PHYSICAL AND CHEMICAL PROPERTIES OF ARIZONA EARLY BAART WHEAT CORRELATED WITH ITS BAKING STRENGTH

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by

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Charts and Tables

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INTRODUCTION

Importance of Wheat

Wheat and wheat products have maintained their important place throughout the years. Bread has been a part of man's food for centuries and has been called the "staff of life." Good bread is nutritious and is easily and almost completely digested. Owing to its mild flavor it can be successfully combined with other foods. Although white bread is deficient in mineral and vitamins, these may be supplied by the other foods with which it is combined. Bread is also one of our cheapest foods, and is readily secured from any market.

Kinds of Wheat

All bread is not made from one kind of flour, nor all flour milled from one kind of wheat. There are hundreds of cultural varieties of the wheat plant with great differences between them. For practical purposes, however, wheat is divided into two classes; the hard wheats and the soft wheats.

The hard wheats have a small grain and produce flour of a granular texture that is often referred to as a "hard wheat flour" or sometimes as a "strong flour." Hard wheat contains more gluten and has a higher absorption than soft wheat. Agriculturists have thought that a short, quick growth results in greater amounts of gluten and gluten of better quality and this way account for the higher gluten content of hard wheat. These wheats are grown in the more severe climates of the Central and North Central States, including Kansas, the Dakotas, and Minnesota, where the winter snows and ice would injure the wheat sown in the autumn.

The soft wheats, on the other hand, have a large, soft grain, which produces a smooth, powdery flour, known as "soft wheat" or "weak flour." The absorption is usually low. This flour contains a smaller proportion of gluten than hard wheat which again may indicate that the culture of the plant influences the constituents of the wheat grain. This wheat is sown in the autumn and reaped the following summer in the milder climates of the Southern States, Eastern Seaboard States, and Western States, including Missouri, Texas, California, and Arizona.

The flour that is milled from the soft wheat is used by the baker for pastry, therefore it is called "pastry flour." Soft wheat flour is also used in the manufacture of crackers. This flour is adapted to these uses owing to its low protein content. A flour low in protein content gives a tender, flaky product, which is a requirement for pastry and crackers. In contrast, flour milled from the hard wheat is used almost exclusively by the baker for light bread and is referred to commercially as a bread flour. Some of the Red Duran hard wheats, that are not used for breadmaking, are used for the manufacture of macaroni.

The Present Wheat Situation

In General: Alsberg[(1)] has given us a clear idea of the present wheat situation when he says, "If we assume that all the wheat of the Central and North Central States is hard wheat--which is by no means the case--the total hard wheat production during the last ten years has averaged something over 386 million bushels. This kind of wheat cannot be produced in other states because the climate is not suitable. Hence the possibility of increasing the production of this sort of wheat is limited to the possibility of increasing acreage and yield in these states. Neither can be expected to take place except under the stimulus of very much higher prices than are now prevailing--even under stimulus of very high prices, very definite limits are set by climate to the possible increase of hard wheat production."

"Now as soft wheat can be produced almost anywhere in the more humid parts of the country--it follows that the production of soft wheats in the United States might be greatly increased if there were even moderate price inducements." With the increasing population, the demand for hard wheat will in all probability exceed the supply.

Although soft wheat flour was used for breadmaking until about 1870, the baker has since popularized the hard wheat flour for that purpose, and it is now being used extensively. The home maker also prefers the "stronger flours" for breadmaking, but she does not insist upon as strong a flour as the commercial baker. However, if it is not possible to meet the demand for hard wheat flour, we must then substitute soft wheat flour for breadmaking.

In Arizona: Due to the climatic conditions, Arizona produces soft wheat almost exclusively. The chief soft wheat varieties grown in this State are Sonora, Club, and Baart. About 20 percent of the State's wheat production is Sonora and Club. The Sonora wheat is the oldest variety in Arizona, having been brought in by the Spanish Fathers 100 to 150 years ago. Both the Sonora and Club wheats are low in protein content and produce a dark flour. For these reasons they are used principally for feed. There is a small amount of the hard wheat marquis grown in the state, but this wheat has a lower yield per acre than the soft wheats.

"Of the one and one-quarter million bushels of wheat grown in Arizona--it is believed that fully 75 per-cent is Early Baart.(2) Owing to this fact, the Early Baart may be considered a typical Arizona soft wheat.

The Early Baart Wheat was introduced into the United States about 30 years ago from Australia, but it is not of Australian origin. It probably originated in South Africa. The word "Baart" is a Dutch word meaning bearded. Twenty-five years ago, the Arizona Agricultural Experiment Station began work with this wheat in order to supply a bread wheat which would be suited to the irrigated lands of Southern Arizona. Early Baart has proved itself to be a consistent heavy yielder, yielding 40 to 50 bushels of grain to the acre on well drained soil that is supplied with plenty of organic matter.

This wheat grows to a height of 45 to 55 inches, and the heads are from three to five inches in length, some-what loose and square in appearance. The glumes are white and almost free from hairy growth. The grain yields a flour of semi-hard texture.

STATEMENT OF THE PROBLEM

The purpose of this investigation has been to develop a method and a formula which is best adapted to the use of Arizona soft Baart flour for breadmaking, it being se-lected as the typical Arizona soft wheat.

Review of Literature

Chemical and Physical Properties Related to Baking Strength: It is evident that few industries use for their raw materials substances which are as complex in their chemical nature, composition, structure, and properties, as is a kernel of wheat or the flour milled from it. In the face of these facts the progress of Cereal Chemistry has been slow, but definite and satisfactory, and is now one of the most important branches on the bio-chemistry tree. Chemistry is necessary to evaluate and standardize the raw materials of the cereal industry. In recent years the Cereal Chemists and the testing laboratories have become more prominent and the standardization has become more abrupt in the wheat industry than in any other. This was possibly due to the increased production of wheat products stimulated by the World War.

Probably one of the most serious handicaps to the development of Cereal Chemistry has been a decided lack of exact knowledge of the physical and chemical factors which are responsible for the baking qualities or strength of wheat flour. Workers in the field have endeavored to relate such factors as, crude gluten, quantity and quality, hydration capacity, and diastatic activity with the baking strength of flour.

