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KANSAS FLOURS:

Chemical, Baking and Storage Tests.

MANHATTAN, KANSAS

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KANSAS FLOURS.

Chemical, Baking, and Storage Tests.

C. O. SWANSON, J. T. WILLARD and L. A. FITZ.

SUMMARY.

The scope of the bulletin can be seen from the index. In the summary only the salient points are mentioned. In Part I are described the equipment and the method used in making the baking tests. This method has undergone several changes since the work on wheat and flour was begun, and it is yet in a stage of development. A baking test should show not only the comparative value of a flour when tested by a uniform standard, but it should also show the best method of treating a particular flour so as to produce good bread. For that reason the method should be adapted to the character of the flour tested. From investigations already made and those now under way, it is hoped that progress will be made towards this end. The bread made by the method used conforms very closely to the ideal for good baker's bread. The equipment and the method used were planned so as to secure the greatest accuracy in all the measurements taken, and eliminate external influences as far as possible.

In Part II are given the results of the baking tests and the chemical analyses of thirty-five commercial flours collected from Kansas mills. Following this are given the chemical analyses of twenty-one wheats collected at the same time as the samples of flour. They represent the wheats from which the flours were made. The flours were classified into three grades: short patent, long patent, and straight. The baking tests show that these flours are all of good quality and strength. The chemical composition brings out the fact that there is a close relation between acidity and phosphorus, both total and water-soluble. There is also a relation between ash and acidity. This is probably due to the fact that a high ash means a high phosphorus content. A high acidity value may be due to a high phosphorus content rather than to any unsoundness.

The chemical composition of the wheat brings out the fact that the variation in the moisture content of the flour is more affected by the water added in tempering than by the variation of the moisture originally present in the wheat, also that the protein content of the wheat has a pronounced effect on the protein content of the flour. It is further shown that the method of milling has a more pronounced effect on the acidity, ash, and phosphorus content of the flour than any variation of these constituents in the wheat.

In Part III are given the chemical composition and baking tests on flours from two sets of mill streams. The chemical data bring out very clearly the close relation between the phosphorus and the acidity, together with the ash and the amino compounds. It is hoped that further studies on these compounds will give a better method for the determination of true acidity and give some of the fundamental causes for the differences in the baking qualities of flours.

Part IV gives the report of two seasons' work on the effect of conditions of storage on flour. Bleached and unbleached flours were used, and the flours were stored in a steam-heated room, in a nonheated room, and in sealed cans. Flours with an average moisture content may lose two per cent of their original weight. The different storage conditions do not show as much effect on the chemical composition and baking qualities as might be expected.

Part I.

Description of Apparatus and Method.

Equipment for Making Baking Tests.

The equipment consists of a sponge closet, an electric oven, special baking pans, special cylinders, a Koelner dough kneader connected with a one-fourth horsepower motor, a device for measuring the loaf volume, and accessories, such as beakers, porcelain cups, measuring cylinders, burettes, scales, and other needful apparatus of a general character.

The Sponge Case.

This is made of oak, and is six feet wide, four feet high, and twelve inches deep. It has eight small glass doors in front which are closed with refrigerator locks. The doors have beveled edges so as to make them fit quite tightly. The shelves are made of wire cloth, one-fourth inch mesh, nailed on a frame. This allows a free circulation of the air in the case. The shelves may be raised or lowered to accommodate different sizes of apparatus, should such changes be necessary. In front, below the doors, and in the top of the case, are series of holes, which may be opened or closed by means of shutters. In this way the ventilation of the sponge case can be properly regulated. The case is heated by incandescent lamps varying from four to thirty-two candlepower. Small boards covered with asbestos are supported above the lamps. The air from the outside passes through the holes beneath the doors into the case, then under the asbestos-covered boards, and over the lamps to the back part of the case, where it is deflected upward. This gives a small current of warm air all through the case and helps very much to equalize the temperature in the different parts. By suitable choice among the different sizes of lamps it is an easy matter to maintain a constant even temperature all through the case.

Baking Oven.

The oven is the well known "Simplex Quality," with inside dimensions as follows: Thirteen inches high, twenty-one inches wide, and nineteen inches deep. The electrical connection is capable of three adjustments of high, medium, and low heat, respectively. Also, there is in the top toward the back a small vent which may be opened or closed, and this makes possible additional regulation of temperature.

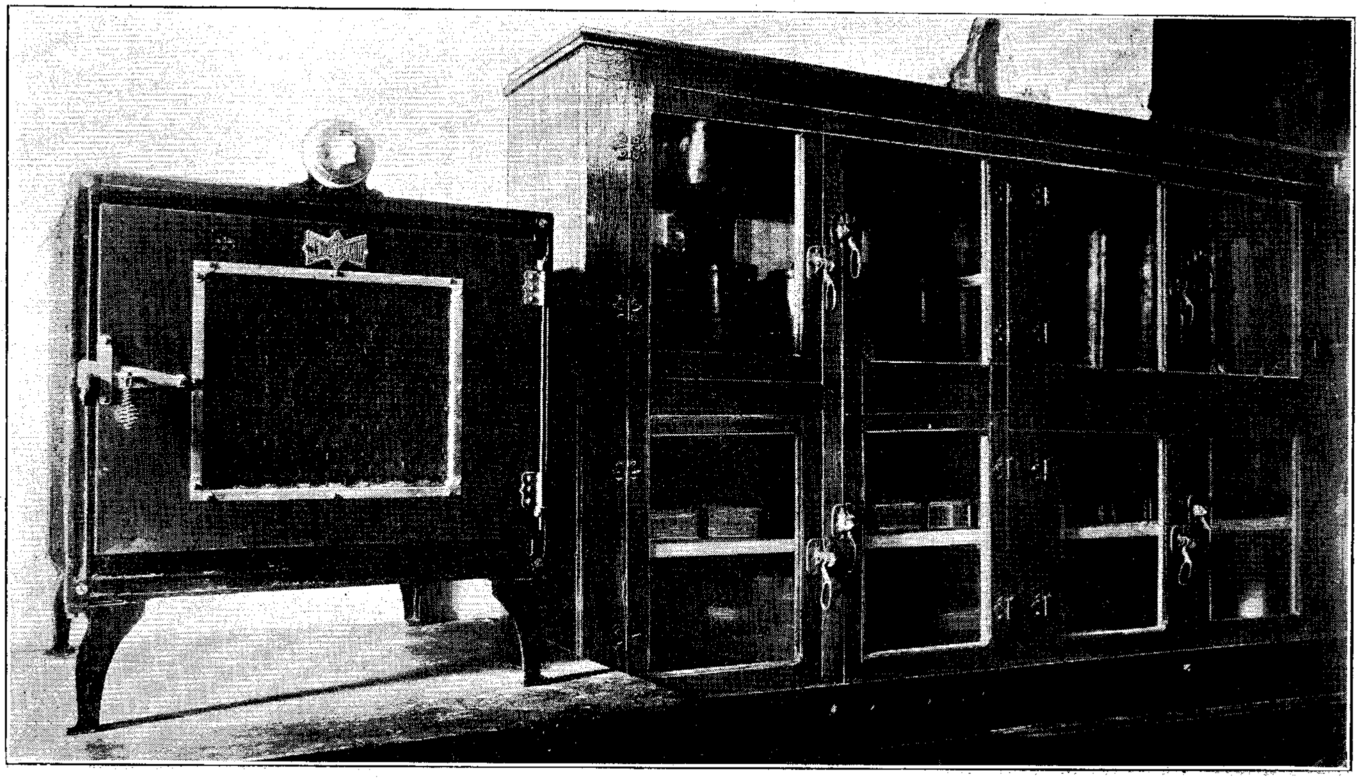

PLATE I.

Baking Pans.

The baking pans have been described in a previous bulletin. The chief feature is that the amount of rise of the dough before it is put in the oven, as well as the rise during baking, can be accurately measured. It is well known that loaf volume depends, to a large extent, upon the rise of the dough before it is placed in the oven, hence if loaf volume is to have any meaning, this amount of rise must be carefully controlled. Just exactly what value should be attached to the amount of the oven spring, or the expansion during baking, may yet be an open question, but this form of pan enables the operator to measure it quite accurately. The pans used at present were made from copper by E. H. Sargent & Co., according to a design furnished them. This material was chosen because more accuracy of construction is possible with copper than with sheet iron. The lower part of the pan has the form of a truncated cone, the lower diameter of which is four and one-fourth inches, the upper diameter four and three-fourths inches, and the height four and one-half inches. The upper part isin the form of a cylinder three and one-half inches high and four and three-fourths inches in diameter. This form permits easy removal of the loaf from the pan. The cover has the general shape of an ordinary can cover and fits somewhat loosely. In the cover are four circular holes one inch in diameter to allow free escape of steam and secure for the top of the loaf the same heat as the sides. The cover, by means of a brace above, supports a plunger in a vertical position. The lower end of the plunger carries a slightly concave disk four inches in diameter. The lower position of this disk extends a little below the clindrical part of the pan. When the dough rises beyond a certain point it touches this disk and the further rise can be measured on the plunger. It has been found that with this size pan and the method used the dough is ready for the oven when the top of the plunger has risen two centimeters. The subsequent rise of the dough in the oven is also measured on this plunger. This device makes possible an accurate study of the effects of different amounts of rising before baking, particularly in regard to texture. The measurements are made with a pair of dividers and a millimeter scale. (See Plate II.)

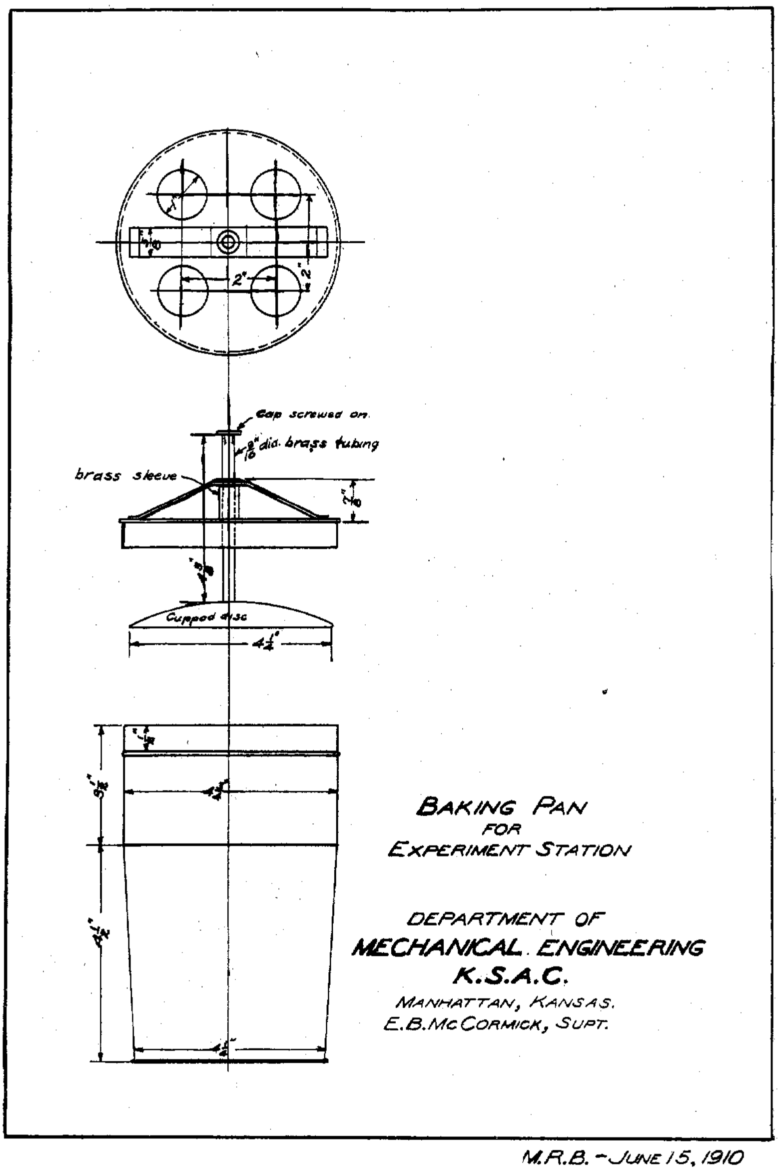
Cap screwed on.
dia. brass tubing
brass sleeve
Cupped disc
BAKING PAN
FOR
EXPERIMENT STATION
DEPARTMENT OF
MECHANICAL ENGINEERING
K.S.A.C.
MANHATTAN, KANSAS.
E.B.McCORMICK, SUPT.
M.R.B. - JUNE 15, 1910

PLATE II.

