it throughout. 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 has formed 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 is called the "crust." The sum of these changes in the oven is called "baking." When this has been continued long enough the bread is "done" and is ready to be cooled and eaten.

The purposes which bread or any other food serves when it is taken inside the body have sometimes been compared to the use of coal in a steam engine, but the comparison is far from perfect. Food is the fuel which furnishes the energy for all the bodily activities, as coal furnishes the heat to make the steam which drives the engine, but it does more than this. It also builds the body engine and keeps it in repair. Hence there are two main functions which food must perform—to build up and keep in order the tissues and fluids of which human bodies are composed, and to furnish fuel or energy for their varied activities. Different as they look on the table, all food materials are found by the chemist to be made up of water and four different groups of substances which, in turn, play different parts in the building and running of the body machines, sometimes one or two and sometimes all of these constituents being present.

Water is found in varying quantities in almost all foodstuffs, even in such dry looking ones as flours; it is necessary to the body, and is usually available in sufficient quantities in the ordinary diet. Though necessary for carrying on the vital processes it does not build tissue or yield energy, hence it is not commonly classed as a nutrient or nutritive ingredient of food.

The four groups of true nutrients are protein compounds, carbohydrates, fats, and mineral matters or ash. The protein compounds include a great variety of materials, such as the albumen (white) of egg, the casein of milk curd, the lean of meat, and the aleurone and gluten of wheat and the similar bodies in other grains. They differ from other food ingredients mainly in that they contain nitrogen, and they are the only nutrients which can be used both to build tissue and to furnish energy in the body. The carbohydrates and the fats are fuel and not building foods. The carbohydrates include the different forms of starches, sugars, and cellulose or wood fiber and make up a large part of wheat and other grains. There are a great many kinds of fat in the different food materials; the more obvious forms are the fatty parts of meat, butter, fat, olive oil, etc., but some are also present in wheat and other grains. The fourth and last group of nutrients are the mineral matters or ash, which are found in very small quantities in foods but in great variety. During the period of body growth they supply the material out of which the bones and teeth are made, and at all times of life they perform many other important functions connected with body changes. An important point to be kept in mind about mineral matters is that while they are extremely important an ordinary mixed diet is believed to supply them in larger quantities than the body actually requires. For this reason under ordinary circumstances much anxiety with reference to securing enough mineral matter in the food is unnecessary.

Another important consideration in regard to the nutritive value of any food is its digestibility—that is, the completeness and ease with which it can be transformed by the digestive organs into the forms in which the body can utilize it.

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. One cereal may be more important in one part of the world, another in another, but probably in Europe and certainly in North America wheat is the leading breadstuff. This is partly because it can be successfully cultivated in a wide range of temperate climates, but chiefly because it yields the flour best suited to bread making, the aim of which is to produce an appetizing and nutritious loaf at the least expenditure of money and labor. While the various cereals differ largely in their chemical composition, most of them are very similar in the structure of their grains, so that a study of the formation and milling of wheat makes it easy to understand the production of flour from the others.

As a class the cereals may be said to contain on an average about 10 per cent of protein, a very small percentage of fats, and from 60 to 80 per cent of carbohydrates.

When the composition of cereals is considered, with reference to bread making, it is not enough to think of the amount of nutrients; the characteristics of the latter must also be considered. For example, the kind of cereal protein known as gluten is extremely tenacious and elastic. It captures and holds any gas which may come in contact with it, and for this reason it is most important in the making of light doughs. Other protein compounds, while of equal nutritive value, are wholly lacking in this quality. It is essential also to consider the amount of sugar present in the cereals, for this is the substance upon which yeast acts directly and out of which it can form carbon dioxid, the gas by which bread is usually made light.

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 envelope 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. Within lie the starch-containing or flour 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 the 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 thoroughly ripened and is surrounded by 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.

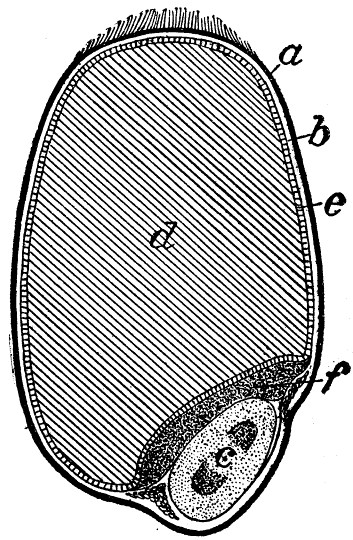

FIG. 1.—Diagrammatic section of grain of wheat: *a*, Skin and testa; *b*, membrane; *c*, embryo; *d*, flour cells; *e*, cereal or aleurone layer; *f*, scutellum.

The different parts of the wheat kernel 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 middle 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

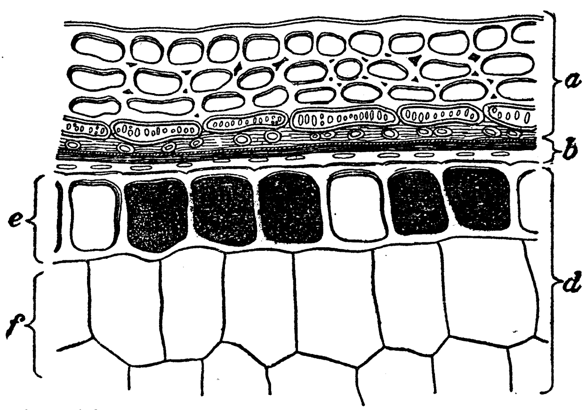

FIG. 2.—Cellular structure of a grain of wheat. (After Winton and Moeller.)

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 or aleurone 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 a large proportion of fat.

