A COMPARISON OF SPRING AND WINTER WHEAT FLOUR AS INFLUENCED BY COMPRESSED, DRY AND LIQUID YEASTS

Thesis for the Degree of M. S.

Bessie Belle Hoover

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INTRODUCTION.

The purpose of this work has been to determine by baking tests, the difference in the bread making qualities of spring and winter wheat flour, and, if possible, to work out a method by which bread from the latter could be made to equal the former in quality. It has been said that good bread cannot be made from winter wheat flour. The extent to which this crop is grown in the United States, shows the importance of proving the contrary.

The Agricultural Outlook for May, 1914, Farmers' Bulletin 598, reports the year's yield of winter wheat in the United States to be 630 million bushels and estimates that of spring wheat at 250 million (the average yield for five years), making a total of 880 million bushels, of which nearly three-fourths is winter wheat. The following statistics of state yield from the same bulletin show the wide range of territory over which it is grown.

Table I.

WINTER WHEAT.

STATE	ACREAGE	BUSHELS. Forecast from May 1 conditions
New York	360,000	7,500
New Jersey	79,000	1,400
Pennsylvania	1,312,000	23,400
Delaware	114,000	1,900
Maryland	612,000	9,900
Virginia	779,000	10,000
West Virginia	236,000	3,200
North Carolina	611,000	6,500
South Carolina	80,000	900
Georgia	140,000	1,600
Ohio	2,090,000	38,900
Indiana	2,485,000	45,500
Illinois	2,576,000	47,500
Michigan	879,000	15,800
Wisconsin	85,000	1,600
Minnesota	41,000	----
Iowa	479,000	11,100
Missouri	2,549,000	44,200
South Dakota	69,000	----
Nebraska	3,123,000	63,000
Kansas	7,950,000	132,000
Kentucky	745,000	102,000
Tennessee	709,000	8,600
Alabama	31,000	400
Mississippi	1,000	----
Texas	1,082,000	15,600
Oklahoma	2,465,000	35,500
Arkansas	105,000	1,300
Montana	481,000	12,900
Wyoming	41,000	1,100
Colorado	194,000	4,800
New Mexico	42,000	900
Arizona	31,000	900
Utah	223,000	5,500
Nevada	18,000	400
Idaho	339,000	10,100
Washington	1,201,000	33,000
Oregon	633,000	15,200
California	408,000	7,800
United States	35,387,000	630,000

In August, 1896, this College sent out a circular* to about two hundred farmers of the state, asking what varieties of wheat were grown in their locality and which were grown most extensively. Seventy-five varieties were reported and of these but three were of spring wheat and these were grown only in limited sections north of Saginaw Bay where winter varieties do not thrive.

The Iowa Agricultural College Experiment Station, Bulletin 51, on Winter Wheat, gives a comparison of the acreage of spring and winter wheat grown in that state, showing the increase in the latter. In 1885, one twentieth of the crop was winter wheat while in 1898, it had increased to one sixth. The yield per acre with but few exceptions was larger from winter than from spring wheat. At the Experiment Station, the yield from winter wheat was almost double that of spring. The following quotation from this bulletin shows the value and advantage of growing this crop.

"The Station wishes to encourage farmers to grow a larger acreage of winter wheat. The spring wheat belt is creeping northward, leaving in its trail lands admirably adapted to the growth of this crop. It furnishes one of the best nurse crops with which to establish grasses and clover, for the reason that it draws lightly upon the supply of soil moisture as compared with other cereals, and is ready to harvest before warm weather sets in, the season most liable to injure

*Michigan Agricultural College Experiment Station, Bulletin 141, February, 1897.

young clover. By giving it place in the rotation, labor is distributed more evenly throughout the year, seed time coming as it does when work is slack in the fall, and harvest immediately after haying. Besides, it is one of the most profitable crops on the farm, the Station wheat being worth upwards of thirty dollars per acre this season".

Since winter wheat is grown so successfully and so extensively in the United States, the importance of developing a variety that will withstand the cold winters, yield a large crop and at the same time possess good milling and baking qualities has long been recognized. The Agricultural Experiment Stations have been working along this line for many years. The problem of the farmer is, therefore, to raise a good winter wheat, of the miller, to produce a good flour and of the housewife, to understand how to use it successfully in order that it may hold its place on the market with spring wheat as a bread making flour.

Differences between Spring and Winter Wheat.

Since spring wheat is considered essentially a bread making flour, it is of interest to note what qualities are necessary for this, and wherein it differs from winter wheat. Spring wheat is grown in the Northwest, principally in Minnesota, the Dakotas, and Canada where the winters are too severe for winter wheat. It is planted in the spring and harvested the same year. Winter wheat is grown in various sections of the United States, as the above tabulation shows. It is planted in the fall and harvested in the early

summer of the following year. The kernels of winter wheat, especially the soft varieties, are large, plump, and starchy, while those of spring wheat are small, hard and glutinous.

Winter wheat flour is white and powdery with a tendency to cake when gently shaken in a sieve. It feels velvety and retains the imprint of the fingers when pressed in the hand. Spring wheat flour is creamy in color, feels granular, readily passes through the sieve and does not retain the imprint of the fingers when pressed. A given weight of spring wheat flour will absorb more water than an equal weight of winter wheat flour. A given volume of spring wheat flour weighs more than an equal volume of winter wheat flour.

Chemical Composition.

The chief difference in the chemical composition of spring and winter wheat is in the starch and gluten content. Since winter wheat must live through the winter, it is necessary to store up nourishment, hence it usually contains a larger proportion of starch. Spring wheat grows and matures more quickly, does not require so much nourishment, and is usually richer in gluten. However, there is a wide range of variation in the composition of the different varieties of both spring and winter wheat as Table 2 shows. This is influenced largely by soil, climate and rainfall.

Table 2.*

COMPOSITION OF WHEAT.

a.

	Water %	Protein %	Fat %	Carbo-hydrates %	Ash %
Spring Wheat	10.41	15.50	2.28	69.88	1.93
Straight Patent Flour	12.38	13.60	1.30	72.04	.68
Winter Wheat	10.25	12.34	1.35	74.23	1.83
Straight Patent Flour	10.97	10.92	.50	77.15	.46

b.**

Spring Wheat Patent Flour	7.68	12.42	1.16	78.08	.63
Winter Wheat	7.74	10.53	.98	80.30	.45

c.***

Spring Wheat	10.4	12.5	2.2	73.	1.9
Winter Wheat	10.5	11.8	2.1	73.8	1.8

* U.S. Dept. of Agriculture, Office of Experiment Stations, Bulletin 126, p. 13.

** North Dakota Agricultural College, Experiment Station, Bulletin 82, p. 763,764.

***Farmers' Bulletin 389, p. 16.

Gluten is the substance in flour that retains the carbon dioxide formed during the fermentation of the dough, thus making possible a light spongy loaf. It forms thin elastic walls about the gas bubbles, and as these are expanded by the heat of the oven, the walls become distended and are coagulated. It is formed when flour is mixed with water, by the combination of two proteins, gliadin and glutenin.

Gliadin is an elastic glue-like substance, sometimes called a plant gelatin, which binds the flour particles together and gives tenacity and elasticity to the dough. It may be extracted from gluten or flour with dilute alcohol.

Glutenin is the substance to which the gliadin adheres. It prevents the dough from becoming too soft and sticky. It is soluble in dilute alkali.

Gliadin and glutenin together constitute about nine-tenths of the protein of the wheat kernel.

Osborne and Vorhees*, who have made an extensive study of the subject, have found three other proteins in wheat, namely:

1. Edestin, a globulin belonging to vegetable vitellins, soluble in saline solutions. This constitutes from .6 to .7 percent of the wheat kernel.

2. Leucosin, an albumin which coagulates at 52 degrees and is unlike animal albumin in being precipitated on saturating its solutions with sodium chloride or magnesium sulphate.

* Jour. of American Chemical Society, 16, pages 524-535.

3. A proteose, precipitated (after globulin and albumin have been removed) by saturating the solution with sodium chloride or by adding 20% of sodium chloride and acidifying with acetic acid.

Qualities of a Bread Flour.

Among the essential qualities of a good bread making flour are strength, color and flavor.

Strength of Flour.

Spring wheat is usually spoken of as a strong flour, winter wheat a soft or weak flour. Authorities agree in conisdering strength an important factor in a bread-making flour, but just what constitutes strength has been a matter of wide discussion. It has been defined as the "water absorbing power" of a flour. Since the ability to absorb water depends upon the gluten present, a high gluten content is often associated with strength. Some investigators say it is not the amount but the quality of the gluten that is important. Snyder* maintains it is the ratio of gliadin to glutenin, which should be in the proportion of 63 : 35. Other investigators have found that flour may have the right proportion of gliadin to gluten and yet be lacking in baking qualities.

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* Minnesota Experiment Station Bulletin 63.

T. B. Wood* adopts Humphries and Bissen's definition of strength: "The capacity to yield a large well piled loaf" and maintains that two factors are involved in it, size and shape which he finds are due to different causes. Size, he says, depends upon the capacity of the flour to give off gas during fermentation. The amount of gas evolved depends upon the quantity of sugar contained in the flour together with that formed in the flour by diastatic action. Shape, he finds, and possibly gas retention, depend upon the physical properties of the gluten as modified by the presence of varying proportions of salts.

Color.

Good bread flours - those with a large proportion of gluten - are not white but are of a creamy color. Since there was a demand for a flour that would yield a white loaf of bread, the practice of bleaching flour became common. According to Leach**, in 1908, about eight percent of the flour produced in the United States was bleached by nitrogen perodide, but as a result of the enforcement of federal law, the practice has been largely abandoned. Whiteness in flour may be due to a low gluten content, age or bleaching. A grayish color indicates a poor grade of flour.

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* Jour. Agr. Sci. 2, 1907, pp. 131 - 160.

** Leach, Food Inspection and Analysis, p. 315.

Flavor.

A good flour should produce a bread with a sweet nutty flavor. Winter wheat is said to yield a better flavored flour than spring wheat and is often blended with it because of its tenderness and flavor.

Nutritive Value of Bread from Spring and Winter Wheat Flour.

The question sometimes arises as to the comparative nutritive value of bread from spring and winter wheat flour. Harry Snyder of the Minnesota Agricultural Experiment Station has made experiments with three different grades of flours - graham, entire wheat, and patent - from both spring and winter wheat.* He finds the patent flour of both varieties of wheat to be more thoroughly digested and to yield a larger proportion of nutrients than the graham and entire wheat flours, though the latter are richer in mineral salts and protein. The coarser particles of the latter two are not so readily acted upon by the digestive juices, so more is lost in digestion. The results of his experiments show the digestibility and availability of energy to be a little higher for winter than for spring wheat. Since the calorific value of spring wheat averages a little higher than that of winter wheat, the nutritive value of each would probably be about the same. The calories per

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*U.S. Dept. of Agr., Office of Experiment Stations, Bulletin 126.

gram are given as follows: Spring Wheat, Straight Patent Flour 3.861; Winter Wheat, Straight Patent Flour 3.799*.

Digestibility of Nutrients and Availability of Energy of Bread.

Hard Spring Wheat. (Page 29)

Kind of Food	Protein	Carbo-hydrates	Energy
White Bread (Standard patent) Average of 3	88.3	97.7	90.9
Average of 3 (1899-1900)	85.3	97.5	90.1
Average of 6	86.8	97.6	90.5

Soft Winter Wheat. (Page 45).