Cylinders for Proving the Dough.

The cylinders in which the dough rises are thirty-five centimeters (fourteen inches) high, and have a capacity of one hundred cubic centimeters for each centimeter in height. On one side of this cylinder, extending from near the bottom to the top, is a glass strip about an inch wide graduated to half centimeters. By means of this the behavior of the dough inside the cylinder can be observed, and the volume read to within fifty cubic centimeters. The height of the dough is read with reference to the top of the curvature. The advantage of these cylinders over the battery jars, sometimes used for this purpose, is that the volume of the dough can be observed more accurately. These cylinders were made to order by a local tinner.

Kneader.

The dough kneader is of the Koelner type. It is connected with a one-fourth horsepower motor controlled by a speed regulator. This working of the dough closely imitates the human hand working the dough on a bread board. The mixing and working is very thorough, but it does not, however, give the effect of the pulling action secured by some machines. The temperature is controlled by means of a water compart-, ment, against one wall of which the dough is worked. By means of the speed regulator both beating and working effects can be secured as desired.

Loaf Volume Apparatus.

The apparatus for measuring loaf volumes consists of four pieces: a cylindrical tin can with a capacity somewhat larger than the loaf, a tin funnel of the same capacity, a support for the funnel, and a device for measuring the excess of flaxseed, which is used to fill the space in the tin can not occupied by the loaf. The funnel is made without a stem, but has a shutter to control the rate of flow of seed. The device for measuring the excess of flaxseed is so constructed that the loaf volume is read direct. The difference in volume of the tin can and that occupied by the largest probable loaf is equal to the enlarged lower portion of the device, which has the shape of an inverted funnel. One side of the portion above this is made of glass, which is graduated, the smallest division being equivalent to ten cubic centimeters volume. The lowest placed mark is 1900, and the numbers decrease upward because the smaller the loaf the greater the excess of flaxseed. The upper mark is 1100. Should a loaf measure more than 1900 cubic centimeters or less than 1100, aliquot portions of 100 cubic centimeters of flaxseed can be added or removed. This set of volume-measuring apparatus is adapted from a similar one used at the Fargo, N. D. baking laboratory. (See plate III.)

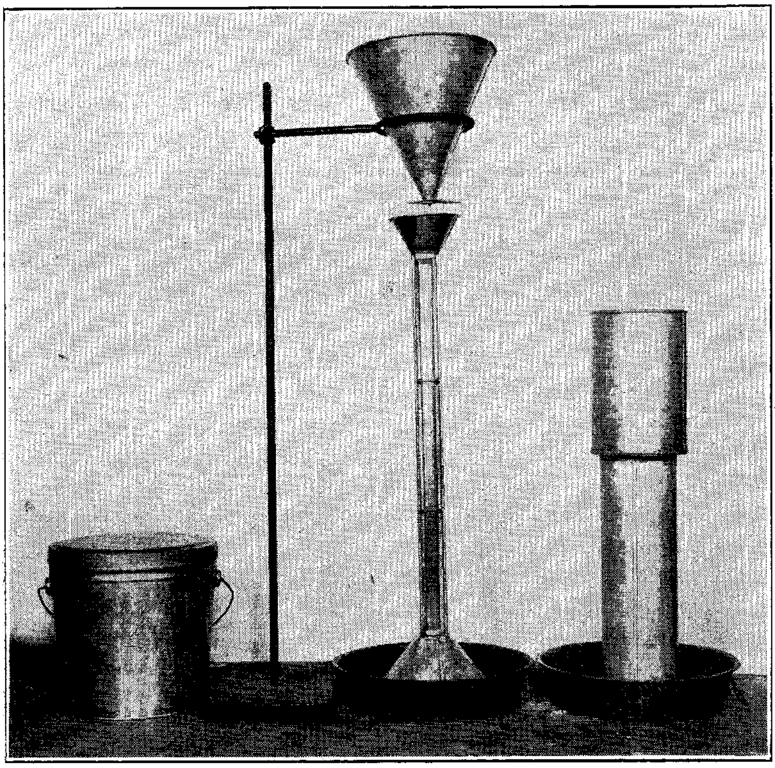

PLATE III.

Apparatus for Making Absorption Tests.

The apparatus used in determining the water-absorbing power of flour consists of strong porcelain cups, a steel spatula, and a burette with supports. (See plate IV.)

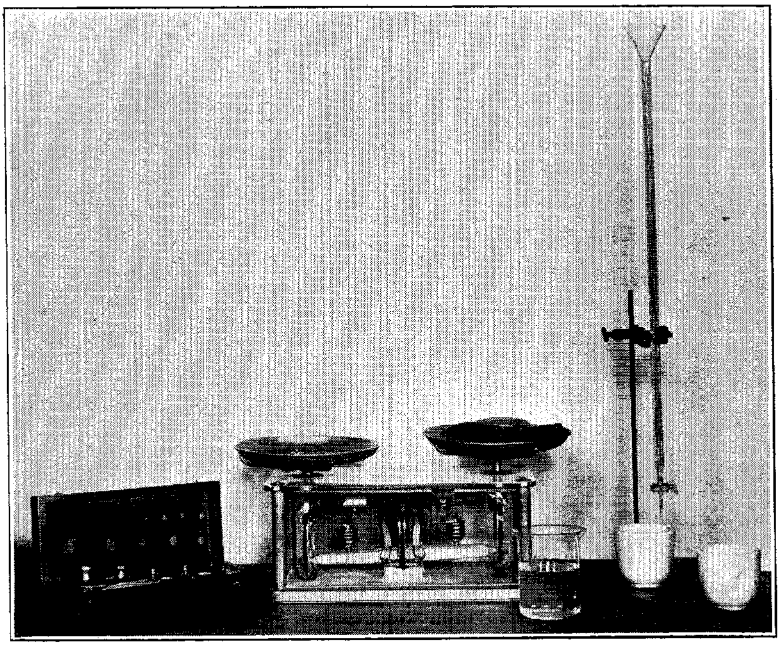

PLATE IV.

METHODS USED IN MAKING THE BAKING TESTS.

It should be remembered in connection with all baking tests, that all of the conditions are not under the operator's control, and further, that a skilled operator can often tell, from the way the dough handles, many things in regard to the test which he can not put down in figures. However, in making a series of tests the influence of the uncontrolled factors must be reduced to a minimum. This is done by scrupulous attention to details and baking check loaves from a flour the quality of which is known. It is also desirable to eliminate the personal equation to such an extent that it shall not influence the comparative scientific accuracy of the work. This can be done in part by obtaining as many measured factors as possible. The number of readings and measurements taken in baking seven loaves can be seen from the accompanying blanks. Further, if in making a baking test, a loaf can be secured which conforms to standards generally accepted for good bread, the result is more desirable than to so conduct it that the loaf secured is subject to criticism because of failure to conform to such standards.

BLANK USED IN RECORDING RESULTS.

Kansas State Agricultural College Experiment Station.

BAKING TESTS.

DATE..

EXPERIMENT..

	Standard.	No.	No.	No.	No.	No.	No.
Per cent moisture............	....	....	....	....	....	....	....
Water absorbed by 30 grams..	....	....	....	....	....	....	....
Percentage of absorption......	....	....	....	....	....	....	....
Flour, ... grams.......	....	....	....	....	....	....	....
Water, ... grams.......	....	....	....	....	....	....	....
Sugar, ... grams.......	....	....	....	....	....	....	....
Salt, ... grams.......	....	....	....	....	....	....	....
Yeast, ... grams.......	....	....	....	....	....	....	....
Shortening, ... grams...	....	....	....	....	....	....	....
Total materials	....	....	....	....	....	....	....
Mixed	....	....	....	....	....	....	....
Turned first	....	....	....	....	....	....	....
Volume when turned.....	....	....	....	....	....	....	....
Turned second...........	....	....	....	....	....	....	....
Volume when turned.....	....	....	....	....	....	....	....
Panned	....	....	....	....	....	....	....
Dough and pan, ... grams...	....	....	....	....	....	....	....
Pan, ... grams.........	....	....	....	....	....	....	....
Dough, ... grams.......	....	....	....	....	....	....	....
Loss of materials, ... g'ms,	....	....	....	....	....	....	....
Temperature for proving......	....	....	....	....	....	....	....
Rise in pan............	....	....	....	....	....	....	....
Put in oven............	....	....	....	....	....	....	....
Taken from oven........	....	....	....	....	....	....	....
Rise in oven............	....	....	....	....	....	....	....
Temperature of oven.....	....	....	....	....	....	....	....
Weight of loaf...............	....	....	....	....	....	....	....
Loss in baking and cooling,	....	....	....	....	....	....	....
Volume of loaf, ... cc...	....	....	....	....	....	....	....
Color of crumb..........	....	....	....	....	....	....	....
Texture of crumb........	....	....	....	....	....	....	....
Condition of crust.......	....	....	....	....	....	....	....

Yeast.

Yeast is one of the most important factors in making a baking test and one which is very difficult to control. In actual baking practice, especially in home baking, yeast causes trouble as often as any other factor unless it be temperature. The compressed yeast used in these tests was of the Fleischmann brand and bought from a local baker. As soon as the yeast was received it was stored in a dry refrigerator, being kept in the laboratory only long enough to weigh out the amount needed for the day. Yeast exposed to moist air will not keep well even if it is cool. To avoid exposure to moisture the yeast was wrapped in heavy filter paper and placed in a sealed Mason jar. The amount needed for the day was cut into small pieces, the size of rice grains, thoroughly mixed, and from this ten-gram portions weighed out. These portions were placed in small covered beakers, and set aside in a cool place until needed. This method was preferred over that of making a yeast liquor as is sometimes done in bread testing. The advantage of the method chosen is that it gives each yeast portion exactly the same chance. It has been found by experience that yeast which has stood four or five days after being received from the dealer is not satisfactory for making baking tests, although it may be satisfactory for ordinary bread making. For a baking test it acts too slowly.

Absorption Test.