Since flour is the most important product of wheat, and since it is made up largely of the flour or starch cells of the endosperm, these are 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 these figures (3 and 4) united so that the starch grains would be 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

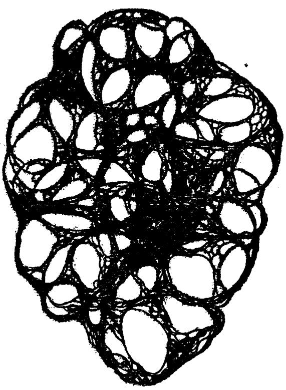

FIG. 3.—Diagram of protoplasmic structure of a flour cell.

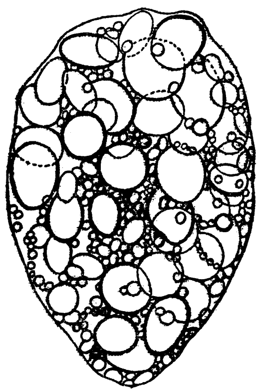

FIG. 4.—Diagram of starch grains in a flour cell.

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.

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. The character of the protoplasm varies in different parts of the kernel, indicating that each set of cells plays a different rôle in the development 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.

The knowledge of the protein compounds of the wheat kernel has been much increased lately, notably by the elaborate work of Osborne[a] at the Connecticut Agricultural Experiment Station. These compounds are more varied than was formerly supposed, but the most important fact to be remembered in connection with bread making is the character of those in the endosperm. Gluten is the term formerly employed to describe them and still in common use; but it should be borne in mind that gluten is not a simple compound, but one which itself contains several kinds of protein. Of these gliadin and glutenin are the most abundant and in the present discussion the most important. As will be seen later, the bread-making power of a flour depends largely on the relative amounts of gliadin and glutenin which it contains.

The cellulose also differs in character in different parts of the grain, being both more woody and more abundant in the outer layers which are ordinarily sifted out from the finer grades of flour. The proportion of cellulose carbohydrate which the body can utilize depends upon the character of the cellulose, woody cells being little digested while cell walls of softer texture are apparently rather well digested. Between these extremes are many variations. The portion of the grain called the testa contains coloring matter, and it is the presence of this which makes flour dark.

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.

Milling.—When people first began to grind their grain they did so simply by crushing it between any two stones which happened to be at hand; a little later they kept two 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 mills have been built covering acres of ground.

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[a] Carnegie Institution of Washington, Publication No. 84, 1907.

In Hungary the old Roman system of cylinder milling has been developed, but elsewhere the systems which are known as high and low milling are more common. This is 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, advocated by an American physician, Dr. Sylvester Graham, is really wheat meal containing all of the grain; it is made by simply 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 screened and cleaned and then tempered; that is, treated with heat and moisture in such a way as to make it easier to remove all the bran at one grinding. After removal of the bran, the stock is run through 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 through a series of six straight breaks there are as many as eighty 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 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 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," as these by-products of milling are termed, 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 portions of the bran, 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 (with the exception of those for gluten flours) those for products all milled from the same lot of Minnesota hard spring wheat, hence they are 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
First clear-grade flour	10.13	13.74	2.20	73.13	.80
Straight or standard-patent flour	10.54	11.99	1.61	75.36	.50
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
Germ	8.73	27.24	11.23	48.09	4.71
Gluten flour, true to name	9.99	84.09	.66	5.01	.22
Gluten flour, not true to name	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 mixed before milling. Sometimes the miller, or even the baker, mixes two kinds of flour, but such a proceeding seems to be regarded by the users of flour as less satisfactory because it gives less uniform results.

Tests for quality.—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. In general, the flour housewives prefer is white with a faint yellow tinge. After being pressed in the hand flour 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. Wholesale bakers usually demand a more granular, darker flour and one with a greater power of absorbing water than is ordinarily chosen for household use; they also make careful baking tests with each fresh lot of material, and as each barrel which leaves the first-class mills is individually numbered, it is possible to trace back to their source any undesirable characteristics if they should be noted. Housekeepers who buy flour under fancy trade names have less opportunity of knowing the character of the product, nor does it ordinarily seem worth while to make baking tests for the small quantities purchased for home use; but an intelligent housekeeper who wishes to know the quality of the flour she is buying could easily learn from the dealer or the miller the character of different brands and could use samples to compare their bread-making qualities in her own kitchen before buying her supply for the season.

Possible impurities of wheat flour and the ways in which they may be avoided.—Certain impurities may accidentally occur in a bag of grain or the flour made from it. They consist mainly of seeds of other plants, some of them harmful to color or flavor, and of blighted or molded grain. Modern methods of sorting and cleaning the grain in well-conducted mills almost eliminate the danger of foreign seeds and careful methods of storing make the dangers from molds and other fungus growths much less than formerly. Careful milling processes also tend to remove such accidental impurities as bits of sand, earth, or metal which occasionally slip in.

Of course flour which is in good condition when it leaves the mill may deteriorate if it is not properly cared for. All such products are attractive fields for molds and bacteria, and in their growth these minute organisms may spoil the flavor and bread-making qualities of flour. Dampness and darkness are very favorable to their growth, hence dry, well-lighted storerooms are the best for flour. Damp, dark cellars should not be used for storing any cereal products. The color of flour, like many natural colors, fades more or less during storage and the flour becomes whiter.

RYE.

The grain of rye is darker in color than that of wheat, but is otherwise similar in appearance. Rye flour differs from wheat flour in flavor, the liking for the one or the other being a matter of preference. It differs, however, in another way and in an important particular—its gluten has not the same elastic, tenacious quality and does not yield so light and well-raised a loaf. Although this fact and its dark color make it less popular than wheat, it is second in importance as a breadstuff. It is more easily raised than wheat, especially in cold countries, and therefore generally has a lower market value. In many parts of Europe it practically replaces wheat among the poor and in army rations. 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 making.