Kind of Food	Protein	Carbo-hydrates	Energy
White Bread (Standard patent)			
Michigan Wheat Average of 3	92.8	98	94.2
Indiana Wheat Average of 3	88.9	96	90.4

* Page 13.

Yeast.

Yeast is a microscopic unicellular plant belonging to the fungi family which includes those plants that contain no chlorophyll and that reproduce by buds and spores. Yeasts are classed as true yeasts, Saccharomyces, including wild and cultivated, and pseudo yeasts, or false yeasts, Torula and Mycoderma.*

True yeasts produce fermentation and usually are able to form endospores. During fermentation some of the yeasts tend to sink to the bottom while others rise to the top and form a thick foamy layer on the surface. The former are called bottom yeasts, the latter, top yeasts. The cultivated varieties used in brewing and some of those in producing distilling material are grouped together as Saccharomyces cerevisiae. They are divided into three groups: the bottom yeasts, used in making German beer which produce only a small amount of alcohol; the top yeasts, used in English beers, which produce more alcohol; and the distillery yeasts which have great fermentive power and produce large amounts of alcohol.** Among the wild yeasts are Saccharomyces minor, the yeast of leaven and Saccharomyces ellipsoideus and Saccharomyces apiculatus, the wine yeasts. Wild yeasts are abundant in the air and produce spontaneous fermentation in various substances. The leaven of the ancients was obtained

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* M.A.C. Bacteriology Syllabus, page 70.

** Marshall, Microbiology, page 31.

by allowing dough to ferment spontaneously. The wine yeasts are found on grapes. These are cultivated and pure cultures are often used in wine making.

Pseudo yeasts do not form endospores and produce little or no fermentation, though they often occur in fermenting liquors. Those known as Torula are not considered harmful, but those classed as Mycoderma, which grow upon the surface of the liquid, producing there a thick film, cause wine to become insipid and cloudy, and finally spoil it completely.

Structure and Reproduction of the True Yeast, Saccharomyces.

The cells of this yeast are large, round or slightly oval. The vigorous young cells, when seen under the microscope, appear nearly transparent. A thin well-defined cell wall encloses the cell contents, or protoplasm, which is slightly granular with one or more small cavities, called vacuoles, which are filled with cell sap and contain small granular bodies. These bodies are probably waste products. As the cell grows older, the wall thickens, the protoplasm becomes less transparent, the size of the vacuoles increases and the granular bodies become more numerous. Dead cells are usually opaque and take the stain more readily than living cells.

Budding.

When the cell has reached a certain size and is kept under suitable conditions, a protuberance or bud is sent out from part of its surface which gradually increases in size and becomes separated from the old cell by a cell wall. The new cell or daughter cell may or may not remain attached to the mother cell. If it does so, and the old cell continues to form buds, a mass of cells is produced. If each new cell formed produces a bud, a chain of cells will be formed. The old cell may produce a number of buds, but in time its reproductive energy is exhausted and the cell breaks up.*

Formation of Spores.

"When young, vigorous, well-nourished cells are supplied with abundant air and moisture at a comparatively high temperature under conditions that discourage budding (lack of nutriment), they form endospores. These spores are usually about half the diameter of the mother cell and from one to eight or more may occur in each cell".**

The spores are very resistant and will remain dormant a long time, but when placed in a nutrient solution will swell and burst the mother cell, forming new cells which reproduce by budding.

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*Ontario Agricultural College and Experiment Farm, Bulletin 118. "Yeast and Its Household Use". William Jago and William C. Jago, "The Technology of Bread Making",page 155.

** Marshall, Microbiology, page 30.

Conditions Necessary for Growth of Yeast*

In order that the yeast cells grow and induce fermentation, certain conditions are necessary, namely: proper temperature, food and moisture.

Temperature -

The optimum temperature for growth is from 25° to 35° C or 77° to 95° F. Below 25° C growth proceeds slowly, at 9° C (49.6° F) growth ceases, but will begin again under favorable temperature. Freezing does not kill the cell unless it be mechanically ruptured or injured. Temperatures above 35° C weaken the action of yeast. At 60° C, the coagulating temperature of albumen, the cells of moist yeast are destroyed. Dried cells may be heated to 100° C without destroying their vitality.

Food -

Yeast requires for its growth sugar, nitrogenous compounds, and mineral salts. Of these, sugar is by far the most important. Glucose is the only sugar that is directly fermented by yeast. Cane sugar must be changed to glucose before it can be assimilated. This is effected by the enzyme, invertase, which is secreted by the yeast cell. Yeast is said to contain another enzyme, maltose which is capable of changing maltose to glucose.**

* Jago, 158 -165
**Jago, 138.

Experimental work has shownthat the action of yeast on the proteins of wheat and barley flour will enable them to produce diastatic action on starch - that is, change it to dextrin and maltose - after which it is fermented by the yeast.* Sufficient nitrogen is usually present in the growing medium; must, wort, potato water, etc. Hard water usually contains the necessary mineral salts.

Moisture -

A certain amount of water is necessary for the growth and development of yeast. Solutions containing over thirty-five percent of sugar will not ferment. The housewife makes use of this fact in making jellies and preserves.

Action of Yeast.**

When yeast is placed in a nutrient solution, it feeds upon the sugar present and excretes alcohol and carbon dioxide. The former remains in the solution, while the latter rises to the surface in small bubbles carrying some of the yeast cells with it which form a foam or scum. This phenomenon is known as fermentation, the word being derived from the Latin, ferveo, I boil, and is so called because of the boiling or seething appearance of the liquid.

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* Jago, 135.

**Jago, 145 - 150.

It is only within the last century that the true nature of fermentation has been understood. Previous to this time, various views were held. One of these regarded fermentation as a peculiar condition assumed by nitrogenous matter during the process of decomposition. Another held that it was due to a vegeto-animal substance, called a ferment, which was found in grapes and grain, and which, when the grapes were crushed and the grain moistened, produced an active change. Scientific researches with the microscope aroused further discussion. As early as 1680, Antonius van Leeuwenhoek, a Dutch naturalist and a maker of lenses, discovered that yeast consisted of minute granules. Nothing further was learned of its structure until 1836 when de Latour discovered that it consisted of a mass of little cells capable of reproduction by budding. "Yeast", he said, "must be an organism which, probably by some effect of its growth, effects decomposition of sugar into alcohol and carbon dioxide." After much discussion yeast was finally placed among the fungi and a new order, Saccharomyces, created for it.

De Laltour's view, however, found many opponents. Prominent among them was Liebig, the celebrated German chemist, who maintained that yeast was a lifeless substance and fermentation a purely chemical action unassociated with any vital process. For a number of years, there were three contending theories of fermentation: de Latour's, or the vital hypothesis; Liebig's, or the mechanical hypothesis; and other views based on catalytic action.

In 1857, after careful and exhaustive research work on the subject, Pasteur concluded that fermentation is a "correlative phenomenon of a vital act beginning and ending with it" and that there is "never any alcoholic fermentation without there being at the same time, organization, development, and multiplication of globules, or the continued consecutive life of globules already formed."

In 1870, Liebig admitted that yeast was an organism but still maintained fermentation was a mechanical act similar to enzymic action, basing his opinion on the fact that the amount of sugar decomposed was out of all proportion to the amount assimilated. This led to further discussions and researches, which resulted in the discovery of zymase by Buchner in 1897. This is an enzyme secreted within the cell, but which may be extracted from it and convert glucose into alcohol and $C O_2$ independently of the living organism. It has no reproductive power and only a fractional part of the fermentive power of yeast. It is destroyed during fermentation almost as soon as formed, so there is no accumulation of zymase in yeast.

According to the zymase theory of fermentation, sugar enters the interior of the living cell by diffusion and is there acted upon by the enzyme, invertase, which changes it to glucose; glucose is then converted into alcohol and carbon dioxide by the action of zymase. No clear explanation has been offered for the fact that the matter consumed during fermentation is so much greater than the consuming agent. It is suggested, however that it may be because the yeast not only derives nutriment from the sugar, but also the heat necessary for the continuance of life. Hence, during fermentation, in order to obtain heat and nourishment, yeast attacks sugar and excretes carbon dioxide and alcohol as waste products.

Varieties of Yeast Used in Bread Making.

The yeasts used in bread making are compressed, dry and liquid or brewer's yeast.

Compressed yeast* is the product of distilleries where malt and raw grain are fermented for spirits. Most of it is made from whiskey wort, some from the worts used in the manufacture of gin and other distilled liquors. The top yeast, which is the most desirable for bread making, is skimmed off, washed in cold water, and strained through silk or wire sieves to remove impurities. It is then pressed in bags in hydraulic presses, after which it is cut into cakes, wrapped in tinfoil and kept in cold storage until distributed for use.

Potato, corn or tapioca starch is often added to compressed yeast, on the ground that it acts as a drier, increases the keeping qualities, and produces a cleaner product and one that is more readily mixed with the other ingredients of the bread. The quantity added varies from 5 to 50 percent, the larger amounts being added to make weight.

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* Food Inspection and Analysis, Leach. page 328.

T. J. Bryan* maintains that the carbon dioxide value of yeast is reduced by addition of starch, and that the percentage of reduction is greater than the percentage of starch present, while the keeping qualities are less than those of pure yeast.

U. S. Rulings. Food Inspection Decision, No. 111, Jan.7, 1910.

1. The term compressed yeast without qualification means distiller's yeast without admixture of starch.

2. If starch and distillers yeast be mixed and compressed, such a product is misbranded if labeled or sold simply under the name "Compressed Yeast". Such a mixture or compound should be labeled "Compressed Yeast and Starch".

3. It is unlawful to sell decomposed yeast under any label.

Compressed yeast does not keep well, so it should be used fresh. When fresh, it should have a uniform creamy white color, a pleasant odor and should break with a sharp grain. Dark color and a cheesy odor indicate decomposition. When it becomes soft, it is unfit for use.

Dry Yeast -

Dry Yeast is a mixture of fresh yeast and starch or cornmeal. It is molded into a stiff dough and dried either in the sun or at a moderate temperature under reduced pressure. When dry it is cut into cakes and put into packages. Since drying renders the cells torpid and temporarily inert, it acts more slowly than compressed or brewer's yeast, hence can not be

*Bulletin 116,p. 25. Bureau of Cehmistry. U.S.Dept. of Agr.

used for short process bread. This yeast will keep a year or longer, hence is convenient where compressed yeast can not be obtained.

Brewery or Liquid Yeast.

Brewer's yeast is obtained from the fermenting vats of the breweries, the top fermentation being preferable. The first yeast that rises contains impurities, so should be rejected as should also that formed during the last period of fermentation since the yeast cells have been weakened by growing in an exhausted medium. The best yeast is produced while fermentation is most active and vigorous.

Liquid yeast is often made in the home, various recipes being used which consist of mixtures of potato, flour, potato water or water with a little yeast for a starter. This should be kept in a cool place to prevent the growth of bacteria which develop when the yeast cells are not active. Since the food supply becomes exhausted during fermentation, a little sugar added from time to time will keep the yeast more vigorous. Better results will be obtained from this yeast if it be made frequently.

Experimental Work.