The purpose of an absorption test is to determine the amount of water necessary to make a dough of standard stiffness from a given flour. In making this test several thirty-gram portions are weighed out and placed in strong porcelain cups. The probable amount of water needed to make a dough of standard stiffness is added from a burette. This amount can, to a large extent, be determined from the kind of flour, its age, and season of the year. Flour from new wheat will take less water than flour from old wheat. Flour from soft wheat will take less water than flour from hard wheat. Flour with a high moisture content will take less water than flour with a low moisture content. When baking tests are in continuous progress it is comparatively easy to determine about how much water to add. When the probable amount of water has been added to the flour it is all worked in with a spatula, care being taken that nothing is lost or left sticking to the sides of the cup. As soon as the dough permits handling with the hands it is worked to a homogeneous, even texture. The standard stiffness is decided upon by the operator, and in this he must be guided largely by experience. The way the dough handles in the machine, as well as subsequent operations, together with the texture of the resultant bread, will tell whether the proper standard has been adopted. When the water needed for thirty grams of flour has been determined, the amount needed for the flour used in the baking test is calculated by simple proportion.

Flour.

The flour for each loaf is weighed out in shallow pans and placed in the sponge case. These pans are made of heavy tin, two inches deep, four inches wide and ten inches long, and fitted with a loose cover. For shortening, five grams of lard are weighed out and placed in the flour. To eliminate the influence of the difference in moisture content of the various flours, the same amount of dry matter was used for each loaf. The Standard chosen was 297½ grams of dry matter, or 340 grams of flour containing 12.5 per cent of moisture. Accordingly, the higher the moisture content of the flour, the larger the amount of the flour weighed out for the test. To facilitate work, table I was computed, showing the amount of flour to to be used for each of the different moisture percentages.

TABLE I.—*Amount of flour used for each loaf, based on the percentage of moisture in the flour.*

Moisture, per cent.	Amount of flour to use.	Moisture, per cent.	Amount of flour to use.
10.0	330.5	12.6	340.4
10.2	331.3	12.8	341.2
10.4	332.0	13.0	341.9
10.6	332.8	13.2	342.7
10.8	333.5	13.4	343.5
11.0	334.2	13.6	344.3
11.2	334.9	13.8	345.1
11.4	335.7	14.0	345.9
11.6	336.5	14.2	346.7
11.8	337.3	14.4	347.5
12.0	338.0	14.6	348.3
12.2	338.8	14.8	349.1
12.4	339.6	15.0	350.0

Baking Formula.

Flour, 340 grams, more or less, according to moisture content.

Water, as determined by the absorption test.

Sugar, 15 grams.

Yeast, 10 grams.

Salt, 5 grams.

Shortening, 5 grams.

Preliminary Fermentation.

The sugar and salt are weighed out and the requisite amount of water measured into as many beakers as there are tests to be made. Thirty minutes before the doughing commences this solution is heated to 35°C. (95° F.) and the yeast added. The yeast is thoroughly mixed with the solution and placed in the sponge case, where it is allowed to ferment thirty minutes. One of these preliminary fermentations is started every ten minutes. In this way a continuous process is kept up. This preliminary fermentation shortens the time of making the test, and besides gives a good indication in regard to the strength and behavior of the yeast.

Making the Dough.

About one-half of the warmed flour, together with the lard, is placed in the kneader and the fermented yeast liquor added. The machine is started and allowed to work at a high speed just five minutes. This amounts to a very thorough beating of the batter. The machine is then stopped and the rest of the flour added, and again it is allowed to work for five minutes at a low speed. This gives the dough a very thorough working and molds it into a ball. As the dough stiffens all of the flour is worked into it by means of a flexible steel spatula, stopping only long enough to work the very last portion into the dough. A small amount of dough will adhere to the mixer and thus be lost, but the amount seldom exceeds two grams and is accounted for in subsequent weighing.

Proving the Dough.

While the machine is yet in motion the dough is removed with a deft motion of the hand. This can be done very readily if the dough has the proper consistency, and it is more easily removed while the machine is in motion. The behavior of the dough during the last stages of kneading will tell much in regard to its proper stiffness. Whether it is too hard or too soft can readily be observed by the way in which it works in the machine. The dough is worked into a ball, placed in the cylinder, previously described, pressed down firmly, and set in the sponge closet, the time being recorded. The first rising is allowed to proceed until the dough has trebled in volume. It has been found by experience that this is when the top of the dough is 16½ centimeters high, corresponding to very nearly 1650 cubic centimeters volume. When this point has been reached, the dough is removed from the cylinder, worked lightly for one minute, then returned to the cylinder, pressed down gently, and the time recorded. The dough is now allowed to rise as much as it will, or shows signs of falling. This point is one of the most difficult to determine and requires persistent care. The total height is now read in the same manner as before, and the time noted. This last reading gives the maximum volume of the dough, and these figures correspond very closely to the figures obtained for loaf volume by a number of operators, notably the bread-testing laboratories of the Northwest. The dough is now removed from the cylinder, worked lightly for one minute, and placed in the greased baking pan and punched a number of times with a long pin to puncture any large gas bubbles which may not have been kneaded out. This last working is just sufficient to remove the larger gas bubbles from the dough and no more. The manipulation of the dough at this point is very important as affecting texture. Too much working will give a heavy, close texture, and too light working will result in too many large holes. The dough in the pan is weighed and set in the sponge case to rise, the time being noted. This rising is allowed to continue until the dough has reached a definite volume, which is indicated by the height to which the plunger has risen. This optimum height has been found by experience to be two centimeters. This point has to be watched very carefully as more or less rising at this time affects very materially the texture and the volume of the loaf.

Baking.

The loaves are baked for just forty minutes at 220° C. (438° F.). At the end of this time the loaf is taken from the oven, the height of the rise of the plunger is measured, and the loaf is removed from the pan. The hot loaf is placed on a wire screen and allowed to cool for just thirty minutes, when it is weighed and the volume taken.

Taking the Volume.

The volume is taken by means of the apparatus described above. The loaf is placed in the cylindrical tin can and the flaxseed allowed to flow from the funnel so as to fill loosely all empty spaces. The flaxseed is always allowed to fall through the same distance, and the top is leveled off in such a way that the seed is not packed. The seed is removed from the can and placed in the funnel, from which it is allowed to run into. the special measuring device and the volume read direct.

Judging the Bread.

In all cases this bread was judged by two or more persons. It was scored for color and texture on a basis of 100 for pef-fection.

Check Loaves.

In all tests a check loaf is also baked each day from a se-dected lot of flour which is used through a series of tests. This indicates any unusual conditions. If such are found to be present the test is repeated. All these flours were tested twice; first, all were tested in succession and then the whole series were repeated. This made the two tests come several weeks apart and under slightly different conditions. In all the tables that follow the figures are from the average of these two tests.

Part II.

Work on Commercial Flours and Wheats.

TABLE IIA.

Description of flour samples as given by the manufacturer.

Serial No.

272 High-patent flour, 80 per cent; not bleached; sold mostly to family trade.

273 Straight flour, 97 per cent; not bleached; yield, 4 bus., 24 lbs.

275 Highest patent, 80 per cent; not bleached; sold mostly to family trade; some sold to bakers' trade.

276 High patent, 95 per cent; not bleached; sold to bakers' trade; yield, 4 bus., 30 lbs.

278 Patent flour, 65 per cent; not bleached; sold mostly to family trade.

279 Patent flour, 90 per cent; not bleached; sold to bakers' trade; yield, 4 bus., 28 lbs., to 4 bus., 30 lbs.

281 Patent flour, 85 per cent; bleached; sold to family trade; yield of total flour, 4 bus., 26 lbs.

283 Straight flour, 99 per cent; bleached; sold to both family and bakers' trade; yield, 4 bus., 30 lbs.

285 Patent flour, 83 per cent; not bleached; contains no break flour; sold mostly for family use; yield of total flour, **4** bus., **30** lbs.

287 Patent flour, 65 per cent; lightly bleached; sold both to family and bakers' trade; yield 4 bus., 30 lbs.

289 Patent flour, 65 to 70 per cent; not bleached; sold to family trade.

290 Straight flour, 95 per cent; not bleached; sold to bakers' trade; also family trade in Pennsylvania; yield, 4 bus., 30 lbs.

292 Patent flour, 77½ per cent; not bleached; sold to family trade; yield of total flour, 4 bus., 27½ lbs.

294 Patent flour, 65 per cent; not bleached; sold to family trade; yield of total flour, 4 bus., 35 lbs.

296 Patent flour, 70 per cent; not bleached; sold to family trade; yield of total flour, 4 bus., 40 lbs.

298 Patent flour, 65 per cent; bleached; sold to family trade; yield of total flour, 4 bus., 20 lbs., to 4 bus., 24 lbs.

300 Patent flour, 70 per cent; not bleached; sold to family trade.

301 Straight'flour, 95 per cent; not bleached; sold to family trade; yield of total flour, 4 bus., 30 lbs.

303 Patent flour, 75 per cent; moderately bleached; sold to family trade.

304 Straight flour, 95 per cent; moderately bleached; sold to family trade; yield of total flour, 4 bus., 40 lbs.

306 Patent flour, 87 per cent; not bleached; sold to family trade; yield of total flour, 4 bus., 30 lbs.

308 Straight flour, 95 per cent; not bleached; sold to bakers' trade; yield of total flour, 4 bus., 20 lbs.
310 Patent flour, 80 per cent; not bleached.
311 Straight flour, 96 per cent; not bleached; yield of total flour, 4 bus., 30 Ibs.
313 Patent flour, 85 per cent; not bleached; sold to family trade; yield. of total flour, 4 bus,, 30 lbs.
314 Patent flour, 70 per cent; not bleached; sold to family trade.
316 Patent flour, 95 per cent; not bleached; sold to bakers' trade.
318 Patent flour, not bleached; sold to family trade.
319 Straight flour, not bleached; sold to bakers' trade; yield of totaI flour, 4 bus., 40 lbs.
321 Patent flour, 70 per cent; bleached; sold to family trade.
322 Straight flour, 95 per cent; bleached; sold to family trade; yield of total flour, 4 bus., 30 lbs.
324 Patent flour, 80 per cent; not bleached; sold both to family and bakers' trade; yield of total flour, 4 bus., 30 lbs.
326 Patent flour, 84 per cent; not bleached; sold to bakers and macaroni manufacturers; yield of total flour, 4 bus., 26 lbs.
328 Patent flour, 90 per cent; bleached; sold to family trade.

CLASSES OF FLOUR.

The flours used in these tests were divided into three classes based on their percentages. Class 1 includes all whose percentages are below 75; class 2, all those whose percentages are from 75 to 85, inclusive, and class 3 all those whose percentages. are more than 85. The flours of the first two classes are all patents, while in class 3 some are called patents and some straights. Strictly speaking, all in class 3 should be called straight, Such loose use of the term patent shows that it. has very little real significance. While it is true that a 95 per cent from one mill may be better than a 95 per cent from another, there ought to be a closer adherence to some standard. In tables IIA and IIB is found the description and classification of these flours.

TABLE IIB.—Classes of flours.