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 both barley and oats the bran makes up a higher percentage of the entire grain than in wheat. Both oats and barley on an average contain less moisture than wheat. They do not contain any true gluten (which appears in wheat and rye), and although 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 proportion of relatively indigestible cellulose.

CORN, OR MAIZE.

This cereal, generally known in the United States as Indian corn, and on the continent of Europe as maize, is a native of America. It is commonly grown in North and South America, Africa, India, China, 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 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, the cell nucleus, the 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

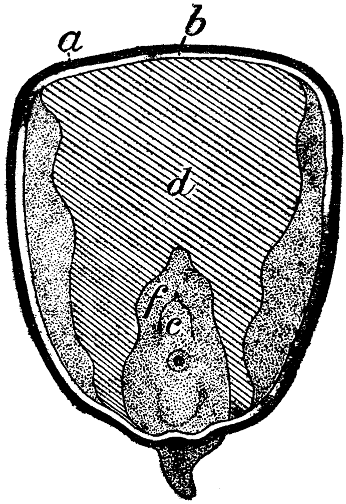

FIG. 5.—Diagrammatic section of grain of corn: *a*, Skin and testa; *b*, membrane; *c*, embryo; *d*, endosperm; *f*, scutellum.

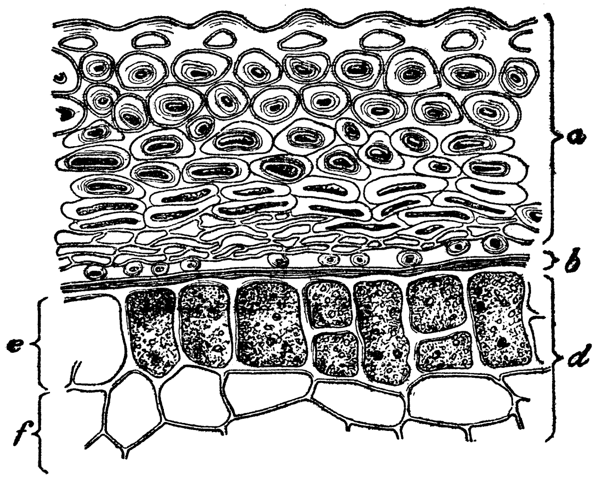

FIG. 6.—Cellular structure of a grain of corn: *a*, Skin and testa; *b*, membrane; *d*, endosperm, consisting of aleurone cells (*e*) and starch cells (*f*). (After Winton and Moeller.)

with wheat, maize is rich in fat, poorer in cellulose and protein, and about equal to wheat in carbohydrates, mineral matter, 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 these dry so quickly that they must be eaten fresh. Since maize flour contains no tenacious, gluten-forming proteids 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 of the peasants in large districts throughout a considerable part of the year. In Servia the unripe corn is eaten much as in this country, and corn-meal bread and mush are staple articles of diet. In the Orient, corn where grown is used in much the same ways as other grains.

RICE, MILLET, BUCKWHEAT, ETC.

Rice, which is grown and eaten to a large extent in the United States, is the most 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 China, and in the United States buckwheat is often made into batter cakes. Yet 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. Grain sorghums, especially Blackhull Kafir, are used in the United States to a limited extent for batter cakes, etc. In Africa and India they form the principal cereal food of large numbers of native peoples.

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

Composition of cereals.

Kind of cereal.	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 a little yeast is added to a sweet liquid like fruit juice and kept warm, bubbles 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 produce, 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 it gives 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 may therefore be 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, which is much like diastase, and 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 the organized ferments that they 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. Moreover, 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. Though much has been learned in recent years concerning fermentation, there still remain many things to be explained. It is known 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 though the original yeast 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 starch by diastase, grows and spreads throughout 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

[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.

of 77° to 95° F. (25° to 35° C.). It has already been 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.

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 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 yeast" 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 mixed with the dough. The "barms" so much used in Scotland are made by letting yeast grow in malt extract and flour (p. 24). Brewers' and distillers' yeasts are taken from the vats in which malt extract has been fermenting. Compressed yeast is made with yeast taken from distillers' wort, washed in cold water, and further cleaned by being passed through silk or wire sieves or by precipitation. It is then pressed, cut into cakes, and done up in tinfoil. When fresh it becomes firm, moist, and of a light, creamy color throughout. On account of its moisture, it soon decomposes unless it is kept in a cool place. Dry yeasts are prepared by mixing

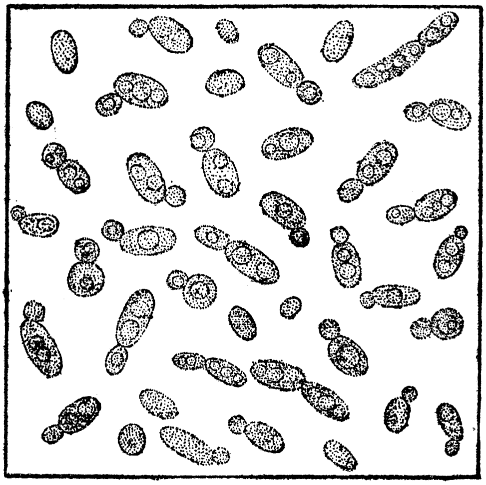

FIG. 7.—Yeast plant.

fresh yeast with flour, meal, or starch, pressing the mixture into little cakes, and then drying them. Without moisture the yeast cells must remain inactive, and well-made dry yeast should keep for a long time. The strength of any yeast depends on the care with which it is made and preserved. Ordinary liquid 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. Compressed and dry yeasts, if carefully made, are more uniform in strength and composition than such liquid yeast. Usually a few of the microscopic plants or bacteria other than yeast plants are not regarded as a detriment, as the slight acid taste which their presence gives to the bread is considered desirable by many.