In 1728 Beccari detected an "animal" or "protein substance" in flour, and it was thought to have an important relation to its strength. This protein substance has since been called gluten, and other experimenters have found that it is usually definitely associated with loaf volume which is an index of flour strength. Stein (1904)[3] and Stockham (1920)[4] added gluten to a weak flour and an increased loaf volume resulted. Snyder (1901)[5] diluted flour gluten by the addition of starch and concluded that when 20 percent of starch was added, the quality of the bread was impaired. Bailey and Johnson (1924)[6] also decreased the proportion of protein in a flour by the addition of starch and said, "That the reduction in gluten content which results from dilution of flour with starch injures the gas-retaining power of dough made from such mixtures." Mangles and Sanderson (1925)[7] discuss this point from a slightly different point of view. They point out that in flours with protein contents ranging between 11.98 percent and 15.02 percent, the loaf volume increased slightly but not regularly with the increasing protein content. Bailey and Sherwood (1926)[8] added one percent of protein to flours with a protein content of 9.5 percent to 10.5 percent, with a remitting increase in the volume of 6.6 percent. When one percent protein was added to flours with a protein content of 13.5 percent the loaf volume increased only 0.8 percent. Therefore it is apparent that the loaf volume did not increase regularly in the same proportion as the protein increased. Nevertheless it is a significant fact that there was a definite increase in volume.

However, a high gluten content does not always mean a large loaf volume. In fact in very high gluten flours there is a condition occurring that is known as "gluten bound." The percent of gluten is so high, and the resistance to the action of the distending gas is so great, that a small loaf volume results.

Although the gluten quantity is a factor to be considered, gluten quality is perhaps even more significant. Two flours of the same gluten content may differ in baking strength due to the quality of the gluten.

The gluten is composed of the two proteins, gliadin and glutenin, and gluten quality has been associated with the quality of these proteins and their quantitative relation to each other.

Gliadin is a glue-like substance which binds the flour particles together and renders the dough and gluten tough and cohesive. In discussing gliadin, Snyder pointed out that the percent of gliadin in the gluten or the gliadin number was of prime importance. He said, "The percent of gliadin is not always in accord with the size of the loaf, but if the gliadin number is abnormally low, a large loaf is not produced," but he considers the ratio between gliadin and glutenin more important than the quantity of either. Homer Blish and Pinckney, in (1924)[9] conclude that "It is fairly well established that the gliadin-glutenin ratio does not vary as much as was formerly supposed, being usually not far from 1:1.

Gliadin has been associated with gluten quality for some time, but at present glutenin is considered more important. Experimenters believe that glutenin content is a better indication of the quality of the gluten. If glutenin is absent the dough lacks the necessary elastic, gas-retaining properties, for this constituent imparts the solidity to the gluten.

The hydration capacity, or the amount of water absorbed by the gluten, was shown to be closely related to the gluten quality and quantity by Sharp and Gortner (1924)[10]. Since weak flours as a rule have a low protein content and a low hydration capacity, and the strong flours have a high protein content and a greater hydration capacity, it is believed that the hydration capacity and the protein content are related. However, the rate of hydration is believed to be more valuable than the maximum hydration capacity in determining the quality of gluten. Gortner and Doherty, (1918)[11], Sharp and Gortner (1924)[10], showed that glutenin was the protein responsible for the increased rate of hydration which is now considered a factor in judging gluten quality.

It is known that two flours with a good quality and quantity of gluten do not always show the actual strength thus indicated. The limiting factor in these cases was attributed by Bailey (1925)[12] to the lack of the starch splitting enzyme, diastase, which acts upon the starch of the flour, changing it to soluble starch and then to sugar. Wood, (1907)[13] was the first to relate the activity of this enzume to the loaf volume. Later Rumsey (1922)[14] indicated that the increased diastatic activity is accompanied by an increased loaf volume. Bailey and Weigley (1922)[15] found that flour strength depended upon factors which control the rate of carbon dioxide (CO_2) production as well as the amount lost during fermentation. Therefore, the increase of sugar by the action of the diastase would also affect the rate of the gas production, increasing the loaf volume. Collatz (1922)[16] increased the loaf volume by the addition of a limited amount of diastatic malt flour and malt extract. He believed that a slight increase in the sugar content in the latter part of the fermentation determined the size of the loaf.

Though all the chemical and physical tests are aids in determining the strength of the flour, the most satisfactory one of these tests is the total protein test. This is the best single index of the flour quality and is the most consistent in its results. This test is used as a basis for judging wheat and fixing its price.

PART I

EXPERIMENTAL PROCEDURE

Physical and Chemical Tests

The flour used in this experimental work was a straight grade flour milled from Early Baart Wheat grown on the University Agricultural Experimental Farm located at Mesa, Arizona.

Chemical and physical tests offer constructive suggestions to the experimental baker in handling the flour. From these tests, information is obtained which indicates the strength of the flour so that a formula for the bread dough and a method of handling may be intelligently developed. Therefore, the following chemical and physical tests were made.

Moisture: Flours contain varying amounts of moisture. Obviously it is necessary to have a single moisture basis upon which to calculate the chemical determinations of flour. Under the United States Pure Food and Drug Act, a flour cannot carry a moisture content above 13.5 percent. Water above this amount is considered an adulterant. Therefore, in these experiments, 13.5 percent moisture has been the basis upon which the chemical constituents have been determined. The moisture content of the experimental flour, as determined by drying the samples of flour in an electric oven at 108^{o} c until a constant weight was reached, was found to be 12.53 percent. From this result, the factor .997 was determined, by which all the results of the chemical tests were calculated upon the 13.5 percent moisture basis.

Ash: The percentage of ash in a flour is generally employed as a means of grading the flour. The higher grades of flour from a wheat usually have a low ash content, indicating that more of the outer portion of the wheat kernel has been removed by the milling process. Soft wheats as a class usually have a lower ash content than hard wheats. This, however, is not a factor usually associated with the strength of the flour. The average straight grade soft wheat flour has an ash content between .37 percent and .58 percent. The corresponding grades of hard wheat flours have between .42 percent and .63 percent ash. Burning the flour in an electric oven until a gray-white ash remained, showed the Early Baart flour to have an ash content of .55 percent. This, however, is without special significance except from the grading standpoint.

Acidity: The amount of water soluble acid in a flour that can be neutralized by an alkali is known as the acidity of the flour. This is often expressed as percent of lactic acid. The patent grades of flour made from sound wheat usually have a low acid content, around

.10 percent. The straight grade flour made from the same wheat has a higher acid content of about .125 percent. A high acid content of flour is due to the lack of complete maturity of the wheat or to unsound, sprouted wheat. The acid extracted from the flour with carbon dioxide free, distilled water and titrated with n/10 sodium hydroxide was .111 percent.

Total Protein: The determination of the protein in a flour is outstanding as a chemical test for the breadmaking qualities of that flour. By this test, wheat is bought and sold, and the value of flour for breadmaking indicated. The percent of protein nitrogen of the Early Baart flour was obtained by the well-known Kjeldahl method. From this the protein percent was determined by the conversion factor 5.7 and found to be 9.84 percent on the 13.5 percent moisture basis.