Class I—Below 75 per cent.			Class II—75 to 85 per cent.			Class III—Above 85 per cent.		
Serial number.	Percentage flour.	Trade designation.	Serial number.	Percentage flour.	Trade designation.	Serial number.	Percentage flour.	Trade designation.
278	65	Patent.	272	80	Patent.	273	97½	Straight.
287	65	Patent.	275	80	Patent.	276	95	Patent.
289	65 to 70	Patent.	281	85	Patent.	279	90	Patent.
294	65	Patent.	285	83	Patent.	283	99	Straight.
296	70	Patent.	292	77½	Patent.	290	95	Straight.
298	65	Patent.	303	75	Patent.	301	95	Straight.
300	70	Patent.	310	80	Patent.	304	95	Straight.
315	70	Patent.	313	85	Patent.	306	87	Patent.
321	70	Patent.	318	Not known	Patent.	308	95	Straight.
....	....	....	324	80	Patent.	311	96	Straight.
....	....	....	325	84	Patent.	316	95	Patent.
....	....	....	....	....	....	319	Not known	Straight.
....	....	....	....	....	....	322	95	Straight.
....	....	....	....	....	....	326	97	Patent.
....	....	....	....	....	....	328	90	Patent.

TABLE III.—Baking tests, short patent flours.

Serial No.	Percentage grade.	Percentage moisture.	Percentage absorption.	Flour for loaf, grams.	Water for loaf, cc.	Time for proving, minutes. First rise.	Second rise.	Third rise.	Total.	Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams.	Loss in baking and cooling, grams.	Weight of loaf, grams.	Pounds of bread per barrel of flour.	Volume of loaf, cc.	Texture of crumb. 100=Perfection.	Color of loaf. 100=Perfection.
278	65	12.27	53.3	339	181	69	88	27	184	2,575	4.5	8	40	506	293	1,778	96	97
287	65	11.42	53.6	336	180	79	85	28	192	2,625	3.9	4	41	507	296	1,755	92	96
289	65–70	12.06	53.3	338	180	79	83	31	193	2,525	5.3	9	40	506	294	1,875	96	97
294	65	12.63	53.3	341	182	73	104	31	208	2,525	3.9	8	40	509	293	1,745	95	98
296	70	12.55	54.0	340	184	74	91	28	198	2,650	4.7	14	44	503	290	1,830	96	98
298	65	11.67	55.3	337	186	63	88	27	178	2,675	5.2	9	43	507	295	1,880	95	98
300	70	12.51	55.0	340	187	77	95	30	201	2,575	3.9	10	40	513	296	1,735	96	96
315	70	12.75	55.0	341	188	64	79	29	172	2,700	5.4	26	35	504	289	1,905	96	97
321	70	12.22	55.6	339	189	102	106	33	251	2,550	4.5	9	48	505	292	1,790	94	97
Average,	....	12.23	54.3	339	184	76	91	29	197	2,600	4.6	11	41	507	293	1,810	95	97

TABLE IV.—Baking tests, long patent flours.

Serial No.	Percentage grade	Percentage moisture	Percentage absorption	Flour for loaf, grams	Water for loaf, cc.	Time for proving, minutes. First rise.	Second rise.	Third rise.	Total.	Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Pounds of bread per barrel of flour	Volume of loaf, cc.	Texture of crumb, 100 = perfection	Color of loaf, 100 = perfection
272	80	12.76	53.3	341	182	76	93	25	194	2,675	5.3	8	42	509	293	1,848	95	98
275	80	12.16	54 7	339	185	71	90	22	183	2,600	5.0	8	42	510	295	1,850	95	97
281	85	12.05	54.3	338	184	84	94	28	206	2,525	4.1	5	45	508	295	1,770	95	98
285	83	12.07	54.0	338	183	78	88	23	189	2,575	5.6	10	41	506	293	1,870	95	97
292	77½	12.95	53.3	342	182	78	90	31	199	2,700	5.3	10	44	506	290	1,908	97	98
303	75	13.16	54.0	343	185	77	89	28	194	2,575	5.2	14	39	510	292	1,920	96	98
310	80	12.40	54.6	340	186	67	97	31	195	2,650	4.8	11	44	505	291	1,850	95	97
313	85	12.56	55.0	340	187	59	86	24	169	2,550	3.3	11	40	512	295	1,680	92	93
318	....	12.09	54.6	338	185	133	111	35	279	2,375	5.0	11	49			1,915	95	07
324	80	13.42	55.0	344	189	73	103	26	202	2,650	4.9	13	43	499	296	1,860	95	07
325	84	13.72	55.0	345	190	82	91	28	201	2,600	5.4	11	42	517	294	1,925	94	95
Average,	....	12.67	54.3	341	185	80	94	27	201	2,589	4.9	10	43	509	293	1,854	95	97

TABLE V.—Baking test, straight flours.

Serial No.	Percentage grade.	Percentage moisture	Percentage absorption.	Flour for loaf, grams.	Water for loaf, cc.	Time for proving, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams.	Loss in baking and cooling, grams.	Weight of loaf, grams.	Pounds of bread per barrel of flour.	Volume of loaf, cc.	Texture of crumb, 100 = Perfection.	Color of loaf, 100 = Perfection.
						First rise.	Second rise.	Third rise.	Total.									
273	97½	12.56	55.0	340	187	72	92	23	187	2,475	5.8	10	42	511	295	1,868	94	95
276	95	12.71	55.0	341	188	68	91	23	182	2,650	4.5	14	44	506	291	1,760	94	95
279	90	13.06	55.0	342	188	80	99	25	204	2,625	4.6	10	44	513	294	1,790	95	98
283	99	12.93	55.0	342	188	78	88	24	190	2,650	4.3	15	47	504	289	1,700	93	95
290	95	11.80	55.0	337	186	75	93	30	198	2,675	5.0	13	42	504	293	1,888	97	98
301	95	12.22	56.6	339	192	69	93	29	191	2,550	4.0	12	44	512	296	1,798	96	96
304	95	13.50	53.3	344	183	72	89	27	188	2,500	4.4	12	41	510	291	1,815	95	96
306	87	13.31	55.0	343	189	66	97	24	187	2,650	4.8	16	45	507	290	1,845	93	96
308	95	13.29	53.3	343	183	71	95	31	197	2,350	4.4	11	43	508	290	1,780	94	96
311	96	12.30	54.6	339	185	65	97	26	188	2,475	5.4	13	44	504	291	1,885	96	97
316	95	12.83	55.0	341	188	135	112	38	285	2,325	4.2	10	55	500	288	1,780	96	96
319	....	12.12	54.6	338	185	133	104	35	272	2,225	4.4	14	45	500	290	1,810	91	96
322	95	12.26	55.3	339	188	111	103	35	249	2,425	3.8	14	42	506	293	1,775	93	96
326	97	13.59	54.6	344	188	72	97	25	194	2,525	5.2	15	46	508	289	1,860	94	94
328	90	14.11	54.3	346	188	69	94	25	188	2,600	4.5	17	44	510	289	1,800	97	97
Average,	....	12.84	54.8	341	187	82	96	28	207	2,513	4.6	13	45	507	291	1,810	95	96

BAKING TESTS ON COMMERCIAL FLOURS.

Tables III, IV and V give the results of the baking tests on these classes of flour. Table III gives the results from class 1, table IV from class 2, and table V from class 3. For convenience in discussion, those in class 1 will be called short patents, those in class 2 long patents, and those in class 3 straights. The serial number refers to the number given to the flour in the description of flour samples.

As a rule, the patent flours are sold to family trade and straights to the bakers. The column for percentages refers to the per cent of total flour represented by the sample. Thus a 65 per cent patent means that 65 per cent of the total flour made is separated as patent flour. In this grade only the best and purest is used, while from 1 to 5 per cent of the poorest quality is separated as low grade. The remainder, which is of medium quality, constitutes what is known as "clear." The quality of the clear flour, often designated as "first clear" and "second clear," depends upon the percentage of high-grade flour separated out as patent and the percentage of poor quality separated as low grade. It is also frequently referred to as bakers grade. Most of the flour sold to family trade is known as patent. Bakers use some clears and low grades for certain purposes, but the greater portion of bakers' bread is made from patents or straights.

In many cases the low-grade flour, when it amounts to only a few per cent, is put into the shorts. Whether this low grade is added to the shorts or sold as flour depends upon the mill equipment, and the demand for shorts. A 95 per cent straight would include all the flour except 5 per cent of low grade. With a good milling system a straight flour is as good for ordinary bread baking as many patents, the only difference being the color. Patents are, as a rule, preferred by the family trade, as they are better adapted to the various requirements. They are better for pastry work than the straight flours, as they produce a smoother, softer, more pliable dough, which qualities are much prized by the housewife.

Moisture Content.

The moisture percentage refers to the amount of hygroscopic water present in the flour. The method of determining this moisture will be described under "Chemical Composition." All substances in contact with the air contain moisture, the amount depending upon the nature of the substance and the temperature and humidity of the air. Sugar, as compared with flour, takes up very little atmospheric moisture. Each substance seems to have a definite percentage of moisture with reference to humidity. If the amount present is below this definite percentage, moisture is taken from the air, and if above, moisture is lost. Thus under certain conditions flour will lose moisture and under other conditions it will gain. Flour piled up around the stoves in the country grocery stores will lose moisture, while if stored in damp places it will gain. Although a sack may have full weight when it leaves the mill, this is no assurance that such will be the case several months later if stored in a warm, dry place. Dampness is always a danger. The best storage place for flour is a cool, well ventilated place. Here the flour will maintain its weight unless it contains a high percentage of moisture or the weather conditions are unusually dry.

The moisture content of the short patent flours varies from 11.42 per cent to 12.75 per cent, or a difference of 1.33 per cent between the highest and the lowest. These two flours came from mills located about fifty miles apart in central Kansas. In this case the difference in moisture was not due to climatic conditions, but to the moisture content of the wheat, modified more or less by tempering. As both of these mills are located on main east-and-west lines, they would get wheat from sections differing widely in climatic conditions.

The moisture content of the long patents varies from 12.05 per cent to 13.72 per cent, or an extreme variation of 1.67 per cent. Here location of the mills seems to have its influence; the flour with the lower moisture content comes from a mill in central Kansas, while that of a higher comes from a mill near the Missouri river in northeastern Kansas. The source of the wheat and the method of tempering would in both cases be the factors of greatest moment.

The moisture content of the straight flours varies from 11.80 per cent to 14.11 per cent, or a difference of 2.31 per cent. Both of these flours came from mills in north central Kansas. Both would get their wheat from different parts of Nebraska or Kansas.

The variation is greater in the long than in the short patents, and greatest of all in the straights. The average moisture content is lowest in short patents, intermediate in the long patents, and greatest in the straights.

Percentage of Absorption.

The method of getting the figures for absorption was described under the method of malting baking tests. These percentages vary from 53.3 to 55.6, a rather small variation considering the variation in moisture content and the different quality of these flours. The absorptive power of a flour depends on several factors, among which are kind of wheat from which the flour is made, amount and quality of gluten, mill streams from which it comes, and moisture content. From our present knowledge of flour it is difficult to determine which one of these is most dominant. Also, in determining the percentage of absorption we are dependent upon the judgment of the individual operator. In this respect the determination differs fundamentally from the moisture determination which, under proper conditions, is well nigh absolute in its correctness. Under most conditions, however, the absorption test can be made of very accurate comparative value. Thus if a miller were making absorption tests every day on his different flours, he could tell very accurately how they would differ from day to day in absorptive power. The practice of the miller of simply making a dough ball without any regard to the relative amounts of water or flour used tells him something in regard to the quality of the dough formed, but the information would be of immensely greater value if the quantities were accurately measured, and this could be done with very little expense. The extent of apparatus needed can be seen from the description of the absorption test given previously.