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 the middle of the nineteenth century 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 mixed 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 is a flour ready mixed with such a preparation. In the United States leavening agents other than yeast are more commonly used for such kinds of bread as tea biscuit and batter cakes, or for cake and pastry, than for loaf bread. Soda, cream of tartar, or saleratus biscuit are examples of breads frequently made in the home with these chemical 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 mixed with the flour in a specially constructed machine. Sometimes a little fermented barley infusion from a brewery, or "wort," is put into the water. This renders the gluten more elastic, aids in absorbing the gas, and improves the flavor of the bread. The bread is about as porous as that raised with yeast, but is less agreeable to the taste of many persons, apparently because of a lack of the by-products resulting from the action of the yeast in the fermentation process.

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 mixed 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 throughout. 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 thoroughly kneaded together and set in a warm place for several hours. The leavening action started in the batter spreads through the dough and produces a light, porous loaf, which many persons consider very palatable. Such a bread is comparatively free from acidity, as the presence of the salt hinders undesirable acid fermentation.

RAISED BREAD, GENERAL METHODS.

Ordinarily a baker mixes his dough with water, and most of the data summarized in this bulletin refer to such bread. Sometimes, especially in private families, milk is used in the place of part or all of the water. Such dough is slower in rising but makes an equally light loaf. Milk bread 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, though 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 diastase by which starch is converted into sugar, and on other ferments.

When the flour is of good quality, the dough well prepared, and the bread properly baked, the loaf has certain definite characteristics. Thus it should be well raised and have a thin, flinty crust, which is neither too dark in color nor too tough, but which cracks when broken. The crumb, as the interior of the loaf is called, should be porous, elastic, and of uniform texture, without large holes, and should have a good flavor and odor. In this connection the breadmaking and judging contests in some of the household science departments of the farmers' institutes are of interest. The members are urged to bring

[a] See articles on the digestibility of bread in Maine Sta. Rpt. 1898. Also U. S. Dept. Agr., Office of Experiment Stations Bul. 85.

loaves of their own baking to the meetings, and these are judged on such points as flavor, lightness, grain and texture of the dough, color, depth and texture of the crust, and marked on special score cards with as much accuracy as is used in seed or stock judging contests among farmers. If housekeepers would judge the bread baked in their own kitchens with the same intelligent interest and profit by their findings they could soon learn to make bread as accurately as wholesale bakers.

PREPARATION OF THE DOUGH.

The methods of mixing dough are various, 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 thoroughly mixed 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 ferments. 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 the materials can teach the exact quantities which should be mixed. 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, though expert cooks insist that perfect mixing may be obtained by the use of a knife. Within a few years 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 thoroughly and perhaps more evenly and quickly than the ordinary kneading. In another form the dough is mixed by revolving knife-like devices. These machines seem to give excellent results and are to be recommended at least as labor saving and cleanly. Perhaps where bread is made in small quantities and every precaution is taken to insure cleanliness, the use of the hands may be tolerated, but the practice was long ago given up in wholesale bakeries of good grade where dough is mixed 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 high grade establishments modern kneading machines, in which revolving metal blades do the work of the hands, are in general use, as well as other ingenious machinery; it is even possible to turn out bread in which none of the materials have been touched by hand from the time they enter the bakery until the loaves are taken from the oven. Every utensil used in making and handling bread should be scrupulously clean, not only because it is desirable for food to be clean but because otherwise bacteria may get into the dough and produce harmful fermentations which mean loss to the housekeeper or the baker.

Bread making, as practiced in large bakeries, differs from that as practiced in households more in the amount of materials used and the consequent need of mechanical devices than in any fundamental principles. The question of the amount of bread to be obtained from a given quantity of flour and yeast plays a more important part in bake shops, and of course influences the choice of methods of preparation as well as of the flour to be used.

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 mixed 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 compressed yeast is used, as the dough can be mixed 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 mixed 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 thoroughly, 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 dough. Like offhand dough, it can be started the night before it is baked.

There are of course various other ways of mixing dough with yeast in bakeries, but the ones just described are sufficient to illustrate the general principles involved.

Scotch barm methods.—Probably the majority of European bakers now use yeast in ways similar to those followed by Americans, but in some regions other leavening methods are still common. Thus, many Scotch bakers still use barm, which is literally the foamy scum which rises to the top when beer, etc., is made. To make barm in the household malt is crushed 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 mixed 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. Scotch bakers consider this method 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 probably not be acceptable to the average American palate.

BREAD MADE WITH LEAVEN.

In some parts of the continent of Europe the age-old method of raising bread by leaven is still practiced. According to a French authority,[a] a little of the dough ready for baking is saved and mixed 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 mixed 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 acid 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 generally 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 the commercial yeasts are more reliable and much more convenient.

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

Rising of dough.—After mixing the dough in the way considered most desirable it is set 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 throughout 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.

HOUSEHOLD METHODS OF BREAD MAKING.

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 or kneading. These differences are not so 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 thoroughly kneaded and is then allowed to rise until it doubles its bulk, when it is again kneaded thoroughly. 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 overnight. 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° F.

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 mixed to a dough with water or milk, and some leavening substance is generally added to make the dough porous. Eggs, sugar, and shortening may be added, and sometimes spices, chopped nuts, or raisins mixed in, so that the varieties of bread become numerous.