Soft wheat flours usually have a lower protein content, as shown by Table I, than the hard wheat flours. The Early Baart flour has a protein content high enough to rank it with the best soft wheats. Since the protein content is not high in the experimental flour, it is expected that a method developed for the handling of hard wheat flour might not prove satisfactory.

TABLE I

Comparison of Protein Content of Some Typical Wheat Varieties

Flour	Total Protein Content Percent	
Typical Soft Wheats[17]		
Sonora	7.9	
Pacific Bluestem	10.3	
White Federation	9.9	
Redchaffe Club	7.5	
Average		8.9
Soft Baart		9.84
Typical Hard Wheats[17]		
Kharkof	12.0	
Marquis	12.0	
Turkey	11.0	
Blackhull	11.6	
Average		11.65

<u>Crude Gluten</u>; <u>Quality</u>: By the crude gluten test some knowledge is actually obtained as to the physical properties of the gluten mass itself. The more common method used for this test is to make a dough ball, by adding water to a weighed amount of flour, allow it to stand one hour in washing solution, and then wash out the starch from the gluten.

Wood and Hardy (1909)[18] and Dill and Alsberg (1924)[19] found that distilled water as a wash water affected the physical properties of gluten causing it to disperse. The United States Department of Agriculture, in Bulletin No. 1187[20] recommends tap water for this purpose, but as there is such a variation in water in different parts of the country the results would be difficult to duplicate elsewhere. Therefore, in this experiment a 0.1 percent sodium phosphate solution which was recommended by Dill and Alsberg (1924)[19] was used for washing. The elastic mass that remains after the starch has been washed out is known as wet gluten. In the hands of an experienced worker, such physical characteristics of the wet gluten as the color, stretching quality, the nature of the break, and the cohesiveness, show the quality of the gluten. The light grayish or creamy gluten from the Early Baart flour was elastic and cohesive, but rather soft. When stretched the gluten breaks sharply, showing it is not as tough as gluten from the hard wheats.

<u>Crude Gluten</u>; <u>Quantity</u>: The wet gluten was dried in an electric oven at 108°C until a constant weight was obtained. Results expressed in terms of percent of flour containing 13.5 percent moisture show the Early Baart flour to contain 10.69 percent dry gluten. As seen, the dry crude gluten content is higher than the total protein content of the flour, due to substances present other than protein, such as starch, fat, and ash, that are not washed out.

<u>Hydration</u> <u>Capacity</u>: As purely chemical methods of determining the quality of gluten have not been altogether satisfactory, some physio-chemical methods, such as the determination of the hydration capacity or water absorptive power of the gluten are now attracting attention. The ratio of dry to wet gluten was determined by weight of the wet and dry gluten and finding the difference of the two. The weight of the wet gluten was 38.33 grams. When dried, the gluten weighed 11.61 grams, showing a loss of 26.72 grams of water, or that it had absorbed 2.3 times its dry weight of water. A good gluten on the average absorbs water equal to 2 to 3 times its dry weight. A flour with good baking qualities usually has a higher hydration capacity than a weak flour with poor baking strengh. Commercially a flour with a high hydration capacity is desirable since it produces more loaves of bread per barrel of flour.

Accordingly it is seen that the hydration capacity of Early Baart flour is such that it could be used profitably for commercial breadmaking.

<u>Gliadin</u>: As previously indicated, the alcohol-soluble protein, gliadin, may in a large measure influence the breadmaking qualities of a flour. Accordingly the gliadin was extracted from the soft Baart flour by boiling with 50 percent ethyl alcohol and the nitrogen determined by the Kjeldahl method. (According to Bailey, the nitrogen extracted by this method is approximately 93 percent gliadin nitrogen.) The conversion factor 5.7 was used to change the nitrogen into protein. From the results of this experiment, the soft Baart flour exhibited a gliadin protein content of 6.66 percent. Of the total protein, 67 percent is gliadin. Therefore, the gliadin number is 67. This gliadin number, although within the range of 56 percent to 68 percent as recommended by Snyder(21), is somewhat higher than the amended figure of Blish and Pinckney(9). This may account for the soft character of the gluten.

<u>Gliadin-Glutenin Ratio</u>: Experimental evidence indicates that the gliadin-glutenin ratio is possibly more important than the gliadin content alone in determining the quality of the gluten in the flour. In order to find the glutenin content by difference, the salt-soluble protein content must first be found.

Salt Soluble Proteins: The salt soluble proteins, albumin and globulin, were extracted from the flour in the cold with a 5 percent potassium sulphate solution. From the extract the nitrogen was determined by the Kjeldahl method, then by the factor 5.7, which is the conversion factor for wheat proteins, converted into the protein percent of 1.64.

Glutenin: After having determined the gliadin and salt-soluble proteins and total protein, the glutenin was determined by the difference. According to results the glutenin content of the flour was 1.54 percent. Therefore it is seen that the gluten is about 80 percent gliadin protein and 20 percent glutenin protein. The approximate gliadin-glutenin ratio is 80 to 20. This, however, does not correspond to the ratio of 65 percent gliadin and 35 percent glutenin recommended by Snyder, since in his determinations the salt-soluble proteins were not separated out and were contained in the so called glutenin fraction. According to Snyder's[21] determination, the ratio of gliadin to glutenin in this case would be 67 percent to 33 percent. Another explanation for the high percent gliadin and low percent glutenin may be that given by Bailey and Blish (1915)[22]. They found that the salt-solutions extracted some gliadin in addition to the salt soluble proteins and that dilute alcohol removes some albumin and globulin or both in addition to the gliadin. Since both solvents extract some of the same materials, the total protein extracted by each, using separate samples of flour, is too high. This makes the percent of glutenin, determined by difference, too low.

<u>Diastase</u>: The enzyme, diastase, in flour inverts some of the starch to sugar. Thus the amount of sugar increases with an increased diastase content. As the sugar content of the bread is raised by the diastatic activity, the depth of the color of the crust of a baked loaf deepens. A crude method for the estimation of the diastatic activity is to bake a dough ball without the addition of any sugar. The golden brown color of the dough ball, made with the experimental flour, indicated a satisfactory diastase content.

PART II

PRELIMINARY DISCUSSION OF BAKING EXPERIMENTS

Significance and Use of Baking Experiments

Blish[23] expressed the point of view of many experimenters when he sais, "At any rate it appears that the baking test is the only reliable quality test... Actual baking tests conducted by expert bakers under carefully controlled conditions must still be resorted to in order that flour strength may be accurately judged." In experimental baking, scientific methods are applied in place of the methods used in the home or in the bakery. Swanson[24] states that "When we make a baking test we deal with physical, chemical, and biological forces, and the baking test becomes one of the most delicate test we can imagine."