It is hoped that some day we may develop a method by which we can eliminate the personal equation, and measure the absorption by the force with which the flour holds water. To illustrate: The maximum amount of water might be added to the flour and the surplus removed by centrifugal force. This, however, belongs to the realm of speculation.

Amount of Flour Used for the Loaf.

The weight of flour used for a loaf is determined from the moisture content of the flour on the basis that the flour for each loaf shall contain 297½ grams of dry matter. The amount will vary with the moisture content as shown previously.

Amount of Water for Each Loaf.

The water required is determined by the absorption test. Thus if in making the absorption test it was found that thirty grams of the flour would require 16.5 cubic centimeters of water, the amount needed for the flour used for the loaf was calculated in this way:

$$30 : 16.5 : : 340 : x = 187 \text{ cc.}$$

Considering the different qualities of these flours, there is a remarkable uniformity in the amount of water used for each loaf. The smallest amount of water used for any loaf is 180 cubic centimeters and the highest amount is 190 cubic centimeters. There is very little difference among the classes of flours, and what difference exists is in favor of the longer patents and the straights.

Time for Proving.

The time required for proving would be a valuable indication in regard to qualities in flour if it were possible to have the conditions absolutely uniform, particularly in regard to yeast. As it is, the yeast influences the time of proving more than any other factor. However, even under present circumstances the average time for the first two rises and the total time is less for the short patent flours than for the long patents and less for the long patents than for the straights. The dough from the short patent ripens sooner. This is one of the qualities in the short patents which make these flours more valuable for family baking where the same flour is used for various purposes, such as cakes and pastries aside from bread making. The gluten is of a softer, more pliable nature and lends itself more readily to different conditions. The dough from a short patent is always softer, and has a smoother, more even feel than the dough from a straight flour. Hence it is easier to work and is much preferred by the housewife.

Maximum Expansion of Dough.

'The total volume to which the dough expands on the second rising is its maximum expansion. That the second rising will give a larger expansion than the first has been shown by experiments reported in bulletin No. 177. The difference amounts to from one hundred to two hundred cubic centimeters. The third maximum rise would differ but little from the second. For this reason the second rise has been chosen as indicating the volume to which the dough rises when allowed to expand to the maximum capacity. This volume can be read to fifty cubic centimeters. These figures correspond quite closely to the figures obtained for the loaf volume by the bread-testing laboratories following the methods which have been developed in connection with the Minneapolis flour mills. In these methods the dough is allowed to expand to nearly its maximum capacity, then it is placed in the oven where, with a good quality of gluten, the loaf expands still further. In the method followed here the expansion is due to the yeast and the quality of the gluten. But for the lack of yeast uniformity it would be a very valuable factor, and even under present circumstances it is one of the most valuable indications of the quality of the gluten. Methods are being worked out by which, through a series of check bakings, this can be overcome in such a way as to reduce the tests of a series to a uniform basis. The short patents and the long patents have a much larger total expansion than the straights, and the difference between the two patents is in favor of the short. It is true that such a difference would not mean much on an individual test for one set of loaves, but these are the averages of a very large number of bakings, and further, this larger expansion takes place in a shorter average time. This quality of the gluten of expanding more easily into a larger volume is another reason for the family preference for the patent flours.

Rise in the Oven.

The rise in the oven is a measure of the expansion of the loaf after it is set in the oven to bake. It is due to several factors. The increased heat causes for a few minutes a rapid yeast activity accompanied by an increase in the formation of gas. As the heat increases the yeast activity soon ceases, but rising temperature causes expansion of the carbon dioxide, which in turn does its share in expanding the loaf. The high heat causes a rapid development of steam and this also adds to loaf expansion. In the writer's opinion this is the most powerful factor. The amount of expansion due to these causes will be determined in part by the quality of the gluten. If this is soft and yielding and at the same time has the power to retain gas, the expansion will be greater than if the gluten is more resistant. Fermentation has a softening effect on the gluten. If a loaf from a strong flour is allowed to rise but once and is then baked, it will have a much less volume than if the dough is allowed to rise several times and then worked down before it is baked. Conditions which affect the gluten, such as incipient germination, will make larger oven expansion than similar wheat more sound. Weathered wheat will sometimes produce a flour which gives larger oven expansion than wheat not weathered. On the other hand, if the gluten has such weakness that it is not able to retain the gas bubbles, there will be a smaller oven expansion. This happens when incipient germination or other unfavorable conditions have proceeded too far. Large loaf volume by itself is not an indication of an especially good flour. Together with large oven expansion and consequent large loaf volume go other qualities, such as large absorptive power, easy, smooth working of the dough and good texture. The rise in oven is referred to again under the head of Loaf Volume.

Loss in Mixing and Rising.

The difference between the weight of total materials put into the loaf, and the weight of the dough before it goes into the oven, is the loss in mixing and rising. In the kneader, as well as subsequently, large portions of the dough are exposed to the air, and come in contact with a great deal of surface in the kneader and the expansion cans. This gives an abundant chance for loss of moisture. In fact, only a small amount of the loss is flour or other solids. The loss varies all the way from five to twenty-six grams, with an average for all of eleven grams. With larger amounts there is, of course, more flour lost than in smaller amounts.

Loss in Baking and Cooling.

The loss in baking and cooling is the difference between the weight of the dough as it goes into the oven and the weight of the baked loaf when it has cooled thirty minutes. This, of course, is all water. This loss varies from thirty-five to fifty-five grams, or the same extreme variation as in mixing and rising. Whether or not the loaf should cool more than thirty minutes is an open question, with the probabilities in favor of the longer time. The greatest loss occurs the first few minutes after the loaf leaves the oven, and as the loaf cools the loss grows less and less. If the loaf is exposed to the free air the loss will continue until the bread has acquired a moisture equilibrium, when it is considered too dry. Such bread, however, is often used in some countries, and this is the condition of the ordinary cracker. Such bread will lose or take up moisture according to the condition of the air.

Weight of Loaf.

The weight of the loaf is taken thirty minutes after it has been removed from the oven. Considering the varying nature of these flours, the uniformity of these averages is remarkable, especially when one considers the variation in the losses in rising, baking and cooling. The weight varies from 499 to 517 grams. The amount of moisture in this bread from the short patent amounts to 40.4 per cent, counting both the water added and that present in the flour. The bread from the longer patents and the straights contains a slightly larger per cent, owing to the somewhat higher moisture content of the flour and the larger amount of water added.

Pounds of Bread per Barrel of Flour.

The weight of bread that may be made from a barrel of flour is calculated from the weight of the finished loaf, and the amount of flour used for the same, allowing 196 pounds of flour per barrel. Where pound loaves are made these figures stand for the number of loaves per barrel. These figures, as they stand, have very little, if any, value. The final weight of the loaf, and consequently the amount of bread per barrel of flour, is influenced more by the losses in making than by the variation in materials used. A few comparisons, shown in the following table, will make this clear:

Serial number.	Flour for loaf, grams.	Water for loaf, grams.	Loss in mixing and baking, grams.	Loss in baking and cooling, grams.	Weight of loaf, grams.	Pounds of bread per barrel of flour.
313	340	187	11	40	512	295
273	340	187	10	42	511	295
276	341	188	14	44	506	291
316	341	188	10	55	500	288

Numbers 313 and 273 have equal amounts of materials, and very nearly the same losses, with the resulting loaves of nearly equal weight and the same number of pounds of bread per barrel of flour. Numbers 276 and 316 have equal amounts of materials, but the losses are different. The larger loss results in a lighter loaf and consequently less number of pounds of bread per barrel of flour. Unless the loaves are equalized on some uniform basis the figures for the number of pounds of bread per barrel of flour do not have much value. In table VI the attempt has been made to distribute the losses in such a way that the figures shall be more comparable.

TABLE VI.—Loaf weight and pounds of bread per barrel of flour. Corrected on the basis of average loss.

Short patents. I				Long patents. II				Straight flours. III			
Serial number.....	Total loss in making, grams.........	Corrected weight of loaf, grams.....	Pounds of bread per barrel of flour...	Serial number....	Total loss in making, grams........	Corrected weight of loaf, grams.....	Pounds of bread per barrel of flour...	Serial number....	Total loss in making, grams........	Corrected weight of loaf, grams.....	Pounds of bread per barrel of flour...
278	48	502	290.2	272	50	506	290.8	273	52	505	291.1
287	45	500	291.7	275	50	507	293.1	276	58	506	290.8
289	49	503	291.7	281	50	505	292.8	279	54	509	291.7
294	48	505	290.2	285	51	504	292.3	283	62	508	291.1
296	58	509	293.4	292	54	507	290.6	290	55	501	291.3
298	52	507	294.9	303	53	510	291.4	301	56	510	294.9
300	50	511	294.6	310	55	507	292.3	304	53	505	287.7
315	61	513	294.9	313	51	510	294.0	306	61	510	291.4
321	57	510	294.9	318	60	506	293.4	308	54	504	288.0
....	....	....	....	324	56	516	294.0	311	57	503	290.8
....	....	....	....	325	53	517	293.7	316	65	507	291.4
....	....	....	....	....	....	....	....	319	59	501	290.5
....	....	....	....	....	....	....	....	322	56	504	291.4
....	....	....	....	....	....	....	....	326	61	511	291.2
....	....	....	....	....	....	....	....	328	61	513	290.6
Average.	52	507	293.1	......	53	509	292.6	......	58	507	291.4

The losses in mixing and rising have been added to those of baking and cooling and the results entered as total loss, These total losses are averaged separately for the different classes of flours, in order to have the comparisons more uniform. As the amount of dough left in the kneader is very small, no correction is made for the amount of moisture which it would lose if it were baked as was done in a former bulletin. This correction is so small that it is more than counterbalanced by other factors. The average loss for all the loaves in one class is taken as the normal loss for that class of flour. If a loaf has a greater loss than this, the difference between the actual loss and the average loss is added to the weight of the loaf and the result entered as the corrected weight of the loaf. If the actual loss is less than the average then the difference is subtracted from the weight of the loaf. From these corrected weights the pounds of bread per barrel of flour are recalculated. The results so obtained compare favorably in accuracy with the other data obtained in the baking test.

Volume of Loaf.

The loaf volume was taken by means of the apparatus previously described. The average loaf volume of the short patent flours is 1810 cubic centimeters, the smallest being 1735 cubic centimeters and the largest 1905 cubic centimeters, a difference of 170 cubic centimeters. The average loaf volume of long patent flours is 1854 cubic centimeters, the smallest being 1680 cubic centimeters and the largest 1925 cubic centimeters, a difference of 245 cubic centimeters. The average loaf volume of the straight flours is the same as that of the short patent, the lowest being 1700 cubic centimeters and the highest 1888 cubic centimeters. The long patents have the greatest variation, while the short patents and the straights show the same average volume and variation. Large loaf volume is not of itself an indication of a particularly desirable flour. Sometimes, as was mentioned under "rise in oven," a weak flour may produce a larger loaf than a strong flour. The loaf volume must be judged together with absorption, maximum volume of dough, rise in the oven, and texture. If two loaves are equal in these other factors, then the one with a larger loaf volume is the more desirable. Ability to produce a larger loaf, when accompanied by the other desirable characteristics, is one of the qualities looked for by commercial bakeries, and hence the determination of this factor is important.