The experimental work was done in the Domestic Science Laboratory. An automatic electric sponge oven which maintained an even temperature of 35 C was used for raising the dough and a Hughes electric oven for baking purposes. The dough was mixed with a spatula in the upper part of a double boiler, the water in the lower part being kept at 42 C. The liquid used was heated to 37 C, this being sufficient to keep the temperature of the dough at 35 C without warming the other ingredients.

The pans used for baking were 6-1/4 x 4-1/4 x 2-5/8 inches. This size was a little small for the amount of dough used but was valuable in showing the strength of the flour. Since the sides were not high enough to support the dough when risen to its full height, in unfavorable conditions, that from weak flour ran over the sides.

The following recipe was used, subject to variation in different series of experiments.

340 grams flour - 2-3/4 to 3-1/8 cups sifted flour according to variety.
10 grams lard - 2 tsp.
6 grams salt - 1 tsp.
14 grams sugar - 2-1/2 tsp.
10 grams yeast - 3/4 cake compressed.
170 - 205 cc. water according to the flour used. About 200 cc. was used for spring wheat, from 170 to 190 for winter wheat.

1 cup water = 225 cc.

The dough was weighed as soon as it was mixed. The hot loaf was weighed in the pan when taken from the oven. The moisture loss is so great at first that unless the weight of the loaf be determined at a definite time after each baking, grave errors result. The loss in fermentation and baking was computed in grams and in percent. To obtain the volume, the loaf was placed in a bell jar of 3375 cc. capacity and surrounded with flax seed which was leveled with the spatula and then run out through a rubber tube in the bottom of the jar into a graduated cylinder of 2000 cc capacity. The amount of flax seed displaced was measured and the volume of the loaf obtained by difference. The ratio of weight to volume was computed.

The first series of experiments was performed before the electric equipment was purchased. Because of the difficulty in keeping conditions constant, accurate data could not be obtained, so results are given in a general way only. The series was repeated later under more favorable conditions. The amount of yeast was varied, the other ingredients remaining constant. The same recipe was used for both spring and winter wheat flour, one used the previous year in Problem Cookery. This called for 340 grams of flour and 225 cc. of water, the other ingredients in the proportion cited above. This amount of water made the dough from winter wheat flour so soft that it was necessary to add considerable more flour while kneading. A certain amount was weighed and the quantity used determined by weighing what was left. When an equal amount was used with spring wheat, the dough became too stiff. An unavoidable loss resulted from the dough's sticking to the kneading board. The general result for both spring and winter wheat was an increase in volume and a decrease in the time of rising with the increase in the quantity of yeast used. It was evident that a different method must be adopted if satisfactory and accurate results were to be attained.

Varying the Amount of Water.

In order to determine the amount of liquid necessary to make a dough of desired stiffness for both spring and winter wheat flour, a series of experiments was performed in which the amount of water was varied, the other conditions remaining constant. The same amount of water was used with both spring and winter wheat flour. This time the method used in Problem Cookery was followed. The dough was not kneaded. After doubling its bulk, it was cut down to allow the gas to escape, then given two risings of one half hour each, after which it was cut down for the third time and placed in baking tins. When it had doubled its bulk, it was baked forty minutes in the electric oven at 180° to 200° C. The temperature was allowed to rise gradually from 180° to 200° then to fall gradually to 190° or 180°. After several experiments with different temperatures, this was found to be best for the oven used. In the gas oven, it was possible to use a higher temperature for part of the baking, but since the electric oven heats and cools slowly, it was found best to maintain a more nearly uniform temperature. The texture of the bread was not so fine as when kneaded, but very little of the dough was lost since it was possible to obtain almost all of it with a spatula. In some cases, less than five tenths of a gram was left. In fact, the amount was so small it was disregarded in computing results.

Pillsbury's Best, a Minnesota spring wheat flour and Thoman's Moss Rose, a Michigan winter wheat flour were used for this and the previous series of experiments. 225 cc. of water was used for the first loaves, the amount being decreased 10 cc. with each succeeding baking until 195 cc. was reached. It was then decreased 5 cc. to 180 cc., this amount of liquid being about the minimum for the spring wheat flour.

With 225 cc. of water, the texture for both spring and winter wheat was coarse, due, in part, to lack of kneading, in part, to the soft dough. The loaf from winter wheat flour cracked and ran over the side of the pan as shown in photograph 1, while the one from spring wheat held its shape.

With 215 cc. of water, the loaf from winter wheat again ran over the sides of the pan. Part of it was lost in the oven, so the correct weight and volume could not be obtained. This accounts for the fall in the curve on the chart.

The loaf from spring wheat was lighter, of larger volume and the distribution of gas was more even than that of the first one baked. 205 cc. of water gave better texture and an increase in volume for both spring and winter wheat.

190 cc. gave the best shaped loaf from winter wheat flour. For the first time, there was no crack in the crust. The grain was somewhat coarser than that of the loaf from spring wheat flour, but otherwise the texture was good. This received the highest score, 90.

185 cc. gave an increase in volume in both cases, and a fairly good shaped loaf from winter wheat but the crack so characteristic of this variety of flour was again in evidence.

180 cc. produced loaves somewhat smaller in volume, the decrease in the one from spring wheat being greater than that in the one from winter wheat flour. The loaves were of fine close texture, but too dry.

Results -

(1) With but one or two exceptions, the spring wheat flour yielded a loaf of larger volume and of better texture than the winter wheat flour.

Loaf No. 1, spring wheat, was smaller in volume because it did not have time to double its bulk in the baking tin.

(2) Until too stiff a dough was reached, the volume in both cases increased with the decrease in amount of liquid.

Loaf No. 2, Winter wheat, is an exception, because part of the dough ran out of the pan.

(3) The amount of liquid used made very little difference in the time of rising, the slight variation being due to the condition of the yeast rather than to the consistency of the dough. With a larger amount of dough, this might not hold true.

(4) This variety of winter wheat flour rose more quickly than the spring wheat in the first rising but, in most cases, was a little slower and more irregular in the last.

(5) The ratio of weight to volume tended to increase with the decrease in liquid. The ratio for spring wheat was greater than that for winter wheat.

(6) The loss in weight during fermentation and baking averaged about the same for the two flours, 11.33 % spring; 11.08 % winter.

(7) As the amount of water was decreased, a finer closer texture was produced.

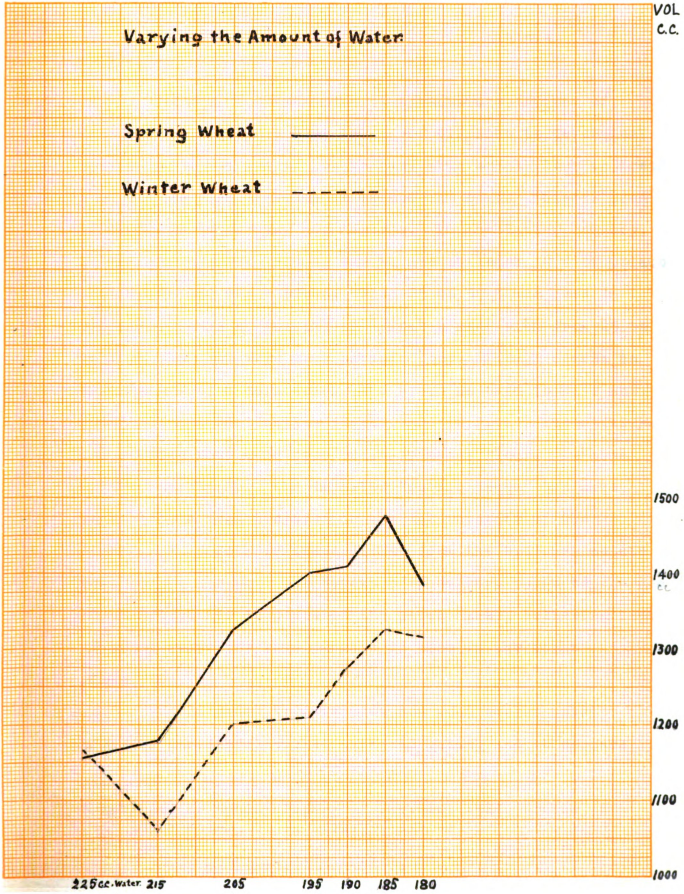
(8) 190 cc. of water for Moss Rose and 205 cc. of water for Pillsbury gave a dough of the desired consistency. The latter was taken as a standard in determining the amount to be used with other flours. A dough made from 30 grams of Pillsbury's Best would require 18.08 cc. of water or roughly 18 cc. In using a new flour, a dough was first made of

Pillsbury's flour in this proportion, 30 grams of flour to 18 cc. of water. 30 grams of the new flour was then mixed with enough water to make a dough of the same consistency. The amount of water necessary for 340 grams of flour was determined.

Va

Kind of Flour	No.	Water	Yeast
	1	225	10 gms.
	2	215	"
Spring	3	205	"
Wheat	4	195	"
Pillsbury's	5	190	"
Best	6	185	"
	7	180	"
	1	225	10 gms
	2	215	"
Winter	3	205	"
Wheat	4	195	"
Moss Rose	5	190	"
	6	185	"
	7	180	"

* No. 2 is omitted in the aver


Varying the Amount of Water.
Spring Wheat
Winter Wheat
VOL C.C.
1500
1400 cc
1300
1200
1100
1000
225 cc. Water 215
205
195
190
185
180

Long Process Bread with Varied Amounts of Potato.

The U. S. Department of Agriculture, Bureau of Chemistry* has been making baking experiments to determine the value of the use of potato meal with wheat flour in bread making, the purpose being to reduce the cost. This is used extensively in Germany and Austria. In the latter country, bakers are now required by law to use at least 30 % of potato meal in making their bread. From 25 to 50 % was used in the experiments at Washington. Loaves made with from 25 to 30 % of the meal were most satisfactory. Though coarse in texture and of a dark color, the bread is said to have an agreeable and distinctive flavor, and to retain its moisture longer than that made from ordinary wheat flour. In some of the experiments, the imported "potato flake" was used, in others, a meal prepared in the laboratories of the department. Both of these differ from the ordinary potato meal on the market. The Bureau of Chemistry suggests the use of cooked potato in place of the potato meal, believing that it might serve the same purpose if used in the right proportion.

In order to determine how much cooked potato might be successfully used in bread making and to compare its

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* Article for Sunday Papers of Feb. 14, 1915. Office of Information, U. S. Dept. of Agriculture.

effect upon spring and winter wheat flour, some experiments were made in which varied amounts of it were used. A loaf from each variety of flour was baked without any potato, as a standard for comparison. Then fifty grams, (half of a small potato) was added to each loaf. This made about one fourth of a cup of mashed potato. This amount was increased twenty-five grams with each succeeding baking until one hundred fifty grams was reached.

Method -

The recipe used in the previous baking tests was followed, in most of its ingredients. 3½ grams of dry yeast was substituted for the compressed and the amount of water was decreased with the increase in potato. The potato was weighed raw after being pared and washed. Enough for the two loaves was cooked in two cups of water. When they were thoroughly done, the water was strained through a sieve, measured in a graduated cylinder and divided equally. While boiling hot, half of it was poured over the sugar, shortening and ¼ cup of spring wheat flour, and the other half over the sugar, shortening and the same amount of winter wheat flour. Each mixture was stirred until smooth. The potato was rubbed through a sieve, weighed, and divided equally, half being added to each mixture. When the dough had cooled to 35 C, the yeast, which had been soaking in 30 cc. of luke warm water, was added.