Work of Other Experimenters With Soft Wheat Flour

In the states which produce principally soft wheat, an effort has been made by experimenters to increase the use of their local wheat by encouraging the use of soft wheat for breadmaking. Willard and Swanson (1911)[25] working with Kansas flours, did some work with soft wheat flour. They varied the yeast, liquid, and amount of rising before baking, and obtained the best results with a stiff dough and a short rising period. Jago (1921)[26] advises an increased yeast content with soft wheat flours. In Ontario, Canada, Harcourt and Purdy (1922)[27] recommend a quick short method for breadmaking with soft wheat flour since the weaker gluten cannot stand a long fermentation. They believe the use of the sponge method is not advisable with soft wheats. Dr. Minna C. Denton of the United States Department of Agriculture, Washington, D. C., in a report of the Inter-Bureau Committee on the Standardization of Bread-Making Test for Hard Wheat Flours, recommended a rich formula of 4 percent yeast and 6 percent sugar used in a straight dough method for soft wheat. Indiana soft wheat is used for breadmaking, and the sponge method has given the best results.

Missouri probably ranks first in the production of soft wheat in the United States, and accordingly more work has been done in that State with soft wheat flour than in any other. The University of Missouri, Agricultural Experiment Station (1924)[28] conclude that soft wheat flour requires more sugar, more yeast, less water but a softer dough, less kneading and a shorter fermentation period. The same workers, Davis and Cline (1926)[29] continuing their work with soft wheat stated that good bread could be made from soft wheat flour with a great saving of time.

Ingredients in a Dough

Flour and Liquid: As indicated above, the flour, which is the basis of the bread, is a very complex substance. It contains inorganic substances such as water and ash, and organic substances such as fatty matters, starch and allied bodies having a similar chemical composition, and the more complex nitrogenous bodies or proteins. Experimenters have found five distinct proteins in the total protein of wheat flour. These are gliadin and glutenin, which make up the gluten, and a globulin, or albumin, and a protease. The gliadin and glutenin are the most important and constitute about 80 to 85 percent of the total protein. In addition to the above mentioned constituents in flour there are two classes of enzymes. One class is the starch splitting enzymes which act upon the starch, converting a small amount of it into sugar. Other enzymes which are proteolytic, convert some of the protein into proteoses and peptones if given time to act but according to experimenters the ordinary time used in breadmaking does not allow this change to occur.

A flour has inherent qualities before the baker gets it, but he can so control the environment that the best results are obtained from those qualities.

The combination of flour and a liquid makes a dough. With the addition of moisture to flour and the mixing of the two, the gliadin and glutenin combine to make gluten. This forms a network that holds the starch grains, thus the dough is formed. For breadmaking, other ingredients, such as sugar, yeast, salt and fat, are added. A good quality dough involves both gas production and gas retention. The ingredients used and the conditions produced and maintained throughout the processes have their effect upon the production and retention of the gas.

Yeast: The yeast is a natural agent which acts upon the sugar producing the carbon dioxide (CO_2) gas, and alcohol. Experimenters believe that the yeast matures the gluten and develops the fragrance of the bread. There are several kinds of yeast used. Perhaps the oldest form of yeast is used by the housewife and is called the "starter." It is a portion of the sponge that has been saved from the last breadmaking. The dry yeast commercially known as "Yeast Foam" is another form. Due to its dry form it retains its active power longer than the wet yeasts. However, the dry yeast acts more slowly at first. The compressed yeast is the most convenient one to use. It may be readily purchased in any quantity and is soft and moist and acts quickly. A cake of yeast contains millions of tiny yeast plants which grow rapidly when placed in a warm environment with sufficient moisture and sugar. In addition to the yeast plants the cake of yeast contains enzymes. The enzyme invertase acts upon starch, changing it to maltose. There is also an enzyme maltase present, which changes maltose to glucose. Zymase is an enzyme secreted within the yeast cell which acts very much like the yeast cell itself, changing the sugar into alcohol and carbon dioxide (CO_2).

Sugar: Sugar is the food upon which yeast acts to form carbon dioxide (CO_2) and alcohol.

$$\underset{\text{sugar}}{C_{12}H_{22}O_{11}} + \text{yeast} + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{carbon dioxide}}{4CO_2} + \underset{\text{ethyl alcohol}}{4C_2H_5OH}$$

The dough becomes charged with the gas which separates the particles of flour and causes the light porous condition. Sugar also adds flavor and food value. Ordinary granulated sugar may be used, but the baker often uses a malt compound instead of sugar. With the substitution of milk in a dough the sugar content of the bread is increased by the lactose of the milk. The bloom of the loaf is improved by an increased sugar content and is as a rule accompanied by good oven spring.

Salt: The salt, besides improving the flavor of the bread thus rendering it more palatable, also has a toughening effect upon it. By the toughening effect salt is said to strengthen a weak flour. The action of the yeast is retarded and controlled by the salt in the dough.

Liquid: Water is believed to be the best liquid for experimental baking and is less expensive for the commercial baker, but milk or potato water may also be used in breadmaking. The milk and potato water are said to improve the flavor and keeping qualities of the bread. Sweet milk also lengthens the time of fermentation but butter milk shortens it. The liquid is not only valuable for making the dough, but the yeast also acts more rapidly in a moist medium. Water dissolves the salt, swells the starch, and makes the bread more digestible.

Fat: The inherent qualities of the flour are aided by the fat in producing a silky texture with a pile that is velvety and has a sheen. The fat also prevents the drying of the bread and improves the keeping qualities. Lard, vegetable fat, or butter may be used as fat. These all have practically the same value but butter is too expensive for the commercial baker to use. Fat is not used in all experimental baking because it is hard to incorporate in a dough and becomes a variable factor. However, if the results are to be used by the homemaker or baker, the experiment should include fat in order that a comparison may be fairly made.

Chemistry of Breadmaking Summarized

The first chemical change occurs in bread when the liquid is added and the two proteins gliadin and glutenin combine to from gluten. About 85 percent of the wheat protein is gluten. In addition to this, there is a globulin and an albumen, but these are in very small quantities in relation to the others. The proteins remain practically unchanged during the fermentation, although some of the soluble proteins are probably changed by the yeast. The fat is slightly oxidized or volatilized, and the color is changed in breadmaking. All the soluble carbohydrates such as the sugars are changed by the yeast into carbon dioxide and alcohol. It is estimated that about 10 percent of the starch flour is changed by the enzyme diastase into soluble sugars. There is also some acid production along with the alcoholic fermentation, but the extent of the action probably depends upon the purity of the yeast, temperature of the dough, and length of fermentation. The result of too much acid fermentation is sour bread. The yeast plant also secretes soluble ferments which act upon the starch to form soluble carbohydrates. In baking, the protein coagulates, the alcohol evaporates, and some of the starch is dextrinized, which along with the sugar causes the brown color of the crust.