That the average loaf volume is greater for the long patent flours than for the other two brings out the fact that loaf volume alone does not necessarily indicate a flour of the highest commercial grade.

Gluten Quality Factor.

The factors maximum rise of dough, rise in the oven, and the loaf volume are closely related. Under certain circumstances the loaf volume may be larger than the spring in the oven would indicate. Loaves for serial numbers 275 and 310 have the same volume, but are different in oven expansion. This is due to the fact that a stronger dough will make a loaf having a more dome-shaped top than one that is weaker or inclined to be "runny" or slack.

TABLE VII.—Gluten quality factors.

Short patent.		Long patent.		Straight grade.	
Serial number.	Gluten quality factor.	Serial number.	Gluten quality factor.	Serial number.	Gluten quality factor.
278	2,060	272	2,620	273	2,682
287	1,797	275	2,405	276	2,099
289	2,509	281	1,832	279	2,161
294	1,718	285	2,697	283	1,937
296	2,279	292	2,730	290	2,525
298	2,615	303	2,571	301	1,834
300	1,742	310	2,357	304	1,997
315	2,777	313	1,414	306	2,347
321	2.054	318	2,274	308	1,841
....	....	324	2,415	311	2,519
....	....	325	2,703	316	1,738
....	....	....	....	319	1,772
....	....	....	....	322	1,636
....	....	....	....	326	2,442
....	....	....	....	328	2,106
Average.......	2,165	....	2,352	....	2,092

If two loaves have the same volume, but one has a larger oven spring, the latter indicates a stronger, stiffer gluten, while the gluten of the former would be weaker or more "runny." In this present method of making the test the shape of the top of the loaf signifies the same characteristics in the gluten that the top of the loaf signifies where such low pans are used that the upper part of the loaf extends above the sides of the pans and so has a chance to run over the side, should there be such a tendency.

To combine the characteristics shown by the figures for the maximum rise of dough, rise in oven and loaf volume, the gluten quality factor has been calculated. This factor is simply the product of these three sets of figures, divided by ten thousand, as differences below that have no significance. The gluten quality factors for the different serial numbers are presented in table VII. The average for the long patent is greater than for the other two classes of flours. This is due to the greater average rise in the oven and loaf volume. In the calculation of this gluten quality factor one millimeter

TABLE VIII.—The gluten quality factor in relation to flour grades.

Flours from the same mill.				Only one flour from a mill.	
Higher grade.		Lower grade.		One grade.	
Serial number.	Gluten quality factor.	Serial number.	Gluten quality factor.	Serial number.	Gluten quality factor.
272	2,620	273	2,680	281	1,832
275	2,405	276	2,099	283	1,937
278	2,060	279	2,161	285	2,697
289	2,509	290	2,525	287	1,797
300	1,742	301	1,834	292	2,730
303	2,571	304	1,997	294	1,718
310	2,357	311	2,519	296	2,279
315	2,777	316	1,738	298	2,615
318	2,274	319	1,772	306	2,347
321	2,054	322	1,630	308	1,841
325	2,703	326	2,442	313	1,414
....	....	....	....	324	2,415
....	....	....	....	328	2,106
Average........	2,370	....	2,127	....	2,133

difference in the oven rise has as much effect as one hundred cubic centimeters, either in the maximum volume of the dough or the loaf volume. This rise in the oven can be measured to one-half millimeter so the measurements as given are accurate. In the way the figures are used in the calculation, the form of the top of the loaf has a pronounced effect on the gluten quality factor.

One aim in developing this method of making baking tests has been to obtain a large number of measured factors, and thus to eliminate the personal equation as much as possible. But too large a number of factors is bewildering, and the only excuse for calculating this gluten quality factor is to simplify results. It is very probable that, as data accumulate, it will be found that some divisor other than ten thousand should be used, or a factor calculated in an entirely different manner.

Some interesting facts are brought out in table VIII. From eleven mills two grades of flour were received and only one grade from the rest of the mills. The gluten quality factors of the two grades of flours from the same mill, together with their serial numbers, are placed in parallel columns. Also, the factors for the flours where only one grade was received are placed in another column. Where two grades of flours were received from the same mill, the gluten quality factor is either very nearly the same or where there is any significant difference the higher grade has the larger factor.

Texture of Crumb.

Texture of bread is determined by arbitrary standards. The loaves are cut into halves and the cut loaves are so placed that all from one baking can be easily observed. General appearance, fineness of cell wall, size and distribution of holes are the characteristics by which texture of crumb is judged. In all cases the loaves were judged by two or more persons. Large holes and uneven distribution indicate a weak gluten. Thickness of cell wall or an appearance of coarseness indicate a stiff and inelastic gluten. Such a flour would be good for blending with a weaker flour, but would not be a desirable flour to be used alone for household purposes. Weakness of gluten shown by large and uneven distribution of holes is one of the worst faults in a flour. As a rule, the bread from short patent flours differs from the longer patents and straights by the finer cell walls and more delicate structure.

Color of Loaf.

Color is judged in the same manner as texture. One difficulty in judging color is to distinguish true color from the color appearance as influenced by texture. The desired color is white with a delicate creamy tint. A chalky white is objectionable, and a grayish white even more so. Some of these flours were bleached, but the effect of bleaching was so slight in most cases that it was almost impossible to distinguish by color those that were bleached from the unbleached. A yellow tint is much less objectionable than a grayish tint or a chalky white. The yellow is due to the color inherent in the wheat kernel, while a grayish tint shows faulty cleaning of the wheat or imperfect dressing of the flour.

TABLE IX.—Chemical composition of short patent flours, percentages.

Serial No.	Per-centage grade.	Moisture.	Ash.	Protein.	Gliadin.	Gliadin No.	Acidity.		Gluten.		Phosphorus.				
							At room tem-perature.	At 40° C.	Wet.	Dry.	Soluble at room tem-perature.	Soluble at 40° C.	Total.	Per cent of total soluble at room tem-perature.	Per cent of total soluble at 40° C.
278	65	12.27	.386	11.66	6.59	56.5	.077	.117	35.6	11.60	.011	.017	.074	15.08	23.10
287	65	11.42	.400	12.31	6.82	55.4	.082	.124	40.1	12.78	.013	.023	.080	16.29	28.70
289	65-70	12.06	.428	11.99	7.49	62.5	.096	.137	41.3	13.16	.021	.027	.083	24.64	32.93
294	65	12.63	.427	10.82	6.26	57.9	.087	.128	31.7	11.22	.014	.030	.086	16.24	34.91
296	70	12.55	.428	12.71	6.90	54.3	.089	.146	35.8	11.29	.019	.025	.081	23.26	30.97
298	65	11.67	.413	11.57	6.59	57.0	.097	.124	35.5	11.33	.022	.029	.084	26.25	35.20
300	70	12.51	.409	10.83	5.54	51.2	.086	.107	31.8	10.33	.018	.019	.071	24.93	27.18
315	70	12.75	.400	11.74	6.44	54.9	.081	.125	34.9	10.44	.015	.043	.075	20.42	56.50
321	70	12.22	.502	13.17	6.98	53.0	.098	.141	40.3	12.94	.018	.029	.086	20.35	33.26
Average,	....	12.23	.421	11.87	6.62	55.9	.088	.128	36.3	11.68	.017	.027	.080	20.83	33.64

TABLE X.—Chemical composition of long patent flours, percentages.

Serial No.	Per-centage grade.	Moisture.	Ash.	Protein.	Gliadin.	Gliadin No.	Acidity.		Gluten.		Phosphorus.				
							At room tem-perature.	At 40° C.	Wet.	Dry.	Soluble at room tem-perature.	Soluble at 40° C.	Total.	Per cent of total soluble at room tem-perature.	Per cent of total soluble at 40° C.
272	80	12.76	.451	13.11	7.04	53.7	.105	.176	41.2	13.20	.021	.032	.086	24.59	37.06
275	80	12.16	.492	12.68	7.08	55.8	.114	.218	39.5	12.53	.029	.042	.096	30.56	43.97
281	85	12.05	.380	10.91	6.26	57.4	.107	.143	34.4	10.91	.026	.033	.090	28.44	36.56
285	83	12.07	.490	13.17	7.28	55.3	.109	.160	44.5	13.87	.026	.028	.103	25.58	27.63
292	77½	12.95	.395	11.94	7.34	61.5	.087	.137	39.9	12.47	.016	.024	.082	19.30	29.13
303	75	13.16	.462	14.17	7.45	52.6	.090	.160	45.8	13.81	.022	.033	.094	23.73	34.43
310	80	12.40	.420	11.46	6.19	54.0	.084	.137	35.0	10.98	.015	.026	.080	19.10	32.54
313	85	12.56	.517	12.01	6.27	52.2	.125	.180	37.4	12.51	.027	.040	.098	27.81	41.10
318	Unknown.	12.09	.464	13.70	7.41	54.1	.119	.154	42.5	13.21	.020	.030	.088	22.56	33.45
324	80	13.42	.534	12.83	6.85	53.4	.115	.162	38.2	12.09	.028	.040	.097	28.62	40.91
325	84	13.72	.480	12.17	6.40	52.6	.100	.164	35.7	12.28	.026	.037	.098	26.28	37.83
Average,	....	12.67	.462	12.56	6.87	54.8	.105	.163	39.5	12.50	.023	.033	.092	25.14	35.87

TABLE XI.—Chemical composition of commercial straight flours, percentages.

Serial No.	Per-centage grade.	Moisture.	Ash.	Protein.	Gliadin.	Gliadin No.	Acidity.		Gluten.		Phosphorus.				
							At room tem-perature.	At 40° C.	Wet.	Dry.	Soluble at room tem-perature.	Soluble at 40° C.	Total.	Per cent of total soluble at room tem-perature.	Per cent of total soluble at 40° C.
273	97½	12.56	.577	13.31	7.48	56.2	.134	.197	43.1	13.70	.034	.038	.090	38.06	41.85
276	95	12.71	.507	13.20	7.42	56.2	.122	.201	40.3	12.94	.034	.046	.104	32.76	44.25
279	90	13.06	.458	11.94	6.90	57.8	.110	.173	35.6	11.86	.028	.031	.096	29.11	32.22
283	99	12.93	.413	13.00	7.01	53.9	.097	.142	41.1	12.80	.021	.025	.090	23.39	27.51
290	95	11.80	.454	12.03	6.79	56.4	.113	.159	40.1	12.88	.032	.033	.095	33.54	34.91
301	95	12.22	.459	11.31	5.91	52.3	.101	.185	32.5	10.61	.022	.027	.087	25.00	31.42
304	95	13.50	.536	14.28	7.38	51.7	.104	.167	46.8	14.16	.032	.048	.112	28.66	43.04
306	87	13.31	.470	13.71	7.04	51.4	.099	.120	43.0	13.08	.024	.036	.085	27.83	42.81
308	95	13.29	.438	10.42	5.47	52.5	.113	.160	28.8	10.28	.032	.041	.098	32.65	40.92
311	96	12.30	.499	11.80	6.30	53.4	.126	.169	34.5	11.10	.033	.048	.103	32.33	46.12
316	95	12.83	.482	11.89	6.38	53.7	.101	.150	34.2	11.31	.027	.031	.085	31.10	36.50
319	....	12.12	.491	13.22	6.93	52.4	.124	.178	39.3	12.41	.032	.038	.100	31.74	37.73
322	95	12.26	.535	13.46	6.93	51.5	.146	.185	40.5	12.89	.033	.031	.104	31.66	30.21
326	97	13.59	.510	12.54	6.80	54.2	.102	.171	36.2	12.60	.029	.041	.106	27.32	38.94
328	90	14.11	.416	11.77	6.20	52.7	.084	.133	36.8	12.05	.019	.029	.085	22.47	34.47
Average,	....	12.84	.483	12.52	6.73	53.8	.112	.166	38.2	12.31	.029	.036	.096	29.84	37.55

CHEMICAL COMPOSITION OF COMMERCIAL FLOURS.