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 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, numerous varieties of unleavened breads. Milk, butter, lard, spices, dried fruits—anything or everything desired to give them a particular consistency, color, or flavor—is mixed with the flour and water, and the dough is then passed through ingenious cutting machines and quickly baked in a hot oven. Such crackers are dry 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 thoroughly 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 clean 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 pressed 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. Some of the diabetic foods now on the market have been recently studied at the Connecticut Agricultural Experiment Station and the analysis for true gluten flour given on page 13 was quoted from its report.[a]

Although macaroni, spaghetti, and other wheat pastes occupy a very different place in 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 and southern Russia, the Mediterranean countries, and South America, but recently they have been successfully cultivated in certain sections of the United States, so that domestic pastes are likely to become more and more common in the markets. Noodles, which are only slowly coming into general use in this country, though they have long been popular in Europe, differ from macaroni and the other flour-and-water pastes in having eggs mixed in, and are therefore lighter and richer in protein.

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 rather solid, uniform mass and comes out a light, porous 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

[a] Connecticut State Sta. Rpt. 1906, Part II, pp. 153–165.

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." The reason why bread made from bran-containing flours turns so dark during baking is not thoroughly understood, but recent French investigations indicate that it may be due to the action of enzyms on pigments present in the bran. 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 through the crust and will lift up the latter, leaving great holes beneath it. To prevent too rapid formation of the crust, bakers sometimes 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. Cooks sometimes get a similar result by spreading the top of the bread lightly with butter. If the oven is not equally heated throughout, a baker usually puts the 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

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

aerated bread factories. Aerated dough is mixed with cold water, and if it were immediately subjected to a high temperature the crust would form before the interior was more than warmed through. Accordingly, a peculiar oven is used for baking it, 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 thorough 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 the 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.

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 thoroughly 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. Well-informed bakers appreciate this and many modern bakeries are models of cleanliness. However, in some bakeries bread is kept where the dust and dirt from the street can get to it, or is delivered in dirty baskets or carts. In this way disease germs and dirt may easily lodge on its surface. Because the crust of fresh bread is so dry and hard molds and bacteria may not grow on it as easily as on a moister surface, but this does not greatly lessen the danger of dirty bread, which in most cases is eaten just as it comes from the shop. In Europe this danger is sometimes avoided by slipping the loaves into bags of parchment paper or something similar 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 or other special 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 pressed 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 is said. 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 distill 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 into the cake box to keep the cake moist may be mentioned. This end 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.

CHARACTER OF BREAD AS RELATED TO THE GLUTEN OF THE FLOUR.

It has already been indicated that gluten is the ingredient of the flour on which its bread-making properties chiefly depend, and that gluten itself is not a simple protein compound, but contains two other compounds, glutenin and gliadin. In different kinds of flours not only does the proportion of gluten to the other ingredients differ, but also the proportion of glutenin to gliadin in the gluten itself. Two flours containing the same amounts of protein compounds when converted into bread by exactly the same process may yield bread of entirely different characteristics because of the different proportions of glutenin and gliadin in the two flours. The gliadin, a sort of plant gelatin, is the material which binds the flour particles together to form the dough, thus giving it tenacity and adhesiveness; and the glutenin is the material to which the gliadin adheres. If there is an excess of gliadin, the dough is soft and sticky, while if there is a deficiency, it lacks the power of expanding. Many flours containing a large amount of gluten and total proteid material and possessing a high nutritive value do not yield bread of the best quality because of an imperfect gliadin-glutenin ratio. This question is of much technical importance in the milling of wheat, especially in the blending of different types of wheat. At the Minnesota Experiment Station considerable study has been made of this and other problems regarding the bread-making properties of wheat, which may at least be mentioned here.

Some of the experiments referred to were planned to test the question whether it is the starch content or the gluten content that determines the bread-making quality of flour. In certain cases the proportion of starch in a normal flour was increased 10 to 20 per cent by the addition of wheat starch, while in others it was decreased to the same extent, and in still others 10 to 20 per cent of corn flour was added to the wheat flour. The breads made from the flours containing increased or decreased quantities of starch were then compared with that made from a like quantity of the normal flour. In the experiments in which the proportion of starch was increased by adding either wheat starch or corn flour there was practically no difference in either the size or the appearance of the loaf as compared with that from normal flour. The results of these tests, as well as of those made in other countries, clearly indicate that it is the gluten rather than the starch content that determines the bread-making properties of the flour.

To get other tests the proportion of starch was diminished, not by removing starch from normal flour, but by adding gluten to it. These tests emphasized the fact that it is not the starch content that determines the bread-making quality of the flour, and they also showed that an abnormally large amount of gluten does not yield a correspondingly large loaf.

Experiments were also made to determine the relation between the nature of the gluten and the character of the bread. This was done by comparing bread from normal flour with that from other flour of the same lot, from which part or all of its gliadin had been extracted. Dough made from the latter was not sticky, but felt like putty, and broke in the same way. The yeast caused the mass to expand a little when first placed in the oven; then the loaf broke apart at the top and decreased in size. When baked it was less than half the size of that from the same weight of normal flour, and decidedly inferior in other respects. It was about as heavy as the same quantity of rubber. The removal of part of the gliadin produced nearly the same effect as the extraction of the whole of it, and even when an equal quantity of normal flour was mixed with that from which part of the gliadin had been extracted the bread was only slightly improved.

Some experiments have recently been made at the Ontario Agriculture College [a] to determine what kinds of flours were best adapted to making milk biscuit with baking powder, and the conclusion reached that soft flours, i. e., those in which the gluten was not too strong, made biscuits that were tenderer and more easily handled than strong flours.

LOSSES OF MATERIAL IN BREAD MAKING.