Methods in Breadmaking

There are two general methods employed in the making of bread; the straight dough method and the sponge method. In the straight dough method, all the ingredients are mixed together at once. In the sponge method part of the flour is mixed with the liquid and yeast and allowed to ferment the desired time before the other ingredients are mixed into the sponge and a stiff dough made.

Processes in Breadmaking

Mixing: The combining of the liquid, flour, and other ingredients is termed mixing. Usually the housewife mixes bread by hand, but the experimental baker and the commercial baker use electric mixers for this purpose. The mixers have two or often three speeds; low speed, high speed, and in some instances an intermediate speed. The time of mixing, varying from 3 to 20 minutes, is determined by the speed of the mixer and the size of the batch of dough.

Fermentation: After mixing, the dough is fermented. Fermentation is the term applied to the chemical changes that take place in a dough after the yeast is added to it. Alcohol, carbon dioxide, and certain acids, are produced. The gluten tends to retain the CO_2 which causes a distension of the dough. Jago[26] states that the most favorable range of temperature for the growth of yeast is 77° F to 95° F. Experimenters usually recommend 82° F. Fermentation may be carried on until a required volume is reached or for a desired length of time. If it is desired that the dough reach its maximum volume during any single fermentation period, this is determined by pressing the dough with the finger. If the imprint remains or the dough falls, the maximum volume has been reached.

Punching: Punching or kneading removes the large gas bubbles from the dough and evenly distributes the smaller ones. The manner of punching varies with the laboratory or bakery. The dough may be allowed to rise or ferment several times with intervals of punching between risings.

Bench Proofing: Before putting in the pan, the bread is bench proofed. This is a rest period for the dough and the recommended time and temperature is fifteen minutes at 82° F.

Proofing: Following the bench proofing the bread is fermented in the pans. This fermentation is something called panary fermentation, but more frequently spoken of as proofing. The dough is proofed to a desired volume or for a definite length of time. The temperature used for this process is 92° F.

Baking: After proofing the bread is ready to be baked. The temperature used for baking by the experimental baker is usually 410° F. The commercial baker uses a higher temperature of about 500° F. However, the commercial baker bakes in such quantities that the initial temperature of the oven is lowered considerably when the large number of loaves are placed in the oven. The time required to bake a loaf of bread depends upon the temperature and size of the loaf. A one pound loaf of bread is baked at 410° F 30 to 35 minutes.

Basis for Judgment of Bread Quality

The quality of the baked loaf is next to be determined. In order to have a uniform basis upon which to judge the quality of bread, some method of scoring must be used. The characteristics of good bread serve as a basis for making a score card.

A good loaf of bread is symmetrical in shape and has a rounded top with a brignt brown colored crust. The grain is close and firm, with small, elongated, thin-walled cells. The cells are uniform in size and evenly distributed throughout the loaf. The crumb is elastic, pliable, smooth and silky. The odor and flavor should be sweet and nutty, typical of the wheat itself. The loaf volume should be good but not excessively large. It has been noted that the volume often is closely tied up with the quality of the bread. A good volume usually indicates a good loaf of bread. The volume varies in different parts of the country, with different flour and different quantities of dough in a loaf.

Score cards differ in the number of points assigned to each factor, but the qualities considered remain practically constant as given below.

Appearance: Bread is scored first upon appearance, as cutting may destroy the shape. A loaf of bread should have a well balanced appearance with a rounded top.

Crust: A good crust is bright in color, crisp, smooth and pliable. It should be free from large holes or blemishes.

Flavor: Odor and taste make up the flavor of bread. Good bread has a rather nutty flavor, and is free from a sour odor or taste.

Lightness: The loaf volume is often considered one of the best indications of the baking strength of a flour.

The lightness is determined from the weight and volume of the bread. The factor indicating lightness is obtained by dividing the weight by the volume. A high factor means a high score.

Crumb: The texture should be a fine and regular mesh. The crumb should be soft, pliable, and spongy. A good crumb is not dry and will not crumble easily.

Grain: The distribution of the gas cavities, their size and number, determine the grain of bread. The cavities should be evenly distributed, small and of uniform size.

EXPERIMENTAL PROCEDURE

<u>Apparatus</u>: In the experimental work, a Torsion balance accurate to .1 gram was used for weighing all the materials used except the water. It was measured in a graduate, graduated to .1 of a cc.

The mixing of the dough was done by the mechanical electric mixer, Mixonette, made by the Bread Machinery Company, Inc., York, Pennsylvania. This mixer had a low and high speed.

The bread was fermented in jars of glass, graduated for each 100 cc.

The fermentation cabinets were made by the Denver Fire Clay Company, Denver, Colorado. By means of an automatic temperature control, a temperature of 82° F was maintained at all times. Water was kept in the cabinet to furnish sufficient humidity.

The proofing cabinet was similar to the fermentation cabinet, made by the same company and maintained a temperature of 92° F to 95° F. Water was also kept in this cabinet to retain a humidity sufficient to prevent the surface of the dough from drying.

Baking ovens provided with air vents, transparent doors and automatic temperature controls were used. These were made by the Denver Fire Clay Company, also. A pan of water on the baking shelf served as a humidity control. The oven was capable of being evenly and constantly heated at temperatures from 100° to 600° F.

Baking pans of tin were used with inside dimensions of: top, 4"x9½"; bottom, 3¼x8½"; height 3".

A loaf volume measuring device, containing small round rapeseed was used. The seed fall around the loaf and the displacement of the seed by the loaf is measured by a graduated tube.

Constant Factors of Procedure: In experimental baking, the results are more accurate if each experiment has one or not more than two variable factors with all other factors remaining constant. In the following baking experiments, the constant factors were: the flour 325 grams, fat equal to 2 percent of the flour, and 2 percent salt. The time of mixing remained the same throughout the experiments, 10 minutes with the low speed. The temperature of fermentation was 82° F. The temperature of proofing was 92° F and the baking temperature was 410° F. Each loaf of bread was baked for 30 minutes. An individual record of time and volume was kept for each loaf of bread during the laboratory procedure upon the following work sheet.

Chart I

Formula

Method

Loaf No. ____

Process

	In	Out	Time	Volume	Temperature
Preliminary					
Mix					
Ferment (1)					
(2)					
(3)					
Bench Proof					
Pan Proof					
Bake					

Total fermentation time ____________ min.

Volume ____________ c.c.

Weight ____________ gms.