This was mixed at noon and allowed to ferment at room temperature until the next morning, when the salt and the rest of the flour was stirred in and enough water added to make a dough of standard stiffness. The amount of water required decreased with the increase in potato, as stated above, but not regularly, since the percentage of water absorbed by the potato while cooking, varied. When the dough had doubled its bulk, it was thoroughly worked with a spatula, placed in baking tins and baked when it had again doubled in volume.

The flour was partially cooked or gelatinized, because in this condition it is more stimulating to the yeast than raw flour, while the dry yeast, being slower in action, requires more stimulation than the compressed or liquid yeasts. The potato and potato water have also a stimulating effect upon the yeast - hence by morning, an active fermentation had set in.

Pillsbury's Best and Lily White were the flours used in this series. The latter is a softer winter wheat than Moss Rose. The sponge test showed that 180 cc.of water was the amount required to make a dough of standard stiffness. This amount was used in the loaf baked without the addition of potato. There was such wide variation in

volume, time of rising, etc. that the experiments were duplicated and the average recorded. More satisfactory and uniform results were thus obtained.

Results -

(1) The bread from winter wheat flour was more nearly like that from spring wheat flour in texture and in volume than in the baking tests in which no potato or potato water was used. In one or two cases, loaves of exactly the same volume were produced. Since average results only are recorded, the table does not show this.

(2) Though the winter wheat flour was a softer flour than that used in the previous experiments, it yielded loaves of larger volume, due to the potato or potato water.

(3) With both spring and winter wheat flour, the volume of the loaf increased with the increase in potato up to the addition of 125 grams. With 150 grams, there was a decrease in volume.

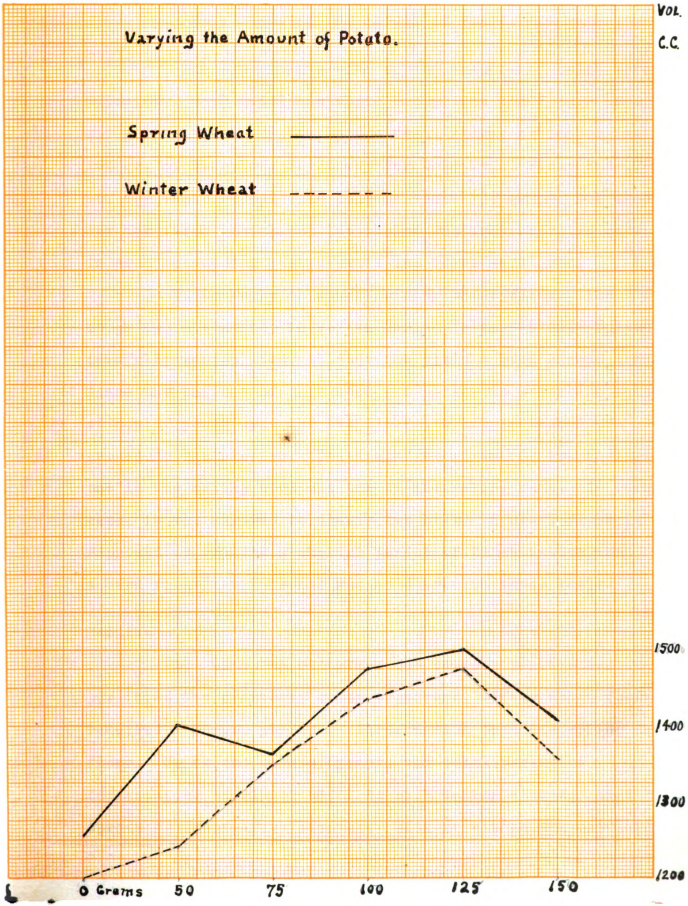
(4) The ratio of weight to volume showed less variation in spring wheat than in winter wheat flour. 100 grams of potatoes produced the highest ratio in both cases, 2.66 for spring, 2.77 for winter, 150 grams the lowest.

(5) Winter wheat flour required a longer period of fermentation in both the second and third risings than spring wheat.

(6) The addition of potato produced a finer silkier texture in the bread from both spring and winter wheat flour. Excellent results were obtained with 100 grams or one-half cup of mashed potato to a loaf. In no case was a soggy loaf produced, yet those from the larger quantity, 125 and 150 grams, lacked lightness and the texture was not so good as when smaller amounts, 50 to 100 grams, were used.

(7) The addition of potato improved the keeping quality of the bread.

MECHANICAL ENGINEERING DEPARTMENT M. A. C.



Varying the Amount of Yeast.

The experiments with varied amounts of yeast were repeated. Gold Medal and White Poppy were the flours used for this series. By the sponge test, it was estimated that 200 cc. of water was necessary for Gold Medal Flour and 175 cc. for White Poppy. 1/4 cake of yeast (3½ grams) was used for the first baking and the amount was increased 1/4 cake in each succeeding baking until two cakes were used.

White Poppy is a soft winter wheat flour. The dough has a tendency to soften during fermentation. Unless carefully manipulated, it does not yield a good shaped loaf. Since the purpose of this test was merely to determine the effect of yeast upon the two flours, a simple method of procedure was adopted. The dough was given but two risings, one in the mixing bowl and one in the baking pans. In each case, it was allowed to double its bulk. A soft flour is supposed to require a shorter period of fermentation than a hard flour but this has not held true in these tests.

Results -

(1) With one exception due to poor yeast which permitted the growth of other organisms, winter wheat flour required a longer period of fermentation than the spring wheat flour. Up to one cake of yeast, the total period of fermentation of winter wheat in each baking exceeded that of spring by twenty-five minutes. With more than one cake, the

difference was not so great. No's 6 and 8 (Winter Wheat), required ten minutes longer, No. 5, six minutes.

(2) Interesting results occurred in No. 7 of both spring and winter wheat. In these loaves, poor yeast was used. It had been kept over from the day before and was slightly discolored. One of the cakes had been opened but was again carefully wrapped in tin foil. This was used with the winter wheat flour. In twenty minutes, the dough had more than doubled its bulk. Its appearance indicated an unusual fermentation. Large gas bubbles were formed which were worked out with difficulty. After the dough was placed in the baking tins, it was ready to bake in fourteen minutes. The loaf was coarse in texture, unsymmetrical in shape, with a rough uneven crust as shown in photograph 7. There was no perceptible difference, however, in flavor. The loaf from spring wheat flour, baked at the same time, required fifty minutes in the first rising and thirty-eight in the second, an increase of twenty-eight minutes over the time required in the previous baking when less yeast was used.

(3) The decrease in the total time of rising was the same for both spring and winter wheat. The greatest difference, sixty-five minutes, occurred between the loaves with one-fourth and one-half of a cake of yeast. With one half and three fourths of a cake, there was a difference of twenty-five minutes; with three-fourths of a cake and one

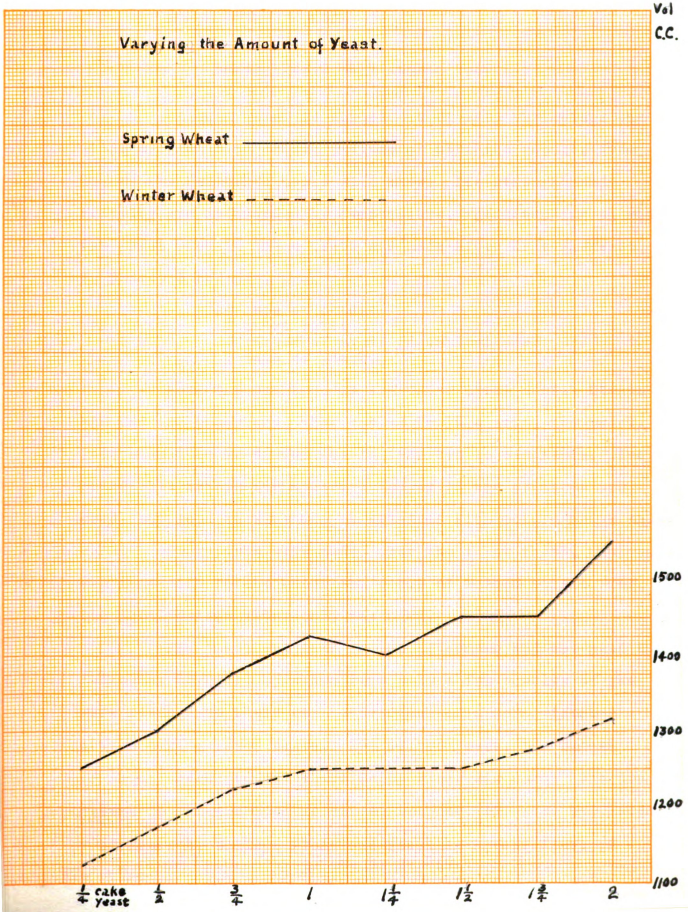
cake, of twenty minutes. With more than one cake, greater irregularities occurred which may be accounted for by the difference in the condition of the yeast. No's. 5 and 7, Spring Wheat, with one and a fourth and one and three-fourths cakes, required a longer time than those of the previous baking. The total decrease in the period of fermentation from one fourth of a cake to two cakes was an hour and ten minutes for spring wheat and an hour and twenty five minutes for winter wheat.

(4) The volume tended to increase with the increase in yeast. The total increase was greater for spring wheat than for winter. The former increased 24%, the latter 14.4 %. Nos. 4, 5, and 6 of winter wheat with one, one and a fourth, and one and a half cakes of yeast were of the same volume. No. 6 and 7 of spring wheat, with one and a half and one and three fourths cakes were the same. With the latter, this was due to the yeast. No. 5 of spring wheat showed a decrease in volume. This required a little longer to rise than the preceding loaf, hence the condition of the yeast may account for this also. With the winter wheat, however, there was a decrease in the period of fermentation in each case, so some other factor must have entered in.

(5) The ratio of weight to volume tended to increase

with the increase in the amount of yeast, and was greater in the spring wheat bread than in the winter wheat bread.

(5) The bread from spring wheat flour was of finer texture than that from winter wheat flour. The increased amount of yeast did not produce a coarser texture, unless the dough was allowed to become too light. Photograph 9, shows the effect of too long a fermentation upon winter wheat flour. The gluten had become softened to such an extent that the loaf could not keep its shape. The loaf from spring wheat flour which was given the same treatment, though coarse in texture retained a symmetrical form.


Varying the Amount of Yeast.
Spring Wheat
Winter Wheat
Vol
C.C.
1500
1400
1300
1200
1100
1/4 cake yeast
1/2
3/4
1
1 1/4
1 1/2
1 3/4
2

Baking Tests with Liquid Yeast.

Liquid yeast is subject to so many variations that it is difficult to obtain uniform or definite results from it, as the following tests will show. Its strength and activity are influenced by temperature, age, cleanliness, etc. The yeast used in these tests was made after Miss Florence E. Dudley's recipe*.

1½ cups of potato
1 quart water
2 ounces of sugar (4 tablespoons)
¼ cake of yeast.

Boil the potatoes in the water until done. Strain and add the sugar and, when cooled to luke warm, the yeast. This should be ready for use in from two to six hours. The bread will retain its moisture longer if the potatoes are used, but good results may be obtained with potato water only.