In whatever way bread is made there is always some loss of materials in the process beyond that of the flour and dough accidentally lost in the mixing and molding, and these losses are especially noticeable in bread made with yeast. In experiments carried on at the Minnesota and New Jersey Agricultural Experiment Stations it has been estimated that anywhere from 1.5 to 8 per cent of the nutrients in the flour may disappear in this way. The yeast plants require a certain amount of nitrogenous material for their growth, but fortunately feed to some extent on the amid compounds, substances of less nutritive value than protein, and thus occasion only slight loss of valuable food material. A small proportion of the fats also disappear, probably volatilized by the heat of baking. The greatest loss occurs in the carbohydrates. It has been seen that during the process of fermentation part of the starch is changed to carbon dioxid and alcohol; in the later stages small amounts of volatile acids are also formed from the decomposition of carbohydrates. In tests in which care was taken to prevent loss the equivalent of 1.68 per cent of the carbohydrates was lost in this way. When bread is less carefully made the loss is likely to be much greater.

Of course part of these losses are inevitable, and the superior lightness, flavor, and keeping qualities of well-made yeast bread more than compensate for them. Evidently the art of producing a well-raised and at the same time the most nutritious loaf depends on letting the fermentation continue just long enough to avoid sogginess and heaviness, and no further.

IMPERFECTIONS IN BREAD.

The heaviness or sogginess such as was just referred to is one of the common and most undesirable faults in bread. As has been

[a] Ann. Rpt. Ontario Agr. Col. and Expt. Farm, 34 (1908), pp. 242–247.

pointed out, it may be caused by the use of flours whose gluten is too weak to absorb the water put into all 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 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 compressed 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 housekeepers and bakers, sour bread. This is due to lactic, or,

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

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

in the worst cases, butyric, acid given off in the growth of undesirable bacteria which accidentally find their way into the dough from the air, the water, or in some other way. A little acid is not necessarily harmful, as was seen in the discussion of 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 thoroughly 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 troubles are, fortunately, very rare, and if bakers and housekeepers guard against all the other dangers they are reasonably certain 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. Soda is often used by housekeepers in bread to prevent souring, and in small quantities does not injure the flavor of the bread. 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.

Besides the acid-producing bacteria, various others sometimes 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.

NUTRITIVE VALUE AND COST OF BREAD.

In order to decide which of several foods furnishes the most actual nourishment for a given cost, it is necessary to 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, provided both are equally wholesome and desirable otherwise.

CHEMICAL COMPOSITION.

The chemical composition of the finished loaf differs somewhat from that of the original ingredients, but depends primarily upon that of the flour from which it is made. If milk and butter (or lard) are used in mixing the dough, as is commonly the case, their nutrients are, of course, added to those of the flour; but when only water and flour are used the nutrients of the bread are simply those of the flour. In either case, however, the proportions of the nutrients in the bread are smaller than those in the flour, because a considerable part of the moisture from the water or the milk used in mixing the dough is present in the bread after baking; that is, a pound of the bread would contain less of any of the nutrients than a pound of the flour, because the proportion of water in the bread is greater. 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.

Materials.	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 decrease in protein and carbohydrates is in part only apparent and is due to the increased proportion of water, but is in part real, as was explained on page 33. 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. 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 has previously been pointed out, has taken definite shape. This really means that it has coagulated very much as the white of an egg does in boiling. The increase of fat 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.

It is apparent that two kinds of bread from the same lot of flour may differ according to the method used in making the bread. On the other hand, two loaves of bread made by exactly the same process, but from different lots of flour of the same grade or brand, do not necessarily have the same composition, because of a possible variation in the flours. The chemical composition of wheat is not a fixed characteristic, different kinds of wheat varying widely in this respect. Furthermore, the composition of the same sort of wheat varies with several factors, such as climate, rainfall, and the soil in which it is grown. It is evident, therefore, that general statements regarding the composition of flour and bread can hardly be universally accurate.

Since durum wheat has become a common crop in many regions of the United States much interest has been manifested regarding the value of durum flour for bread making and other household purposes. As is the case with other types of wheat, the quality varies in different cultural varieties. The many analyses which have been reported show that on an average durum wheat and the flours made from it do not differ materially from similar products of other wheats. For instance, in an extended comparison made by the Bureau of Plant Industry [a] it was found that the durum wheat flours tested showed, on an average, 12.61 per cent protein, and Northwestern spring wheat flours 13.01 per cent, the range in the two cases being much the same, and further, from studies of the proportion of gluten and of gluten constituents in durum flour, the conclusion was reached that on an average it did not materially differ in these respects from flour from other varieties of wheat.

The results of numerous bread-making tests at agricultural experiment stations and elsewhere indicate that bread of good quality and appearance may be made from durum flour, and judging by data gathered by the North Dakota Agricultural Experiment Station,[b] housewives who are familiar with the use of durum flour consider it satisfactory for bread making and other household purposes.

In color, durum flours from different varieties of wheat show a wide range, some flours being white and others rather dark. It seems fair to say that in general it is yellower than flour from the varieties more commonly milled.

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 table on page 38. 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

[a] U. S. Dept. Agr., Bureau of Plant Industry Bul. 70.

[b] North Dakota Sta. Spec. Bul. 19.

Oklahoma flours were likewise specially ground and the breads made in the same way as those from the Minnesota flours. Thus, if the figures for entire-wheat bread from these three classes of flours are compared, 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.

Food material.	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 ct.*	*Per cent.*	*Per ct.*
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
Cod steaks:							
Edible portion	1		79.7	18.7	.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 fifth 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 3,500 calories. The more physical work he does 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 composition of the original grains 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 a high 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 and other nutrients 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 the 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. So much popular discussion has been aroused in late years regarding the relative values of some of them, however, that a more detailed account of the matter may not be out of place here.