Remarks: Flour #

The quality of the bread was judged by the following score card:

Chart II

Score Card

Loaf No. Points Scored

	Score	Comment
Wt. (24 h.) Vol. " "	..... gms. ..... c.c.	
Appearance 10 Symmetry (2.5) Shape top (2.5) Smoothness top (2.5) Break		
Lightness 10		
Crust 10 Depth (2) Color (4) Texture (4)		
Crumb 30 Color (5) Grain (10) Texture (15)		
Flavor & Odor 30		
Keeping Quality 10		
Total Score 100		

Determination of the Absorption: The absorption is the amount of water absorbed by the flour in making a dough of the right consistency. Preliminary to making a baking experiment, the absorption of the flour must be determined. For a trial test 15 c.c. of tap water was added to 25 grams of flour and worked into a dough. A dough is considered of the proper consistency when it will pull away from the dish leaving a clean surface. By varying the amount of water, it was found that the experimental flour gave a dough of the right consistency when water in the amount of 58 percent of the flour was absorbed. This percent absorption is higher than the average soft wheat flour indicating that the yield per barrel would probably be nearer that of a hard wheat flour. Fifty-eight percent absorption was followed for all experimental baking unless otherwise indicated.

Experiment I

Application of the Standard Baking Test

It is necessary to have a starting point and a basis upon which to judge a flour. The standard baking test serves both of these purposes. Fitz[30] stated that, "An experimental baking test is that test which will determine the character and quality of a product that can be produced by using a given formula and method of procedure."

The Committee on Standard Formula and Method of Procedure for Experimental Baking Tests for the Cereal Chemists, made the following recommendations for the formula and method[31].

Formula:	325	grams	flour
	12	"	sugar
	5½	"	salt
	10	"	pure lard
	6½	"	yeast
	q. s.		distilled water

Method: Mix all ingredients together from 3 to 15 minutes to form a smooth dough. All ingredients should be of a temperature to make a dough of 82° F. Ferment at 82° F until ready to punch (determine this by thrusting finger into the dough), calculating this as 70 percent of the total time. Punch and return to jar to rise 3/7 of the time required for the first rising. Then punch, bench proof 12 minutes, and pan. Pan proof to top of pan at 92° F, then bake at 410° F for 30 minutes.

This recommended formula and method for judging the breadmaking quality of flour was accordingly applied to Early Baart flour.

With the standard method and formula the experimental flour gave a fair sized loaf with a volume of 1740 c.c. and a score of 86. As this formula was recommended for hard wheat flour, soft wheat flour cannot be expected to give the best results with it. It is known that it is impossible to have one method for all flours and obtain the best results from each. The success of experimental baking depends upon the ability of the experimenter to adapt the method and formula to the flour in order to secure the desired results. Weaver and Goldtrap (1922)[32] announced that every flour they had experimented with was capable of producing a good loaf of bread; "It all seems to be a matter of starting with the right absorption and finding the correct fermentation period."

In the experiments that follow, attempts were made to find the formula and conditions which might be better suited to the handling of Early Baart flour.

Experiment II

Variation in the Amount of Liquid Used

Since experimenters with soft wheat flours have recommended slack doughs, the liquid was varied in this experiment to determine the effect of decreased and increased moisture above and below the determined absorption upon the bread produced. The standard formula and method was used with only the moisture varied.

Table I

Effect of the Variation of the Amount of Liquid Used Upon the Quality of the Bread Produced

Loaf No.	Percentage Liquid	Total fermentation time	Loaf volume	Loaf score	Remarks
1	52	165 min.	1650	81	Volume small close grain
2	56	145 min.	1700	83	.
3	58	135 min.	1750	86	
4	60	110 min.	1770	87	
5	62	105 min.	1700	85	Coarse grain
6	66	100 min.	1650	80	Coarse grain

It is significant to note from the results that as the percent of liquid increases the time of fermentation decreases, showing that in a slack dough the fermentation is more rapid and in a stiff dough the fermentation has been retarded. In the stiff dough the volume and score is only fair. The grain is very fine. There is a cracked appearance around the top that is known as a shell top, showing that the crust formed and was then broken by the distending gas on the inside. In loaves numbers 2 to 4, with the percent of liquid varying from 56 to 60, the score and volume is best. If the percent of liquid is increased beyond 60 percent, the grain is coarse and dry and the volume is lower. The increased moisture in this case gave a loaf with a very flat top and a coarse uneven grain. If the water used to make a dough is increased more than 2 percent, a striking effect upon the dough is apparent, but an increase or decrease of no more than 2 percent is not significant. Since the 58 percent liquid gives the best results that percent liquid will be used throughout the following experiments.

Experiment III

Comparison of Standard Method of Procedure With a Shorter Fermentation Period

Most experimenters with soft wheat flours have recommended a short fermentation. In this experiment the dough was allowed to double its bulk once before proofing. The dough that was allowed to double its bulk twice before proofing was used for comparative purposes. A 3 percent yeast 4 percent sugar formula was used.

Table II

Comparison of the Standard Method and the Short Fermentation Method

Loaf No.	Percentage liquid	Total fermentation time	Loaf volume	Loaf score	Remarks
1	2	100 min.	1650	80	Yellow color
2	3	140 min.	1740	86	

The results in Table II indicate that the short method does not give as satisfactory a loaf volume or score as the standard method. In the short method the bread was flat-topped, the crumb was harsh and dry and yellow in color. The standard method produced a loaf of bread with a white colored crumb and a soft, pliable texture. The top of the loaf was well rounded with fair oven spring.

Experiment IV

Variation of Yeast and Sugar in the Formula

In order to obtain added evidence that the short fermentation time is unsatisfactory, in this experiment the dough was again only allowed to double its bulk once before proofing. Thepercent of yeast and sugar in the formula was varied. The dough was also allowed to treble its bulk in the pans.

Table III

The Effect of the Variation of the Percent of Yeast and Sugar Upon the Quality of the Bread Produced

(Short fermentation, straight dough method)

Loaf No.	Formula Percent Yeast	Percent sugar	Fermentation time	Loaf volume	Loaf score	Remarks
1	2	3	165 min.	1480	76	
2	3	3	150 min.	1570	79	
3	3	4	145 min.	1660	80	
4	4	3	140 min.	1680	82	
5	4	4	135 min.	1690	83	
6	3	6	130 min.	1700	84	
7	4	6	120 min.	1745	88	
8	6	4	95 min.	1780	84	Coarse Crumbly
9	6	6	90 min.	1800	83	Coarse Crumbly

In reference to Table III it is seen that the bread is consistently poor. The volumes are low, the crumb yellow, dry and crumbly. The yellow color may be due to under-fermentation and the dry crumbly texture suggests over proofing. It is noticeable that the time of fermentation decreases as the percent of yeast and sugar increases. It is evident that the best results are obtained when the yeast and sugar are increased in proportion to each other. Increasing the yeast and not the sugar is of little value since the yeast must have sugar for food. If the sugar is increased and not the yeast, there is considerably more sugar than is necessary and a sweet flavor results. In the richer formulae the volumes are higher but the grain is coarse, indicating that the grain was sacrificed for the volume.