Four tests were made. For the first three, the yeast was made with potato water and ½ cup of mashed potato, for the last, potato water only was used.

The yeast was made in the afternoon and was used the following morning, by which time only a few bubbles of gas were rising and there was no evidence of a more vigorous action having taken place. 175 cc. of yeast, the amount of liquid required for White Poppy Flour was used. The dough seemed to require more moisture, so 5 cc. of water was added.

* Florence E. Dudley. Flour and Yeast in Bread. Jour. of Home Econ. Vol. 4, No. 3, p. 255.

The same amount of yeast and 25 cc. of water was used for the spring wheat flour, Gold Medal. The dough was given two risings as in the previous tests.

The spring wheat dough required an hour and twenty minutes for both risings, while winter wheat required an hour and forty minutes. The volume of the loaf from winter wheat flour was larger than it has been in the previous tests with short process bread, and was almost equal to that of the loaf from spring wheat flour. The ratio of weight to volume exceeded that of the spring wheat loaf. The loaf from winter wheat had more bloom to the crust and was a better shape than usual. In the other baking tests, the crust had been poor in color and character, lacking the bloom of that of the spring wheat bread. The texture of both was good.

In the next baking, the dough was given three risings. Innorder that there might be no variation in the yeast, it was made fresh, started with compressed yeast and used the next morning as before. By morning, a very vigorous ferment-ation had taken place, there being two or three inches of foam on top. Notwithstanding the apparent activity of the yeast, the period of fermentation was very much longer than in the first test. It was longer for winter wheat than for spring, five hours and thirteen minutes for the former, three hours and sixteen minutes for the latter. Each had been given the same treatment. Excess of carbon dioxide seems to indicate exhaustion of the yeast. The volume of the spring wheat loaf showed an incease over that of the previous baking, while that of the winter wheat showed a decrease. The ratio of weight to volume increased for spring wheat and decreased for winter wheat. The texture of winter wheat was poor, that of spring fair.

Another test was made in which the dough was given three risings. In order to determine if the cause of the increase in the time of rising was due to exhausted yeast, this time, the yeast was made in the morning and used after it had fermented about five hours. As in the previous test, a very vigorous action was taking place. However, the dough required a still longer period of fermentation, five hours and forty-six minutes for spring wheat, seven hours and fifteen minutes for winter wheat flour. The volume of the spring wheat loaf was the same as in the previous baking, that of the winter wheat was smaller than before. The ratio of weight to volume decreased in both cases. The texture of each was fair.

In the next test, the yeast was made without potato and used the next day. Since the extra rising did not improve the quality of the bread, it was omitted. The total period of fermentation for spring wheat dough was two hours and forty-eight minutes, for winter wheat, three hours and thirty-eight minutes. The volume of each increased. The ratio of weight to volume was higher for winter wheat than for spring wheat and exceeded that of the previous tests exceptwhere potato was used. There was very little difference in the texture of the two loaves, which was the best of the four tests.

Results -

(1) These experiments confirm the conclusions drawn from the long process series, that when potato or potato water is used with winter wheat flour, the bread is more nearly like that from spring wheat flour in volume and in texture.

(2) The average loss per cent in fermentation and in baking was less than in the previous tests.

(3) No satisfactory explanation suggests itself for the increased period of fermentation of the dough from winter wheat flour in some of these tests.

(4) Excess of carbon dioxide seems to indicate exhaustion of yeast.

(5) Though liquid yeast yields excellent bread, its variability in strength and activity makes it difficult to obtain results in experimental work.

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Temperature Tests.

Some tests were made to determine the inner temperature of the dough at different times while baking, in order to learn if spring and winter wheat flour differ in this respect. Short process bread made with liquid and with compressed yeast, and long process bread to which 100 grams of potatoes had been added, were used for this purpose.

A thermometer was inserted in the middle of each loaf, the initial temperature recorded and the thermometer read every fifteen minutes. A gas oven was used for the baking because the temperature is more easily controlled than that of the electric oven, and the thermometer may be read through the glass without opening the oven door. The bread was baked forty-five minutes.

In some of the experiments, the initial temperature of the oven was 180° C. This was allowed to rise gradually to 190° C during the first fifteen minutes, to 200° C during the next fifteen minutes, and to 220° C during the last fifteen minutes. In some of the experiments, the order was reversed. The bread was placed in the oven at 220° C and the temperature allowed to fall gradually to 180° C.

Results -

(1) The temperature of winter wheat dough tended to rise a little more rapidly in some of the tests than that of spring wheat dough, but the ultimate temperature was the same. In most cases, this rise was due to the inability of

the dough to support the thermometer, the winter wheat dough having a tendency to soften during fermentation. After being placed in the oven, the thermometer fell a little to one side where the temperature was higher than in the middle of the loaf.

(2) There was very little change in temperature the first fifteen minutes, the average rise being about two degrees when the initial temperature was 180°. No. 1a Winter wheat is an exception because of the slipping of the thermometer. With an initial oven temperature of 220° C, the temperature of short process bread was higher than that of long process bread at the end of the first quarter of an hour.

(3) The inner temperature at the end of the half hour was higher in both long and short process bread, when the initial oven temperature was 220°, than when it was 180°.

(4) The initial temperature of the oven did not affect the final temperature of the loaf in short process bread. In long process bread with potatoes, there was a rise of 0.5° when the initial temperature was 220°.

(5) The final temperature of the loaves in which 100 grams of potato was used was lower than that of the loaves in which no potato was used, the former being 95° and 95.5°, the latter 98°. This suggests a longer baking for loaves in which much potato is used.

Table 7.

Inner Temperature Tests.

Flour	No.	Yeast	Initial temperature of dough. Centigrade	Temperature at end of 1st. 15 min. 180° - 190° C.	Temperature at end of 2nd. 15 min. 190° - 200° C.	Temperature at end of last 15 min 200°-220° C
Winter Wheat	1a	Compressed	31°	42.5°	88.5°	98°
Spring Wheat	1b	"	32°	34°	87°	98°
Winter Wheat	2a	Liquid	31°	33°	65.5°	98°
Spring Wheat	2b	"	31°	33°	61°	98°
Winter Wheat	3a	Dry with 100 gms.	31°	33°	67°	95°
Spring Wheat	3b	Potato	31.5°	34°	66°	95°
				220°	200° - 190°	190° - 180°
Winter Wheat	4a	Compressed	32°	62°	93°	98°
Spring Wheat	4b	"	33°	46°	93°	98°
Winter Wheat	5a	Dry with 100 gms.	30°	32.5°	84°	95.5°
Spring Wheat	5b	Potato	30°	32°	77.5°	95.5°

Tests for Loss in Moisture.

Some tests were made to determine and compare the moisture loss in bread from spring and winter wheat flour made with the different yeasts. Two loaves of bread from both spring and winter wheat were made with compressed yeast. In the first baking, 200 cc. of water was used with spring wheat flour, 175 cc. with winter wheat flour; in the other, the water was increased 15 cc in each. The long process bread with dry yeast contained 100 grams of potato.

The compressed yeast loaves with 200 cc. and 175 cc. of water, as noted above, and the long process loaves were kept eleven days and were weighed every two or three days. The compressed yeast loaves with the larger amount of water and the liquid yeast loaves were kept nine days and weighed every day. In order to make a fair comparison, the total loss in weight in grams and in percent was determined for each loaf at the end of six days. In the loaves with compressed yeast baked April 19th, the sixth day fell on Sunday, so the average from the twenty-fourth to the twenty-sixth was taken. The total loss for the entire period was computed for each loaf.

Results -

(1) The loss percent in weight at the end of six days, with one unaccountable exception in the case of bread

from liquid yeast, was greater for spring wheat than for winter wheat bread.

(2) Of the two bakings with compressed yeast, the loss percent in weight was the same for spring wheat, 6.97%, while for winter wheat, the leaf containing the greater amount of water showed the greater loss, 6.40 %, the other being 5.37%. At the end of nine days, the loss for both spring and winter wheat was greater in the loaves containing more water, than in those with a less amount at the end of eleven days. Spring 8.86 % and 8.81 %; winter 8.13 % and 6.52 % .

(3) At the end of six days, the long process bread with potato showed a lower loss percent in spring wheat bread and a greater loss percent in winter wheat bread than in that with compressed yeast in which the dough was of the same consistency. (200 cc.of water for spring, 175 cc. for winter wheat flour). This seems inconsistent with the other results, hence may be due to error in the original weight of the loaf of winter wheat with compressed yeast.

(4) The bread made with liquid yeast showed a lower loss percent for spring wheat than for winter at the end of six days, 3.52% spring, 3.65 % winter. At the end of nine days, however, the loss percent for spring wheat exceeded that for winter. Spring 5.06 %, winter 4.92 %. These percentages may be due to experimental error. The loss percent with liquid yeast was less than with compressed and dry. The loss during baking and fermentation was also less.

(5) The greater loss in moisture in spring wheat bread may be due to the fact that it contains more moisture than winter wheat bread, hence has more to lose, also that it is of larger volume, hence has a larger evaporating surface.

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Comparison of Sponge and Straight Dough Method.

In one test, a sponge was made instead of a straight dough. One half of the flour was mixed with the other ingredients and the sponge allowed to rise until light. This required about 40 minutes. The rest of the flour was then thoroughly mixed in and the dough placed in the baking tins. In 55 minutes, both loaves had doubled in volume, and were ready to bake. The texture of each was good and very similar. The volume was greater for spring than for winter wheat and the ratio of weight to volume higher; the volume for spring wheat being 1400 cc., for winter 1250 cc.; the ratio for the former 2.74, for the latter 2.53.

These results were compared with those made of bread from a straight dough in which the same amount of yeast, 10 grams, was used. The volume of the loaves from both spring and winter wheat increased 25 cc. The ratio of weight to volume increased in each case. The loss percent in fermentation and baking was almost the same in the winter wheat loaves, there being but 0.02 % difference. The loss in spring wheat was 0.32 % higher in the loaf made from the sponge.

The total period of fermentation for spring wheat was 1 hour 25 minutes for the straight dough and 1 hour 35 minutes for the sponge. The sponge was probably allowed a longer time than was necessary in the first rising. The total period of fermentation for winter wheat was 1 hour 50 minutes in the straight dough and 1 hour and 35 minutes in the sponge.

From this one test, which does not afford sufficient data from which to draw conclusions, the period of fermentation for winter wheat seemed to be shortened when a sponge was made and the quality of the bread improved. With spring wheat, equally good results were obtained from a straight dough.

Table 9.
Comparison of Bread Made with a Sponge and with a Straight Dough.

Flour	Kind of Dough	Weight of dough gms.	Weight of Hot Loaf gms.	Volume	Ratio of Weight to Vol.	Loss in fermentation and baking gms.	%	Score	Time of rising 1st	2nd
Spring	Sponge	566.9	510.2	1400	2.74	56.7	10.0	89	40 min.	55min.
"	Straight	572.1	516.7	1375	2.66	55.4	9.68	87	50 "	35 "
Winter	Sponge	540.6	492.2	1250	2.53	48.4	8.95	89	40 "	55 "
"	Straight	546.5	497.7	1225	2.46	48.8	8.93	82	1 hr.	50 "

Varying the Number of Risings.