The chemical composition of these flours is given in tables IX, X and XI. These flours were analyzed for moisture, ash, protein, gliadin, acidity, gluten, total phosphorus, and water-soluble phosphorus. The acidity was determined for two conditions, that obtained at room temperature, the time of extraction being thirty minutes, and that obtained at 40° C., extraction continuing two hours. This last gives the maximum acidity in flours. The water-soluble phosphorus was also determined under these two conditions. The room temperature was very nearly 25° C.

The serial numbers are the same as those given in the tables of the baking tests. The percentage grade column is also the same.

The moisture was determined by drying for five days over sulphuric acid in a vacuum desiccator. The moisture determination in the air oven or in the hydrogen oven has not been found to give good results for flours. These methods give too low a per cent for moisture. Frequently there is as much as one per cent difference between the hydrogen oven determination and that of the vacuum desiccator. Prolonged drying in the hydrogen oven will not solve the difficulty. In this oven it has been found that flour loses weight up to seven hours drying; after that there is a slight increase.

Ash Content.

The ash is determined by the calcium acetate method. To five grams of flour in a platinum dish, ten cubic centimeters of a solution of calcium acetate are added. The strength of this solution is such that one cubic centimeter is equivalent to one milligram of calcium oxide. The flour and this solution are mixed into a homogeneous mass by means of a platinum rod, and then the dish is placed on the hot plate and the excess of the solution is allowed to evaporate. The dish is kept on the hot plate until the flour begins to char, when it is transferred to the muffle. The advantage of this method is that the time for making an ash determination is much shortened, and that there is no danger of fusing the ash by employing too high a temperature. This method has been compared with the regular official methods with very gratifying results.

The percentages of ash in the short patents vary from .386 to .502, with an average of .421. The ash content of flour, serial number 321, is rather high for a short patent.

The percentages of ash in the long patents vary from .380 to .534, with an average of .462.

The percentages of ash in the straight flours vary from .413 to .577, with an average of .483.

It will thus be seen that short, patents, long patents, and straight flours may have the same percentage of ash in individual cases, but that the lower averages are in favor of the short patents, while the straights give the higher averages. The ash content of a flour depends upon several factors : the kind of wheat, the kind of soil, the handling of the wheat before milling, and the method of milling. This last is by far the most important. As a rule hard, flinty wheat kernels give a higher per cent of ash than yellow, soft kernels from the same kind of wheat. In a former experiment ten wheats containing both yellow and flinty kernels were separated into these respective kinds and the ash determined. The average per cent of ash in the flinty kernels was 1.97, and in the yellow was 1.79. The kind of wheat may influence the ash content of the flour. Other things being equal, a hard, flinty wheat would be expected to give a flour with a higher ash content than wheat which is yellow and softer. The ash content of a flour may also be influenced by the kind of soil upon which the wheat has grown. The method of cleaning and of milling influences, to the greatest extent, the ash content. Mills that have superior facilities for cleaning are able to produce, from the same kind of wheat, a flour with a lower ash content than mills whose equipment is lacking in these respects. The larger portion of the ash of the wheat kernel is found in the outer portions which are returned as bran and shorts in the milling process. Therefore, the cleaner the separation of the outer bran coats from the inner floury portion, the lower will be the ash content of the flour. It is for this reason that the lower grades of flour have a higher ash content than the patent flours. However, from the above considerations, it will be seen that in individual cases straight flours may have as low an ash percentage as some patent flours, and that it would not be possible to classify flour on the basis of ash content alone. The ash content simply indicates a general tendency. If the percentage is high it is probable, but not necessarily, a lower grade of flour. In judging a flour the percentage of ash must be considered, together with the other characteristics of that flour.

Value of Ash in Flour.

The ash is the mineral matter of the flour. Judging from the chemical composition, the greater part of the ash is made up of the phosphates of potassium, magnesium and calcium. These salts contain elements essential to the physiological functions of the body. Because white flours contain a percentage of these salts which is small as compared with the amount present in the wheat kernels, objections from a chemical standpoint have been raised against the use of such flours, and whole-wheat flours have been lauded because of their larger content of phosphates. While there is undoubtedly some ground for this, yet many times the argument has been overdone. When all has been said it remains true that white flour gives more good, wholesome and nutritious food for the same amount of money than any other staple article, The American miller. has done much to give the public a superior flour, and most of the attacks on white flour are wholly unwarranted, and some are nothing short of criminal.

Yet perfection in milling has by no means been reached. It may be that we have been too solicitious about removing some of the portions of the wheat kernel which would better be left in the flour. While a great deal has been done along the line of cleaning wheat, it remains true that here will come the greatest changes in our present milling methods. When compared with Graham and whole-wheat flours white flour has an assurance of purity. If a housewife buys Graham flour she has no means of knowing whether or not this has been made by simply grinding the pure wheat kernel. For all she knows it may contain low-grade flour or other undesirable streams from the mill. If part of the coarsest bran is removed and the rest ground into what is called whole-wheat flour, the same criticism holds. There are many people who have better health because they eat Graham bread. Would it not be worth while to develop the art of making this flour? Is it not true that the methods used in making it are the same or even worse than they were over a generation ago? The best flour is not the one which conforms to artificial standards set by millers and bakers, but one which conforms most closely to the physiological requirements of the body. For this reason it is worth while to pay more attention to making a flour which shall supply a legitimate popular demand. There is a demand for flour which contains a larger percentage of the coarser portion of the wheat kernel, but it should be made from as clean wheat as is used to make the very best of the white flour,

Protein Content.

Protein includes all the nitrogenous compounds in the wheat flour. The per cent of nitrogen multiplied by 5.7 is taken as the protein content. The factor 5.7 is used for flour and wheat products instead of 6.25, the factor used for most feeding-stuffs. This is because the average percentage of nitrogen in the nitrogenous compounds of most feeding-stuffs is 16, while in wheat and flour it is nearly 17.6. Protein is the flesh-forming material obtained from the flour. It is the substance found in large percentages in such foods as meat, milk and eggs, and gives the distinctive value to these foods. Naturally it would follow that flours with a high protein content would seem to be more valuable than flours with a low protein content. This supposition may be true from a purely dietetic standpoint, but is not necessarily true for the distinctive purposes for which a flour is used.

The average protein content of the short-patent flours is 11.87 per cent, varying from 10.82, the lowest, to 13.17, the highest.

The average protein content of the long-patent flours is 12.56, varying from 10.91 per cent, the lowest, to 13.70 per cent, the highest.

The average protein content of the straight flours is 12.52, varying from 10.42 to 14.28.

The short-patent flours have a lower average per cent of protein than either of the other two classes, the averages of which are nearly equal. The protein content of a given flour depends on the protein content of the wheat and the mill stream from which the flour comes. High protein wheats will give high protein flours. The flour from the streams near the tail end of the mill has a higher per cent of protein than the streams near the head. For this reason short-patent flour contains less protein than long-patent flour or straight, while low grade and red dog have the highest protein content. Shorts have the highest per cent of protein, while bran and low-grade flour are nearly equal. The portion of the wheat kernel next to the bran is richest in protein; most of the streams near the tail end of the mill come from this portion.

There is some relationship between the protein content of a flour and the baking qualities, but this depends on several factors. The flour streams near the tail end of the mill are much higher in protein than the flour streams from the pure middlings, yet these lower streams are inferior in baking qualities. It is true that some of these streams high in protein when blended with the streams which go into a short patent will add strength to the blend.

What was said with reference to the relation of ash to white flour and the wheat kernel may also be said in regard to protein. From the fact that short-patent flour almost invariably contains a lower per cent of protein than the wheat kernel, while the low-grade flour, bran and shorts contain a higher per cent, the argument has been made that milling removes from the patent flour the best part of the wheat. Some of the discussions on the food value of white flour lead to absurd conclusions. There are people who are led to believe that it is possible in the milling process to separate out nearly all the protein compounds, and that the very highest and best patent flour differs very little from pure starch. Some drawings and figures relative to the composition of the wheat kernel made several years ago are partly responsible for these erroneous ideas. The protein of the wheat is pictured as being present in a layer next to the bran coat, while the inside of the kernel is shown as starch. Nothing is further from the truth than this. While it is true that the layer just under the bran coat is richer in protein than the inside of the kernel, or endosperm, the protein is so intimately mixed with the starch that by no process of milling can any of it originally present in the floury portion be removed.

While it is true that the streams near the tail end of the mill give a flour with a higher protein content than the streams from which the patent flour is blended, this protein does not add to the valuable properties of the flour in proportion to the higher protein content. In other words, the protein in the short-patent flour is so much more valuable in the properties desirable for bread making as to more than offset the higher protein content of the lower grades. Protein is the principal substance in gluten. Flour for bread making must contain gluten of good quality. The protein of the lower grades of flour does not have the properties which produce a gluten of good quality. While this is true to the greatest extent of low grade and red dog, we approach this condition the more nearly the straight flour includes all of the flour made from the wheat, and the greater the flour yield. Yield of flour is expressed by the amount of ,wheat used to make a barrel of flour. That is, 4:10 means four bushels and ten pounds of wheat to a barrel of flour, and 4:30 means four bushels and thirty pounds to a barrel of flour. A 95 per cent flour with a yield of 44:10 will have a higher per cent of protein than 95 per cent with a yield of 4:30, from the same wheat, but the properties which produce quality in gluten are present to a larger extent in the flour with the lower yield. Likewise a 65 per cent flour will have a lower per cent of protein than a 95 per cent, but the protein in the former will produce a better quality of gluten than the latter. It is because of the better quality of gluten that the short patents, are so highly prized by the housewife. These flours produce a dough with a smooth, silky, even texture. The straight flours produce a dough which is harder to handle and lends itself less readily to the variety of purposes for which a flour is used by the housewife. On the other hand, the professional baker, with his equipment and machinery, can easily handle the straight flours and from them produce a good product, and many bakers prefer the straight flour to the patent.

Gliadin and the Gliadin Number.