Experiment V

Variation of the Number of Fermentation Periods With Different Formulae

The previous experiment indicated that the bread was under-fermented, therefore in this experiment the time of fermentation was lengthened. Instead of doubling its bulk once the dough was allowed to double its bulk twice before proofing. Loaves which were allowed to double bulk but once before proofing were baked for control purposes.

The same percentage variations of sugar and yeast were used as in Experiment IV.

Table IV

The Effect of the Variation of the Number of Fermentation Periods Upon the Quality of the Bread Produced

Loaf No.	Formula Percent yeast	Formula Percent sugar	No. of fermentations	Loaf volume	Loaf score	Remarks
1	2	3	2	1500	77	Harsh texture Yellow color
2	2	3	3	1600	83	
3	3	3	2	1565	79	Harsh texture Flat top
4	3	3	3	1680	84	
5	3	4	2	1670	81	Poor grain
6	3	4	3	1745	86	
7	4	3	2	1680	82	Yellow color Poor grain
8	4	3	3	1750	88	
9	4	4	2	1690	87	Yellow color
10	4	4	3	1760	89	
11	4	6	2	1745	86	Yellow color
12	4	6	3	1800	90	Good oven spring
13	6	4	2	1785	88	
14	6	4	3	1860	84	Coarse grain
15	6	6	2	1780	89	
16	6	6	3	1890	86	Coarse grain

From Table IV it may be seen that in every case the volume of the dough with the three rising period is superior to the two rising period. The color is superior in the three rising period.

The score is higher for every loaf with a three rising period than the same formula with only a two rising period. Here again the increase in sugar without a proportionate increase in yeast or vice versa does not give the optimum results. Here also in the high sugar and yeast formulae the larger volumes have been secured with a sacrifice of grain. The bread is porous and crumbly.

From this experiment the conclusion is drawn that a longer fermentation period produces better bread with soft Baart flour than a short fermentation period. The methods that are satisfactory for other soft wheat flours do not give optimum results with Arizona soft wheat flour.

Experiment VI

Sponge Method Compared With Straight Dough Method

Since the longer fermentation period apparently gives the best results with Arizona soft wheat, it was thought that owing to its soft gluten, the sponge method in which the yeast activity is speeded up by the slack consistency might give even better results. The time required for the proper "conditioning" of the gluten would be lessened due to the more rapid action of the yeast and therefore the effect produced upon the soft gluten might prove less disastrous.

In an effort to use a leaner formula the sponge method was also used. By the slack condition of the sponge the diastase would have an opportunity to act more rapidly, increasing the natural sugar content of the flour and might thus permit the use of a leaner formula with results comparable to those with a richer formula.

A preliminary experiment was therefore planned in which the sponge method was compared with the best straight dough procedure.

The dough made from the sixty minute sponge was allowed to double its bulk once before proofing. A 3 percent yeast 4 percent sugar formula was used.

The straight doughs were allowed to double their bulk twice before proofing. A 3 percent yeast 4 percent sugar formula was used for one, and a 4 percent yeast 6 percent sugar formula used for the other.

Table V

Comparison of Straight Dough and Sponge Methods

Loaf No.	Formula Percent yeast	Percent sugar	Method	Time	Loaf volume	Loaf score	Remarks
1	3	4	60 min. sponge	150 min.	1805	89	Good oven spring Good grain
2	3	4	St. dough	140 min.	1745	86	Fair grain
3	4	6	St. dough	110 min.	1790	88	Good oven spring

From the loaf volumes and scores recorded in Table V, it may be seen that the sponge method gave superior bread. It is also indicated that by the sponge method as good a loaf can be made with the leaner formula as with the rich formula. The texture in the sponge method is superior to either of the other two. The pile is velvety and pliable.

Since the sponge method has given the best results in the following experiments, this method will be varied.

Experiment VII

Variation of Amount of Flour Sponged

In the sponge method one-half the flour is usually sponged, but in this experiment an effort was made, by varying the amount of flour sponged, to determine what amount would give the best results. A 3 percent yeast 4 percent sugar formula was used with a 60 minute sponge method, the dough doubling its bulk once before proofing.

Table VI

The Effect of the Variation of the Amount of Flour Sponged Upon the Quality of the Bread Produced

Loaf No.	Amount of Flour sponged	Loaf volume	Loaf score	Remarks
1	1/4	1650	77	Flat top Little oven spring
2	1/3	1660	78	Flat top, cracked Little oven spring
3	1/2	1790	88	Good oven spring
4	2/3	1795	89	Good oven spring

In Table VI, results show that when only one-third or one-fourth the flour is sponged, the loaf volume is low and there is little oven spring. As the amount of flour used for the sponge increases, the oven spring improves, the volume is larger, and the texture, as indicated by the score, improves. Therefore, in the sponge method at least one-half the flour must be sponged in order to obtain a loaf of bread with a satisfactory volume, texture, and grain.

Experiment VIII

Variation of the Time of Sponging

(a) Dough doubled its bulk once before proofing

In the next four Experiments, VIII, IX, X, and XI, the time of sponging is varied for 30 minutes, 60 minutes, 90 minutes, and 120 minutes. In this experiment, all other factors are constant. The dough after sponging was allowed to double its bulk once before proofing.

Table VII

The Effect of the Variation of the Time of Sponging Upon the Quality of the Bread Produced

(a) Dough doubled its bulk once before proofing.

Loaf No.	Time of sponging	No. of fermentations after sponging	Dough volume increase	Total fermentation time	Loaf volume	Loaf score
1	30 min.	1	double bulk	135 min.	1790	88
2	60 min.	1	double bulk	160 min.	1810	89
3	90 min.	1	double bulk	190 min.	1860	90
4	120 min.	1	double bulk	220 min.	1880	91

From Table VII it is seen that the poorest loaf with the sponge method gave a better loaf of bread than the best loaf with the straight dough method in Table V. As the time of sponging increased, the loaf volume and score increased also. The texture of the bread made with the sponge method is more velvety and less harsh and crumbly than the bread made by the straight dough method. The color of the crumb has decidedly improved in this experiment.

Experiment IX

Variation of the Time of Sponging

(b) Dough reached maximum volume once before proofing.

All factors remained the same as in Experiment VII except that the dough reached its maximum volume once after the sponge.

Table VIII

The Effect of the Variation of the Time of Sponging Upon the Quality of the Bread Produced

(b) Dough reached maximum volume once before proofing.