A few tests were made in which the bread was given two, three and four risings and the results compared. Accurate data was not obtained so general results only will be given. Lack of time prevented the repetition of the experiments. The volume of winter wheat bread increased with the increase in the number of risings. With the four risings, however, the texture was not so good as with two or three. The volume of spring wheat increased with the third rising, but decreased with the fourth. In the latter case, it did not have time to double its bulk.

Scoring or Judging Bread.

In scoring the bread, Miss Bevier's score card was used*.

Revised Score Card of Miss Bevier.

General appearance	20
Size (5)	
Shape (5)	
Crust (10)	
Color	
Character	
Depth	
Flavor	35
Odor	
Taste	
Lightness	15
Crumb	30
Character (20)	
Coarse - fine } Texture	
Tough - tender } Texture	
Moist - dry } Texture	
Elastic or not } Texture	
Color (5)	
Grain (Distribution of gas) (5)	
Total	100

*University of Illinois Bulletin No. 25, p. 41.

General appearance is placed first not because it is considered most important but because it gives the first impression.

Flavor is given under two heads because sourness may often be detected by the odor before it is detected by taste. Bread should have a sweet nutty flavor similar to the wheat grain.

Lightness consists of many elements, relation of weight to volume, size, presence or absence of holes, crumbliness, etc.

Brands of Flour Used.

The flours used in these experiments were selected because they were available. The purpose was not to test one flour against another but to work with such as were typical of spring and winter wheat.

Method for Winter Wheat Flour.

When the experimental work with spring and winter wheat flour was completed, recipes for long and short process bread were worked out from the data obtained, in quantities sufficient for a family baking. Bread from soft winter wheat flour has a tendency to crack while baking. This is due to the softening of the gluten, which may be caused by too soft a dough, too long a period of fermentation, or by allowing the dough to become too light.

The consistency of dough which gave the best results was that which could be worked without sticking to the hands, or which could be kneaded with but a slight sprinkling of flour on the kneading board.

Good results were obtained from dough which had doubled its bulk in both risings, but when over light, a poor shaped loaf with poor texture was produced. To avoid over lightness, it is well to bake the loaf before it has quite doubled its volume. If, by chance, it has become too light, it should be baked at a higher temperature, or kneaded and allowed to rise again.

Since a long period of fermentation softens the glutin, short process bread is better for winter wheat flour than the long process. However, the availability of the dry yeast often makes it desirable to use the letter method. After repeated experiments with varied amounts of flour in the sponge, it was found that that which contained a small amount of gelatinized flour gave the best results. Some of the soft wheat flours yield a crust of a dull gray color. If milk be used as a part of the liquid, the crust will have a bloom equal to that of spring wheat flour. The effect of potato or potato water upon winter wheat flour has already been mentioned.

Recipe for Long Process Bread.

1 pint of potato water
1 pint of milk
3 quarts of flour (?) (Measured before sifting)
2 tablespoons of sugar
2 tablespoons of shortening
1 tablespoon of salt
1 cake of dry yeast.

Soak the yeast in enough luke warm water to cover it. Make a batter with the potato water and 1 cup of flour. A more active fermentation will set in if the potato water be mixed with the flour while boiling hot. Add the sugar, and when cooled to luke warm, the yeast. A cup of mashed potatoes will improve the texture and the keeping quality of the bread. This may be mixed in the afternoon. In the morning, add the milk which has been scalded and cooled to luke warm, the salt, shortening and the rest of the flour. The amount required will vary with different flours. Mix in enough to make a dough that can be kneaded with but a slight sprinkling of flour on the kneading board. Knead until the flour is well worked in. Set in a warm place to rise until almost doubled in volume. This should require from one to two hours. When light, knead until smooth and velvety and mold into loaves. Bake in a moderate oven when the loaves have almost doubled in volume.

Recipe for Short Process Bread.

1 pint potato water
1 pint of milk
3 quarts (?) of flour (Measured before sifting)
2 tablespoons of sugar
2 tablespoons of shortening
1 tablespoon of salt
1 cake compressed yeast.

Soak the yeast with 1 teaspoon of sugar in enough luke warm water to cover it. Scald the milk. Place the rest of the sugar, the salt, and the shortening in the mixing bowl and pour the scalded milk and potato water over them. When cooled to luke warm, add the yeast and a pint and a half of flour. Set to rise in a warm place for a half or three quarters of an hour, then add enough flour to make a dough that can be kneaded with a slight sprinkling of flour on the kneading board, and proceed as for long process bread. Mashed potato will improve the quality of the bread.

The following recipe for dry hop yeast may be of interest.

Dry Hop Yeast Recipe.

Take 3 quarts of dry hops, cover with water, and boil 1/2 hour. This should make 1 pint of liquid. Make up a sponge using 1 cup of flour, scalding it with the boiling hop water. Add 1 teaspoon of ginger, 2 tablespoons of sugar, and when cool, add 1 cake of dry yeast. Allow this to ferment about 6 hours or until very light and foamy. Add corn meal until stiff enough to mold in cakes and place in a dry even temperature until thoroughly dry. This yeast will then keep as well as the commercial dry.yeast.

Summary.

1. As the result of seven tests, several of which were duplicated, a decrease in the amount of liquid produced an increase in the volume of the loaf.*

2. A decrease in the amount of liquid produces a finer closer texture in the loaves from both spring and winter wheat.

3. A given weight of spring wheat flour will absorb more water than an equal weight of winter wheat flour. When made from dough pf the same stiffness with the same amount of yeast, spring wheat will usually produce a loaf of larger volume than winter wheat.

4. The use of potato or potato water in winter wheat bread is recommended since it produces a loaf that more nearly equals that of spring wheat bread in texture and in volume.

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* This is contrary to the result obtained at the Kansas Experiment Station, Kansas State Agricultural College, Experiment Station Bulletin 177, p. 91.

5. Bread in which a large amount of potato is used should be baked longer than ordinary bread as shown by temperature tests.

6. The moisture loss in bread depends largely upon the amount of liquid used. In these experiments, the bread in which potato was used,retained its moisture longer than bread from dry or compressed yeast without potato, while that from liquid yeast showed the least loss in moisture.

7. There is no difference in the ultimate temperature of spring and winter wheat bread when baking conditions are the same. The initial temperature of the oven usually makes no difference in the final inner temperature of the loaf if the time of baking is the same.

8. Increasing the amount of yeast increases the volume of the loaf and decreases the period of fermentation of both spring and winter wheat bread. Unless the dough becomes over light a larger amount of yeast will not produce a coarser texture.

9. Winter wheat bread should never become over light.

10. Too soft a dough will soften the gluten of winter wheat and produce an ill-shaped loaf of poor texture.

11. Jago says "Soft flours tend to hasten fermentation".*

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* William Jago and William C. Jago. Technology of Bread Making, p. 430.

Miss Jensen found "the total time required to make a loaf of winter wheat bread less than that necessary to make a loaf of bread from spring wheat flour". * In most of these experiments, however, winter wheat required a longer period of fermentation than spring wheat as shown in tables 4 to 6. In all the tests the two loaves were made at the same time and under the same conditions.

12. Short process bread is better for winter wheat than long process bread. The longer period of fermentation tends to soften the gluten. If the latter method be used, the sponge should be made with as little flour as possible.

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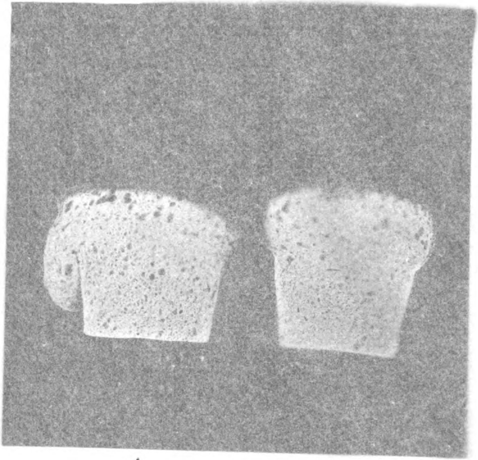


1 2

225 cc. Water

1. Winter Wheat

2. Spring Wheat

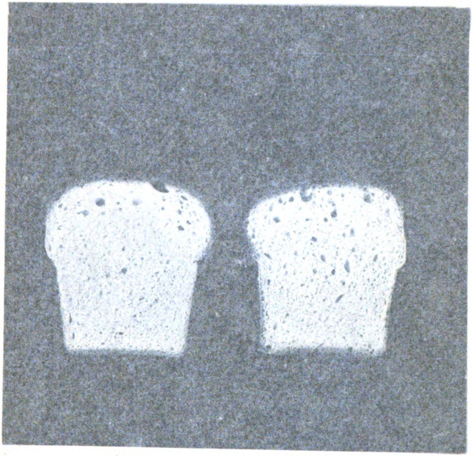
225 cc. Water

1. Winter Wheat

2. Spring Wheat

I.