GRAHAM, ENTIRE WHEAT, AND STANDARD PATENT FLOURS.

The nutritive value of these three classes of flour and the breads made from them has been extensively investigated by Snyder at the Minnesota Agricultural Experiment Station and by Woods at the Maine Agricultural Experiment Station. Graham flour, strictly speaking, is simply wheat meal; that is, the entire grain ground to a powder. It has sometimes been made by removing the outer branny portions of the kernel and grinding this separately from the inner parts, afterwards combining the two, as it was thought that the efforts to grind the naturally coarse material with the rest of the wheat had a deleterious effect upon the bread-making qualities of the flour. It is now commonly made by crushing and grinding the whole of the kernel at once, without bolting or sifting. When thus prepared it contains the same ingredients as the wheat itself and in the same proportions. Even the most successful attempts at fine grinding, however, still leave it fairly coarse and with a large proportion of branny particles. To overcome this objection more or less bolting is frequently resorted to. Much of the flour sold as graham has been thus treated, though, of course, such a product is not really graham flour such as Graham advocated.

The term "whole wheat" or "entire wheat" seems rather inexact and suggests flour practically identical with the graham. The flour thus designated, however, is said to be made often by removing the branny outer covering and grinding the remainder. By such a method some of the outer portion of the wheat kernel would be retained in the flour. So far as can be learned much of the so-called whole-wheat flour is not so ground, but is made by mixing patent grade, middling, and low-grade flours with considerable of the germ. Whole-wheat flour is not so coarse as graham nor so fine as the white flours.

The flour most widely used is that known as straight patent, or standard patent, or family grade. Although this flour contains neither the germ nor the bran of the wheat, in modern exhaustive milling nearly 73 per cent of the kernel is recovered in it.

The following table gives the results of the analyses of flours and breads prepared from special lots of wheat at the Minnesota Experiment Station, and each group represents strictly comparable materials the differences in which are due only to differences in the process of milling and not at all to difference in the wheat used.

Composition of flours and breads as shown by experimental studies.

Material.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Minnesota wheat flour (fresh material):	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
First patent	10.55	11.08	1.15	76.85	0.37
Second patent	10.49	11.14	1.20	76.75	.42
First clear	10.13	13.74	2.20	73.13	.80
Standard patent	10.54	11.99	1.61	75.36	.50
Second clear	10.08	15.03	3.77	69.37	1.75
"Red dog"	9.17	18.98	7.00	61.37	3.48
Entire wheat	10.81	12.26	2.24	73.67	1.02
Graham	8.61	12.65	2.44	74.58	1.72
Oregon wheat flour (fresh material):					
Standard patent	8.94	7.55	1.25	81.82	.44
Entire wheat	8.66	8.25	1.67	80.35	1.07
Graham	8.15	8.97	1.68	79.48	1.72
Oklahoma wheat flour (fresh material):					
Standard patent	9.93	15.06	.92	73.57	.52
Entire wheat	7.46	16.63	1.64	73.05	1.22
Graham	7.73	16.81	1.79	72.35	1.32
Bread made from patent flour (fresh material):					
High grade	32.9	8.7	1.4	56.5	.5
Standard grade	34.1	9.0	1.3	54.9	.7
Medium grade	39.1	10.6	1.2	48.3	.9
Low grade	40.7	12.6	1.1	44.3	1.3
Bread made from Oregon wheat flour (water-free basis):					
Standard patent	....	8.32	1.37	88.93	1.38
Entire wheat	....	9.49	1.82	87.24	1.45
Graham	....	9.94	1.83	85.72	2.51
Bread made from Oklahoma wheat flour (water-free basis):					
Standard patent	....	16.24	1.02	82.03	.71
Entire wheat	....	18.06	1.77	78.75	1.60
Graham	....	18.43	1.94	77.12	2.51

Comparing the three grades of flour from the same lot of wheat, it will be noticed that in each case the proportion of protein was largest in the graham and smallest in the standard patent flour, the entire wheat being between these two. On the other hand, the proportion of carbohydrates was smallest in the graham and largest in the standard patent flour.

The breads from the different flours, made in such ways as to afford comparison, bear the same relation to one another as the flours in respect to the proportions of nutrients. Thus, in the breads made from different grades of patent flour, that from the high-grade flour, which had the lowest protein content, had the least protein, while that from low-grade flour, which is the richest in protein, had the most. This is true of the breads of which the analyses are given in the table, even though the proportion of water is highest in the bread from the low-grade flour; if the computations were based upon the dry matter of the breads the differences would be still larger. In the case of breads made from the different grades of Oregon and Oklahoma wheat the values given are for dry matter, in order that the comparison may be absolute. These data show that in each case the graham bread had the most protein and the least carbohydrates, as was the case with the flours. Considering that these two nutrients are not present in flour in proper proportions for a well-balanced diet, there being an excess of carbohydrates and a deficiency of protein, it might seem from such a comparison of composition that the coarser flours would be the best. Before an adequate discussion of relative nutritive value is possible, however, the digestibility of the three flours must be determined.

DIGESTIBILITY OF DIFFERENT KINDS OF BREAD.

A knowledge of the digestibility of any food material is of prime importance, for two reasons: In the first place, unless a food is completely digested a portion of it does not serve the body as nutritive material, because only that part of the food which is digested and absorbed from the alimentary canal can be thus utilized; and, in the second place, some indigestible materials may act as irritants in the alimentary canal, and while they may stimulate the excretion of the digestive juices they sometimes increase peristalsis too much, thus hastening the contents along too rapidly to permit complete absorption, with the result that nutritive material which otherwise might be absorbed and serve to nourish the body is lost along with the indigestible materials. In estimating the nutritive value of a food material it is therefore necessary to consider not only its composition but also the proportions of its different nutrients that are digested and utilized.