Loaf No.	Time of sponging	No. of fermentations after sponging	Dough volume increase	Total fermentation time	Loaf volume	Loaf score
1	30 min.	1	maximum	145 min.	1810	89
2	60 min.	1	"	165 min.	1870	90
3	90 min.	1	"	230 min.	1890	91
4	120 min.	1	"	260 min.	1910	92

Results from Table VIII show that the loaf volume and score increased as the time of sponging increased. This group has a better volume and score than the sponges in Experiment VIII. The oven spring, grain, and texture, were consistently good throughout this experiment.

Experiment X

Variation of the Time of Sponging

(c) Dough doubled bulk twice before proofing.

All factors remain constant, as in Experiment IX, except the dough after sponging doubled its bulk twice before proofing.

Table IX

The Effect of the Variation of the Time of Sponging Upon the Quality of the Bread Produced

(c) Dough doubled bulk twice before proofing.

Loaf No.	Time of sponging	No. of fermentations after sponging	Dough volume increase	Total fermentation time	Loaf volume	Loaf score
1	30 min.	2	double	180 min.	1820	90
2	60 min.	2	"	200 min.	1865	91
3	90 min.	2	"	240 min.	1895	91
4	120 min.	2	"	270 min.	1910	94

The results from Table IX indicate that the dough doubling its bulk twice is about equivalent to allowing it to reach its maximum volume once. Again it is seen that the loaf volume and score have increased as the time of sponging increased. The texture and grain were somewhat superior to that of the bread which resulted from allowing the dough to reach maximum volume after sponging. Apparently a second punch serves to distribute the gas more evenly.

Experiment XI

Variation of the Time of Sponging

(d) Dough reached maximum volume twice before proofing.

The time of sponging was varied as in Experiment X. The dough was allowed to reach its maximum volume twice after sponging before reproofing.

Table X

The Effect of the Variation of the Time of Sponging Upon the Quality of the Bread Produced

(d) Dough reached maximum volume twice before proofing.

Loaf No.	Time of Sponging	No. of fermentations after sponging	Dough volume increase	Total fermentation time	Loaf volume	Loaf score
1	30 min.	2	max.vol.	265 min.	1810	89
2	60 min.	2	max.vol.	285 min.	1790	88
3	90 min.	2	max.vol.	285 min.	1750	87
4	120 min.	2	max.vol.	345 min.	1740	85

In this experiment it is seen from Table X that the volume and score decrease as the time of sponge increases. It is evident that the dough reaching its maximum volume twice before proofing results in inferior bread unless the time of sponging is greatly shortened. Perhaps such a prolonged fermentation period has a destructive effect upon the weaker gluten of this soft wheat.

SUMMARY

This problem was to develop by means of chemical and physical tests and baking experiments, a formula and method of handling best adapted to Arizona Early Baart flour for breadmaking.

The nitrogen content of the flour was determined by the well-known Kjeldahl method. Then by means of the factor 5.7, which is the conversion factor for wheat proteins, the percent of protein in the Early Baart flour was found to be 9.84. Although this figure is low in comparison with hard wheat flours it is high for the average soft wheats, ranking it as one of the best soft wheat flours.

However, sixty-seven percent of the total protein of the flour was found to be gliadin protein when determined from the alcohol extract by the Kjeldahl method, using the conversion factor 5.7. The salt-soluble proteins were extracted with a five percent potassium sulphate solution. The nitrogen and the protein in the extract were determined by the Kjeldahl method and the conversion factor 5.7 and found to be 1.64 percent. The glutenin protein determined by difference was 1.54 percent. If the salt-soluble proteins were retained in the glutenin fraction, the gliadin-glutenin ratio would be 67 to 33.

A sample of flour was burned in an oven until a white ash was obtained. The percentage ash of this flour was .55. This figure is well within the range of .37 to .58 percent for straight grade soft wheat flours.

That the flour was milled from sound, mature wheat was indicated by a low acidity of .111 percent, as determined by titration of the acid dissolved out with distilled water.

The crude gluten, obtained by washing the starch out of a dough ball, was creamy in color, elastic, cohesive but softer than usually considered desirable.

The amount of water absorbed by the wet gluten or the hydration capacity was about two and one half times its dry weight. This is high for a soft wheat flour, indicating that the yield of loaves per barrel of flour would probably be higher than usual for a soft wheat flour.

The absorption of the Early Baart flour, determined by adding a known percent of liquid to a weighed amount of flour and working into a dough of the proper consistency was found to be fifty eight percent. This figure is somewhat high for a soft wheat flour.

The result of the chemical and physical tests thus made indicate that Early Baart Soft Wheat flour would probably be a good flour for breadmaking if suitable variations in the usual method used for hard wheat flours were developed.

Since neither the baking test for hard wheat flours nor the formula and method recommended by the Missouri Experimenters gave satisfactory results with this flour, the formulae and methods were varied in an attempt to find one that was suited to Arizona soft wheat flour.

The short fermentation time, recommended by other soft wheat flour experimenters, was tried, varying the amount of yeast and sugar from a very lean formula to a rich one. The richer ones gave the best volume, but the grain was yellow and harsh in every case. The volume was low and the top of the loaf flat. In comparison the same formulae were used but a longer fermentation time in which the dough was allowed to double its bulk twice before proofing, instead of once. The longer fermentation time gave results superior to those of the shorter method.

The dough was allowed to treble its bulk in the pan but there was little oven spring and the bread was harsh in texture, coarse grained, showing over proofing. Better oven spring was secured when the dough rose to two and one half times its original bulk in the pans.

In the comparison of the straight dough method and the sponge method using the same formula, the sponge method was found to give superior results. The volume, color of crumb and texture were better in the sponge method. With the use of the sponge method and a lean formula as good a loaf of bread was produced as with a rich formula and the best straight dough method.

The leaner formula of three percent yeast and four percent sugar was used, in the variation of the sponge method. The time of sponging was varied from thirty minutes to one hundred twenty minutes and the length and number of fermentations were varied with each time of sponging. The loaf volumes and scores increased as the time of sponging increased, when the dough was allowed to double its bulk once before proofing, or either, double its bulk twice before proofing or reach a maximum volume once before proofing. If a maximum volume was reached twice before proofing the loaf volume and score decreased with the increase in time of sponging, showing that probably the soft gluten cannot withstand two such long fermentation periods before proofing.

CONCLUSION

From the results of these experiments it was concluded that flour milled from Arizona Early Baart Wheat is a good flour for breadmaking. Even though it is a soft wheat, a good loaf of bread results if it is handled in a suitable manner.

This investigation has shown that the sponge method is superior to the straight dough method for this flour. The best results are obtained when a dough made from a ninety or one hundred and twenty minute sponge was allowed to double its bulk twice before proofing.

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