1 2



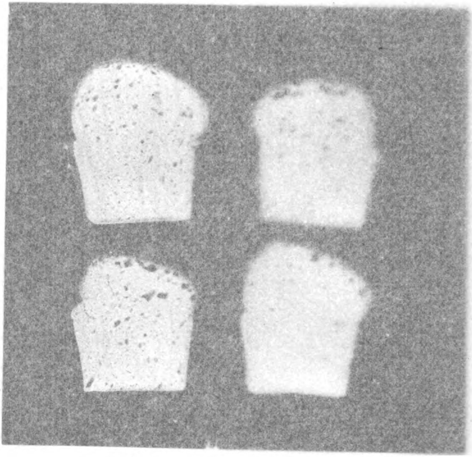
1 2

190 cc. Water

1. Spring Wheat

2. Winter Wheat

1 2



1 2

3 4

Upper - 50 grams of Potato

Lower - No Potato

1 & 4 Spring Wheat

2 & 3 Winter Wheat

Upper - 50 grams of Potato

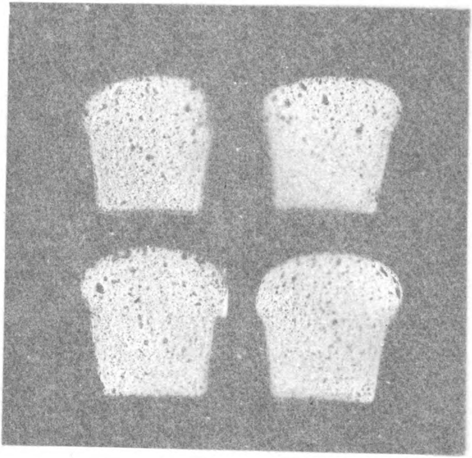
Lower - No Potato

1 & 4 Spring Wheat

2 & 3 Winter Wheat

1 2

3 4



1 2

3 4

Upper - 100 grams of Potato

Lower - 125 grams of Potato

1 & 3 Winter Wheat

2 & 4 Spring Wheat

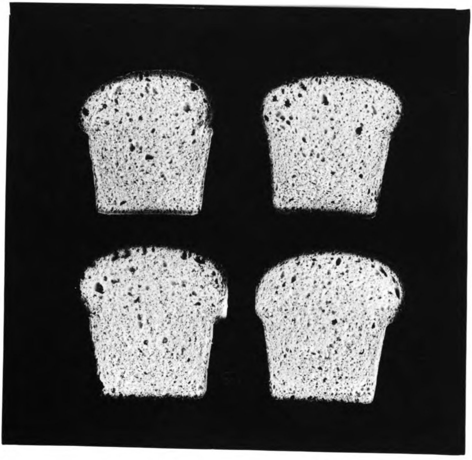
Upper - 100 grams of Potato

Lower - 125 grams of Potato

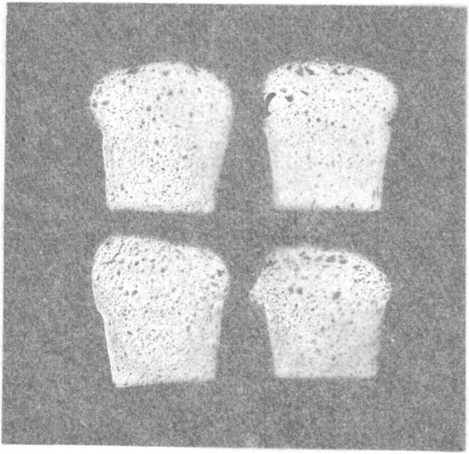
1 & 3 Winter Wheat

2 & 4 Spring Wheat

IV



1 2
3 4



1 2

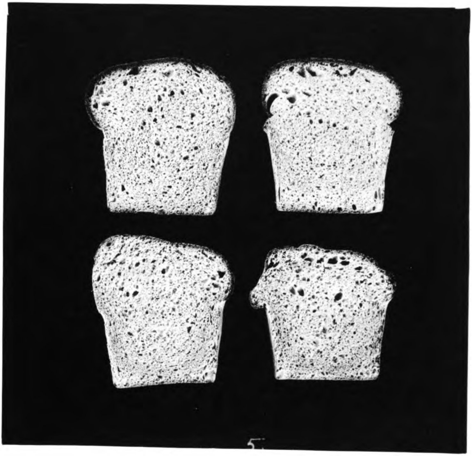
3 4

Upper - 75 grams of potato

Lower - 150 grams of potato

1 & 3 Spring wheat

2 & 4 Winter Wheat



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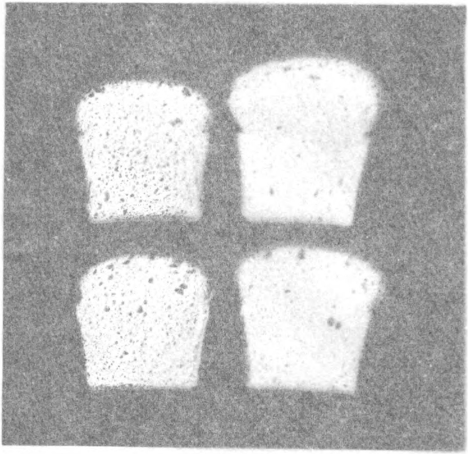
3 4



1 2

3 4

Upper - 3/4 Cake of Yeast

Lower - 1/4 Cake of Yeast

1 & 3 Winter Wheat

2 & 4 Spring Wheat

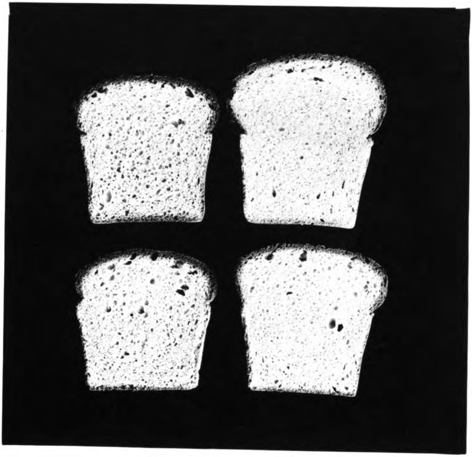
Upper - 3/4 Cake of Yeast

Lower - 1/4 Cake of Yeast

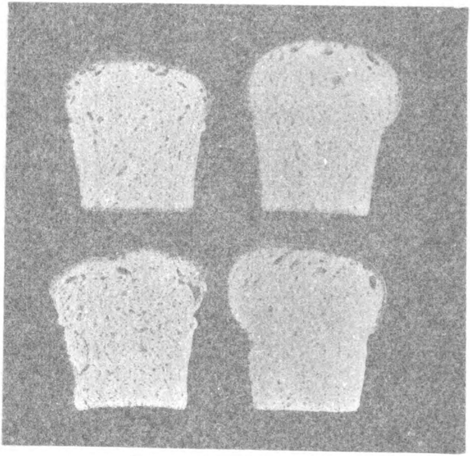
1 & 3 Winter Wheat

2 & 4 Spring Wheat

VI



1 2
3 4



1 2

3 4

Upper - $1\frac{1}{2}$ Cakes of Yeast

Lower - $1\frac{3}{4}$ Cakes of Yeast

1 & 3 Winter Wheat

2 & 4 Spring Wheat

No. 3 shows the effect of an unusual fermentation.

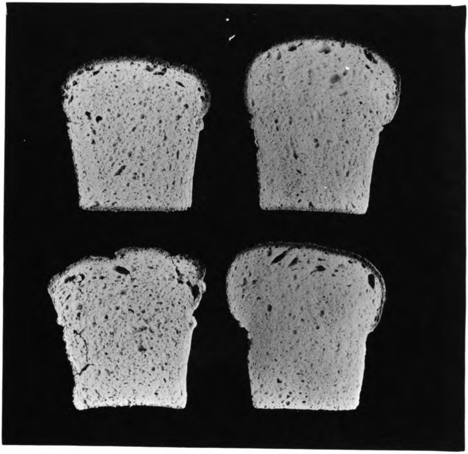
Upper - 1½ Cakes of Yeast

Lower - 1¼ Cakes of Yeast

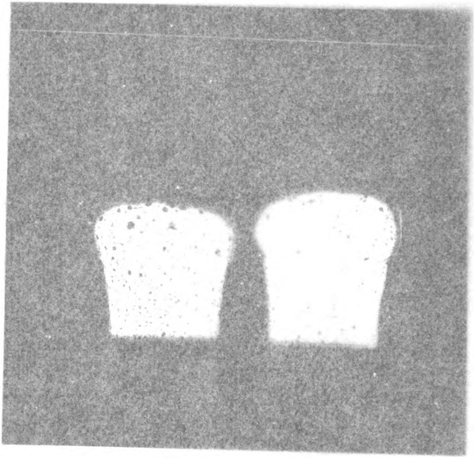
1 & 3 Winter Wheat

2 & 4 Spring Wheat

No. 3 shows the effect of an unusual fermentation.



1 2
3 4



1 2

2 Cakes of Yeast

1. Winter Wheat

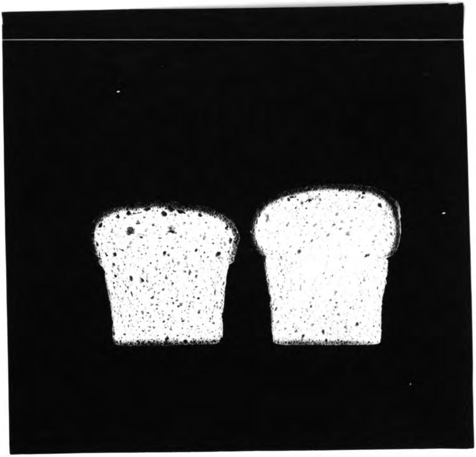
2. Spring Wheat

2 Cakes of Yeast

1. Winter Wheat

2. Spring Wheat

VIII



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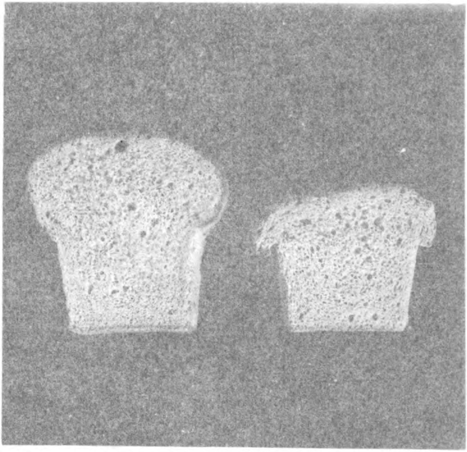


1 2

2 Cakes of Yeast Showing the Effect of Over-lightness on Winter Wheat.

1. Spring Wheat

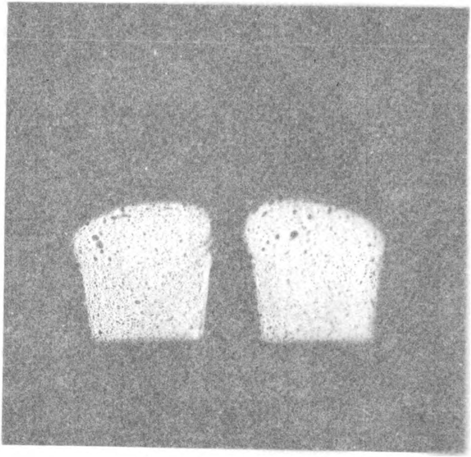
2. Winter Wheat.

2 Cakes of Yeast Showing the Effect of Over-lightness on Winter Wheat.

1. Spring Wheat

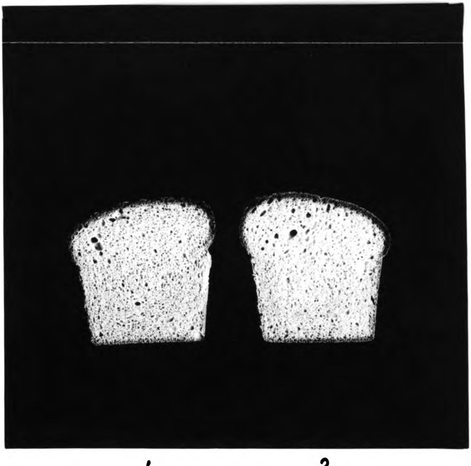
2. Winter Wheat.

1 2

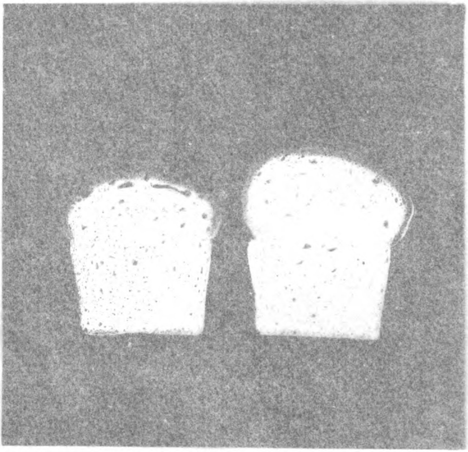


Liquid Yeast

1. Winter Wheat
2. Spring Wheat



1 2



1 2

Sponge Instead of Straight Dough.

1. Winter Wheat

2. Spring wheat.

Sponge Instead of Straight Dough.

1. Winter Wheat

2. Spring wheat.

1 2

Ilena Bailey.