The next question then 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]

Upward of 100 digestion experiments have been made with young, healthy men, with bread from different grades of flour ground from hard and soft wheats from Indiana, Michigan, Minnesota, Dakota, Oklahoma, and Oregon. In all these investigations great care was given to the securing of different grades of flour from the same lot of wheat, to the production of bread from the flours, and to all other details of the experiments, in order to secure uniformity of conditions, and thus insure fairness and reliability in comparison. The results

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

of these experiments, therefore, give very definite information regarding the relative digestibility of bread from different grades of flour.

The larger number of these experiments were made with graham, entire wheat, and standard patent flours from wheats from different sections of the country. The averages of the results with these three grades of flour give the following as the proportions of nutrients that were digested from the different flours, these factors being commonly termed coefficients of digestibility: Standard patent flour, protein 88.6 per cent and carbohydrates 97.7 per cent; entire-wheat flour, protein 82 per cent and carbohydrates 93.5 per cent; graham flour, protein 74.9 per cent and carbohydrates 89.2 per cent.

The digestibility of the fat was also studied in some cases, but the quantity of fat in bread is too small to permit of accurate tests of its digestibility, and for the most part the results were believed to be inexact, and are therefore omitted. This is a matter of no importance, however, as bread is not considered as a source of fat in the diet. The very common custom of eating butter or some other fat with bread is in reality but a method of supplying this deficiency.

With all the subjects, and with all kinds of wheat thus far tested, the uniform result was that the digestibility of the standard patent flour was the highest, that of entire wheat the next, and that of graham the lowest.

The nutritive value of the mineral matters in the bran-containing flours has not yet been satisfactorily determined. Within a few years detailed research into the phosphorus compounds of flours, begun at the New York State Agricultural Experiment Station and later carried on in various laboratories, has revealed a new substance called phytin, which seems to have a distinct physiological action. Interesting and valuable as such work is, more studies are needed before the influence of these constituents of bran and of other parts of the wheat berry can be definitely understood. Probably too much stress should not in any case 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 such 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 are few 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 mixed diet of children and adults furnishes an abundance of mineral matter. A certain "bulkiness" in the diet is desirable, such as is supplied by the crude fiber of plants, and 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 hardly warranted at present. 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 bread is just as pleasing as variety in meats, vegetables, and puddings. The housekeeper may therefore wisely use all the different kinds of flours here discussed 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 discussed 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.

A number of experiments have also been made to study the effect of adding germ to patent flour. The digestible nutrients in the flour made with the germ, as found in these experiments, showed a trifle more protein and slightly less carbohydrates than in the flour without the germ. Therefore, practically no gain in nutritive value was obtained by retaining in the flour the germ that is ordinarily removed in the milling.

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 very definite has yet been learned about the ease and quickness with which these foods are digested. Bearing these limitations in mind, however, it may safely be said that simple, well-made crackers and cakes, at least when eaten in moderate quantities, are digested by persons in health with much the same thoroughness as bread.

HOT, FRESH, AND TOASTED 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 compressed 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. Little difficulty is then experienced in masticating the crumb, and it is doubtless usually finely divided. As far as is now known the changes ordinarily occurring in good bread as it ages do not affect its digestibility unless it becomes so dry as to be unappetizing.

When bread is toasted the chemical nature of some of its ingredients is changed and the carbohydrates at least become more soluble and presumably more easily digested. The ferments and bacteria which may have survived the baking or which have entered the bread later are also killed if the toasting is continued long enough; this may be of considerable advantage to persons of delicate digestion. Owing to its dryness, toast is more likely to be well masticated than fresh bread. These facts and the further one that perhaps owing to its crispness and greater flavor it is often more appetizing than bread explain why toast is so suitable for invalids. Of course its advantages are greater when it has been well toasted throughout than when only the outer surfaces have been subjected to the action of the heat.

PLACE OF BREAD IN THE DIET.

As previously pointed out, bread contains from 35 to 40 per cent of water. Since the remainder, about 60 per cent at least, is nutritive material, bread is really one of the most nutritious of the common foods, but few others equaling it in this respect. Bread supplies a large amount of carbohydrates, a moderate amount of protein, a small amount of mineral matter, and almost no fat. Since there is relatively an excess of carbohydrates and a deficiency of protein in wheat, bread could not serve alone for proper nutrition of the body, because an amount of bread sufficient to supply the requisite protein would furnish much more carbohydrates than necessary. In a mixed diet this discrepancy is of little importance, because the deficiency of protein is made up by such foods as meat or cheese. Bread and milk forms a much more suitable diet than bread alone. Where bread forms the whole or the main part of the diet, as it does among large numbers of the poor, the deficiency of protein is of much more consequence. Most methods of increasing the protein content of bread which have been suggested have a tendency to increase the cost of the bread too much. The use of skim milk instead of water for mixing the dough does not increase the cost of the bread very materially, but it does add appreciably to the protein content. A comparison of skim-milk bread with water bread made from the same flour, as given in the table on page 36, shows that the skim milk increased the protein about 2 per cent.

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 cleaned, crushed, and sifted into a fine soft powder, which is called flour.

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 matter 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 is known, for a given amount of money, white flour yields the most actual nourishment with the various food ingredients in good proportion.

It should be remembered, however, that all kinds of bread are wholesome if of good quality, and the use of several kinds is an easy means of securing variety in the diet.

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 through 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 compressed 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. Though good housekeepers agree that light, well raised bread can readily be made with reasonable care and attention, heavy, badly raised bread is unfortunately very common. Such bread is not palatable and is generally considered to be unwholesome, 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 as the sole article of diet, 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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