CIRCULAR NO. 31 AUGUST, 1916

MICHIGAN AGRICULTURAL COLLEGE

EXPERIMENT STATION

FARM CROPS DEPARTMENT

RED ROCK WHEAT

BY

F. A. SPRAGG AND A. J. CLARK

EAST LANSING, MICHIGAN
1916

RED ROCK WHEAT[1]

By F. A. SPRAGG and A. J. CLARK[2]

SUMMARY

Red Rock is a new variety of wheat that has just recently been introduced among farmers. It is by far the best wheat that has yet been produced for Lower Michigan by the Experiment Station. Sixty bushels were sent to as many farmers in the fall of 1914[3]. It was possible for each farmer who received a bushel to raise all the seed he wished to plant in 1915 and have some for sale. This statement is borne out by the fact that thirty-three sales of farm-grown Red Rock were made through Professor Shoesmith in the summer of 1915. These sales averaged nearly eleven bushels (10.85 bu.). This means that after the growers had sown all they wished and furnished seed to neighbors as far as desired, 358 bushels were sold to farmers of other parts of the state. Besides this, 69 bushels were sent out from the College to nearly as many farmers in 1915. It is likely that a thousand bushels of Red Rock were used as seed in the fall of 1915, insuring a reasonable yield for the benefit of farmers who wish to get the best available wheat for 1916 planting. Such people may buy the seeds through the Secretary of the Michigan Experiment Association, East Lansing, Michigan.

SOURCE

The Red Rock wheat comes from an individual kernel picked out of a white wheat (Plymouth Rock) and planted in the fall of 1908. It was given the number 97003 and is listed in Table I of Bulletin 268 as Bearded Rock. Since that time Red Rock has been considered as describing the variety better, though it is a bearded red wheat. It also has a red chaff (contrary to the table above mentioned).

1. This is an extension of Bulletin 268. That bulletin reported data up to July, 1912, and this continues from that date.

2. The baking tests were made under the direction of Prof. A. J. Clark and reported herewith together with yield and milling tests.

3. Prof. V. M. Shoesmith distributed this wheat as Secretary of the Michigan Experiment Association.

QUALITIES

The principal characteristics of Red Rock are: exceptional winter hardiness, high yield, extra stiff straw, and those characteristics that yield a bread far above that usually produced from Michigan grown wheats. The fact that it is a red wheat of unusually high quality, and that it is a pure wheat, is saying a great deal, when we consider the vast amount of white and mixed wheat that Michigan is growing. Red Rock is out-yielding the best of the white as well as all types of wheat so far tested at the College. It is no longer profitable to grow the softer types as the price on white and

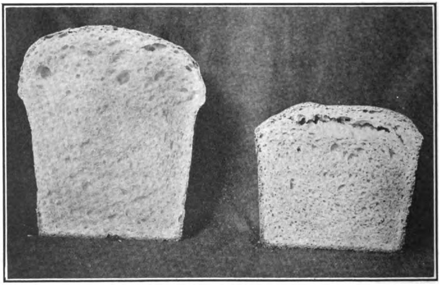


FIG. 1.

mixed wheat is being cut $50 to $120 per car below the market for No. 2 Red wheat. Fig. 1 shows a loaf of bread from Red Rock flour at the left and a loaf from a representative white wheat flour at the right. These loaves were made at the same time and under the same conditions.

The unusual hardiness of Red Rock appeared in the spring of 1912 from its endurance of the ice sheets of the previous winter and the production of about four times as much grain as the check of that year (viz. Shepherd's Perfection). Red Rock is shown in the left of Fig. 2, where it shows a good stand between two wheats that were badly winter killed. Since that time, the Red Rock has been used as a check (or standard) in the wheat variety series.

The extreme stiffness of its straw was previously observed but it was especially tested in 1914. The wheat variety series had been planted on a clover sod that year and as a result the straw grew exceptionally tall. The heads of the wheat could in many places touch the rim of one's hat. A series of rainy spells came just before harvest. The wheat lodged badly and several of the varieties went flat, yet the Red Rock always found its way

FIG. 2.

up until it stood erect at harvest time. During the rainy harvest of 1915 a strip of Red Rock on the College farm was not cut until two weeks after being fully ripe, and during these two weeks the piece received a series of rains, yet it was still standing when cut and had not lost its grain.

The yield of Red Rock has been from a third to a fifth better (on the average) than any other wheat tested with it during the years 1912 to 1915. This fact is brought out forcibly in Table I entitled "Some Wheat Comparisons on a Percentage Basis."

TABLE I.

SOME WHEAT COMPARISONS—ON PERCENTAGE BASIS.
MICHIGAN EXPERIMENT STATION, 1912-1915.

VARIETY	YIELD	MILLING TEST	BAKING TEST % MICHIGAN STANDARD FLOUR		
	% Red Rock	% Flour	Protein	Wt. Loaf	Vol. Loaf
American Banner	74.3	60.0	107.1	100.5	96.6
Buda Pesth	68.3	64.8	110.3	99.4	97.1
Shepherd's Perfection	58.8	63.7	107.9	101.2	96.4
Plymouth Rock	73.4	65.7	101.2	100.7	87.2
Early Windsor	76.9	61.5	103.5	101.2	94.1
Red Rock	100.0	62.6	123.0	100.0	112.0
Mealy	57.8	61.2	114.4	101.3	97.5
European Century	87.1	63.5	112.5	98.7	106.7
Craig's Favorite	86.9	67.3	121.7	102.0	108.4
Stoner "Miracle"	73.4	68.9	117.3	100.0	93.1
Berkley	79.1	65.8	124.3	102.4	100.4
Rock	67.3	61.7	122.5	102.7	106.1
Babcock	84.7	65.1	125.6	102.3	102.4
Early Ripe	72.7	58.3	110.4	99.5	109.8
Michigan Standard Flour			100.0	100.0	100.0

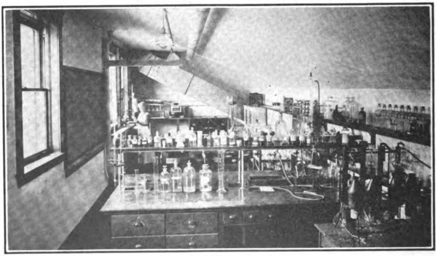


FIG. 3.

In the first column, Red Rock is considered 100%. This is the average for the years mentioned above. During the same years Red Rock has averaged about forty bushels per acre. It will be noticed that several of the varieties yielded less than 75% of Red Rock, that is, less than thirty bushels per acre when compared on the same basis. These, too, include such high quality Michigan wheats as American Banner, Shepherd's Perfection, Plymouth Rock, and Early Windsor, these being the best wheats that the College had to offer before Red Rock came on the scene.

The three columns to the right give the results of analysis for protein content and of the baking tests. The flour used as the standard in these tests was produced by blending equal amounts of Michigan wheat flours obtained from sixteen representative mills. This composite flour was termed the "Michigan Standard," representing 100%. It will be noted that on this basis Red Rock flour contains 123% as much protein as the Michigan Standard and that the volume of the loaf is 112% of that of the standard, showing the flour from this wheat to be of a much higher grade than the average Michigan wheat flour.

WHAT FARMERS THINK OF RED ROCK WHEAT

"I think the Red Rock is the coming wheat as soon as the farmers find out the difference between it and other varieties."—L. H. REMUS, Adrian.

"Red Rock is the best wheat that I have ever raised, yielding 42 bushels per acre and weighing 61 pounds per bushel."—HORACE BLISS, Chesaning.

"Very much pleased with Red Rock wheat. It yielded 12 bushels more per acre than my old variety and ripened a little earlier."—B. W. CADE, Haslett.

"Red Rock wheat looks very good to me, being a much hardier wheat than our Red Wave."—W. G. BOYD & SONS, Waldron.

"After two years experience with growing Red Rock wheat, I would say that it is extremely hardy and will out-yield our local varieties by at least 10 bushels per acre." —FRED F. CORNAIR, Chesaning.

"The Red Rock wheat which I secured from you produced a yield of 44½ bushels per acre, while my old variety yielded 32 bushels per acre."—FERDINAND SPERLING, Saginaw.

Mr. Kurt Sell of Walled Lake and Eugene Strang of Ypsilanti report 64 pounds per bushel from Red Rock wheat, and perhaps a dozen other farmers reported weights above sixty pounds per bushel.

May 14, 1916.—"Have a fine stand of Red Rock now."—J. C. OTTO, Middleville.

"The wheat (Red Rock) and rye (Rosen) that we got look fine, the best I ever had."—GEORGE B. PARDEE, Galien.

The last two are especially interesting as much winter killing occurred last winter.

Ilena Bailey.

1258 Issued April 15, 1910.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 389.

BREAD AND BREAD MAKING.

BY

HELEN W. ATWATER.

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

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

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.

CONTENTS.

ILLUSTRATIONS.

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.

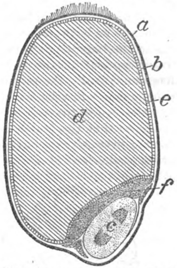


FIG. 1.—Diagrammatic section of grain of wheat: *a*, Skin and testa; *b*, membrane; *c*, embryo; *d*, flour cells; *e*, cereal or aleurone layer; *f*, scutellum.

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

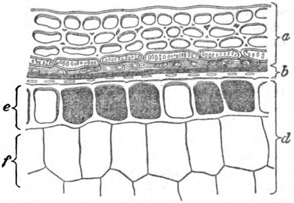


FIG. 2.—Cellular structure of a grain of wheat. (After Winton and Moeller.)

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

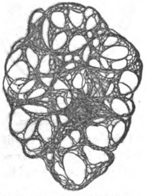


FIG. 3.—Diagram of protoplasmic structure of a flour cell.

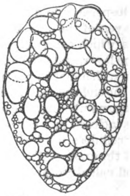


FIG. 4.—Diagram of starch grains in a flour cell.

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.

[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

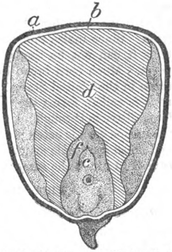


FIG. 5.—Diagrammatic section of grain of corn: *a*, Skin and testa; *b*, membrane; *c*, embryo; *d*, endosperm; *f*, scutellum.

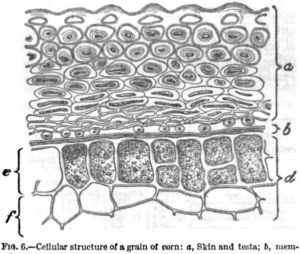


FIG. 6.—Cellular structure of a grain of corn: *a*, Skin and testa; *b*, membrane; *d*, endosperm, consisting of aleurone cells (*e*) and starch cells (*f*). (After Winton and Moeller.)

different parts of the grain, the cells in the endosperm being characterized by the presence of large amounts of starch and those in the germ by fat. The kernels are generally white or yellow. Compared with wheat, maize is rich in fat, poorer in cellulose and protein, and about equal 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

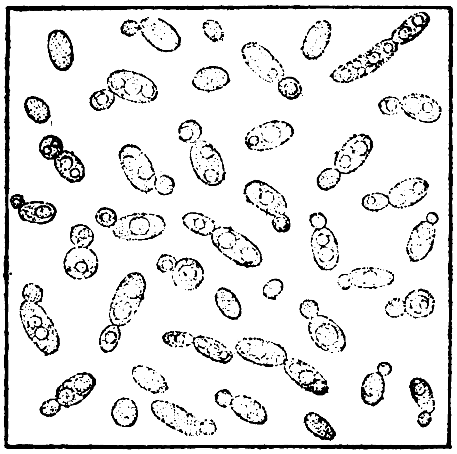


FIG. 7.—Yeast plant.

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.

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[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		35.8	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	130		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.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Minnesota wheat flour (fresh material):					
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."

389

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