The protein soluble in 70 per cent (by volume) alcohol is classed as gliadin. To four grams of flour in a flask are added 100 cubic centimeters of 70 per cent (by volume) ethyl alcohol, and the flour and alcohol are thoroughly mixed by shaking. The shaking is repeated every half hour for four hours, and the mixture is then allowed to stand for twenty to twenty-four hours. The substance is then filtered, and the nitrogen determined in 50 cubic centimeters of the clear filtrate. By dividing the per cent of gliadin by the per cent of protein a quotient is obtained which is known as the gliadin number. Fifty-six and five-tenths per cent means that of 100 parts of protein 56.5 parts are gliadin. The distinct protein substances in flour which have been isolated and studied are: Gliadin, glutenin, leucosin, a globulin, and one or more proteoses. Gliadin and glutenin together make up about 85 per cent of the total proteins of the wheat flour. Gliadin contributes more than half of the protein in the ordinary flour. In the flours reported in this bulletin it averages 55.9 per cent for the short-patent flours, 54.8 per cent for the long-patent flours, and 53.8 per cent for the straight flours. The gliadin shows a distinct tendency to decrease as the proportion of flour from streams near the tail end of the mill increases. This was more fully shown in the investigation presented in bulletin No. 177 (Kansas Experiment Station). The flour made from the tailings near the end of the milling process has a decidedly lower per cent of gliadin. The gliadin in these flours decreases as the protein increases. Such flours are also the poorest in baking qualities. Because of these and similar facts the assumption has been made that a flour of good baking qualities must have a certain per cent of gliadin. While it is true that the percentage of gliadin is different in different classes of flours and shows a distinct tendency to decrease as the proportion of low grade is increased, the percentage of gliadin can not serve as a basis of judging individual flours of the same class. In fact, it was shown in bulletin No. 177 (Kansas Experiment Station) that two flours may have the same percentage of gliadin, and one have very good baking qualities while the other one is very poor.

That the proteins of a wheat flour strongly influence the baking qualities of the same is undoubtedly true, but the question is more complex than merely ascertaining the ratio between gliadin and the rest of the proteins. It should not be forgotten that the physical properties of the flour also add to the complexity of the problem. The other proteins may have as much to do with .the baking qualities as gliadin, and it is not only the proteins present in the sound wheat kernel which determine the baking qualities, but also the protein decomposition products. We know that flour made from old wheat is different from flour made from new wheat, and flour made from shock-threshed wheat is different from the flour made from wheat cured in the stack. The manner of handling the wheat before milling very materially influences the baking qualities. The wheat kernel is alive, though its energy is dormant. Different methods of handling the wheat before milling disturb this dormant vital energy to a greater or less extent. The forces thus set in action alter the proportion and composition of certain of the proteins present in small amounts in the wheat kernel. The presence of decomposition products of the proteins influence the baking qualities of the flour in a more marked way than small differences in the percentage of gliadin. To study the effects of these decomposition products some experiments have already been performed at this station and others are in progress. From the results already obtained it is hoped that more definite data will be secured in regard to the real cause of the differences in the baking qualities of flours.

Gluten.

The wet and dry gluten were determined by the method given by Dr. H. W. Wiley in his "Agricultural Analysis," volume III. While it is true that the expert can tell much about the baking qualities of the flour from the quality of the gluten as he examines it, the figures obtained for wet and dry gluten do not show as close a correspondence to the quality of the flour as do some other factors. The determinations were made and the figures are presented with the others, because so much work has been done on gluten that the record would appear incomplete without it. The figures as given tell more in regard to the quantity than quality, while it is the latter which is the most important. The average per cent is the smallest for the short-patent flours, while it is highest for the long patent. Thus the flours which appear to have the smallest average amount of gluten are those whose quality is considered best by family bread-makers.

The gluten determinations have the most value when made by an operator who has a good general knowledge of flour. His observations intelligently recorded have more value than the quantitative figures for wet and dry gluten. The figures in addition to the notes on the quality of the gluten would have an additional value, but the notes without the figures have more value than the figures without the notes. The correspondence between the figures for dry gluten and protein show that the dry gluten varies approximately as the protein.

Acidity.

The acidity was determined under two different conditions. The figures given in the column "acidity at room temperature" were obtained by the method usually employed. Twenty grams of flour were shaken up in a flask with 200 cubic centimeters of neutral carbon-dioxide-free water. The shaking was repeated at the end of five and ten minutes, when the contents were allowed to settle twenty minutes. Most of the flour settles to the bottom. The supernatant liquid is filtered, and 100 cubic centimeters titrated with a twentieth-normal solution of sodium hydroxide, using phenolphthalein as an indicator.

For the figures in the column "acidity at 40° C." the following modification was used: The water is heated to 40° C. before it is added to the flour, and kept at this temperature for two hours. The shaking is repeated at the end of five, ten, fifteen, thirty, sixty and ninety minutes. The filtration and the titration are the same as in the first method. That this method gives the maximum amount of acidity was determined by a preliminary experiment. Extracting for a longer time or heating to a higher temperature does not materially increase the figures for acidity as far as we have at present investigated.

One cubic centimeter of a twentieth-normal solution of potassium hydroxide is chemically equivalent to .0045 grams lactic acid. The figures given for acidity represent the percentage in terms of lactic acid. The average acidity varies with the commercial grade of the flour. At room temperature for short patent the per cent is .088, for long patent it is .105, and for the straight it is .112. At 40°C. the percentages are: Short patent, .128, long patent .163, and straight 166. But while the average acidity is lower in the higher commercial grades of flour, several individual flours of the long patents have a lower acidity than a number of the short patents and a few of the straights have as low acidity as some of the short patents, though the tendency for the acidity to increase with the lower commercial grade of flour is clearly manifest. The three lowest acidity percentages in the long-patent flour are, .087, .090 and .084, and the percentage flour grades for these are, 77½, 75 and 80, respectively. All the other long-patent flours have a percentage grade of 80 or above. (See under baking test for the meaning of percentage grade.) If we refer to the table for the gluten quality factor, we will find that these three flours are equal to or above the average in quality. There thus seems to be a general average relation between the percentage grade and the acidity. Whether or not the acidity is due to an organic acid or some other factor is discussed later. The temperature at which the acidity should be determined is also an open question. While 40° C. gives the maximum acidity, it remains to be shown whether or not this acidity value gives the desired correspondence with other qualities of the flour. What we can say is that, other things being equal, a low acidity value corresponds to a better, and a high acidity corresponds to a poorer commercial grade of flour. The whole question of the acidity of flour will be referred to several times.

Percentage of Phosphorus.

Phosphorus is very intimately associated with the life of every living plant. If a seed is planted in a medium from which all the phosphorus has been removed it will germinate and grow until all the reserve phosphorus in the seed has been used, and then it will die. New cells can not be developed without the element phosphorus. The embryo, and adjacent portions of the wheat kernel, contain larger amounts of phosphorus than the rest of the kernel. It is known that the compounds called nucleo-proteins are very rich in phosphorus. To ascertain what relation water-soluble and total phosphorus have to the other constitutents of the wheat flour, these determinations on phosphorus were made. The water-soluble phosphorus was determined under the two conditions that were used in making the acidity determinations. There is a great deal of variation in phosphorus content among the individual flours of the different grades. Attempts to correlate these variations do not yield any fruitful results. However, when we confine our observations to the averages we note distinct characteristics and tendencies, which are so marked that the subject well deserves further study, and this study is now in progress at this Station.

Water-Soluble Phosphorus.

The average percentage of phosphorus soluble in water at room temperature is .017 per cent for the short patent, .023 per cent for the long patent, and .029 per cent for the straight flours. The average percentage of phosphorus soluble at 40° C., two hours digestion, is .027 per cent for the short patent, .033 per cent for the long patent, and .036 per cent for the straight flours. The total phosphorus percentages are for these three grades, respectively, .080, .092 and .096. There is thus a distinct tendency of both the water-soluble and the total phosphorus to increase in proportion as the numerical percentage grade of the flour increases or the commercial grade becomes poorer. The greater the per cent of total flour, the greater the per cent of soluble and total phosphorus. That the greater per cent of water-soluble phosphorus in the long patent and the straight flour, as compared with the short patent, is not due entirely to a greater per cent of total phosphorus present in the former two is shown in the last two columns, where we have the per cent of total soluble calculated for the two conditions. The average percentage of the total soluble at room temperature is 20.83 for the short patent, 25.14 for the long patent, and 29.84 for the straights. The average percentages of total soluble at 40° C., two hours digestion, are respectively for these three grades, 33.64, 35.87 and 37.55. The phosphorus is the least soluble in the short patent, more so in the long patent and most soluble in the straight. The solubility of phosphorus increases as the numbers for the percentage grade increases.

Not only is there a larger per cent of phosphorus soluble in the poorer commercial grades, but in these grades it is more easily soluble. Thus for the short patent the increase of the percentage of total soluble at the higher temperature and longer time over the lower temperature and shorter time is 12.81 per cent (33.64 — 20.83), for the long patent the increase is 10.73 (35.87 — 25.14), and for the straights the increase is 7.71 per cent. This seems to indicate that the phosphorus in the poorer commercial grades of flour dissolves more rapidly than that in the better commercial grades. That is, the treatment for a shorter time, and at a lower temperature, extracts a relatively larger proportion of the soluble phosphorus in the flours which contain a larger proportion of the total flour made. The phosphorus in the streams near the tail end of the mill is relatively more soluble.

The Relation of Acidity to Phosphorus.

A few comparisons between these phosphorus determinations and the acidity averages are interesting. It was noted above that the acidity percentage increased with the poorer commercial grade of flours. Exactly the same condition is true in regard to the water-soluble and total phosphorus. These lower commercial grades of flour also have a larger percentage of ash. Acidity of flour seems, therefore, to be very closely associated with the ash, water-soluble, and total phosphorus content. A large portion of the water-soluble phosphorus is probably present in the extract in some form of acid phosphate. That such a compound should influence the acidity value is very evident from the way this acidity value is determined. An acid phosphate, as well as an organic acid, will neutralize a solution of sodium hydroxide. The acidity value in flour as determined at present may also be due to amino-acids. To calculate acidity in terms of lactic acid seems therefore to lack proper foundation. In normal flour it is evident that the acidity value may be as much influenced by the soluble phosphates and amino-compounds as by an acid developed by unsound conditions. That unsoundness in wheat and flour will give a high acidity value is true, but this acidity value is strongly influenced by the soluble phosphates. To bring out in a summary form, these averages, which have been discussed above, are brought together in the following table:

TABLE XII.—*Average percentages for ash, acidity and phosphorus.*

Commercial grade.	Ash.	Treatment at room temperature.		Treatment at forty degrees centigrade.		Total phosphorus.	Per cent of total phosphorus soluble at room temperature.	Per cent of total phosphorus soluble at forty degrees C.
		Acidity.	Water-soluble phosphorus.	Acidity.	Water-soluble phosphorus.			
Short patent........	.421	.088	.0167	.128	.0269	.0796	20.83	33.64
Long patent........	.462	.105	.0233	.163	.0331	.0920	25.14	35.87
Straight...........	.483	.112	.0287	.166	.0363	.0960	29.84	37.55

A study of table XII will show that there is an unmistakable relation between acidity and the soluble phosphorus. There is also an apparent relation between the ash and the acidity. That the total phosphorus should show a relation to the acidity follows from the fact that it includes the soluble phosphates, and the total and the soluble bear a more or less definite relation to each other. The figures for acidity average about five, times the value for the soluble phosphorus. The larger part. of the phosphorus in the flour extract is probably in the form of potassium phosphates, There are also smaller amounts of magnesium phosphates and calcium phosphates, the former. being about four times as abundant as the latter, reasoning from the composition of wheat ash. The acid magnesium phosphates are very slightly soluble in water. While monocalcium phosphate is soluble in water, the possible amount of this salt in the flour is very small. Reasoning from the different amounts of inorganic elements present in the flour, much the larger part of the soluble phosphorus obtained in the extract is in the form of potassium phosphates. All of the potassium phosphates are more or less soluble in water. Some are soluble in alcohol, while others are not. Potassium orthophosphate is slightly soluble in cold water, and the solubility increases at a higher temperature. Monopotassium phosphate and dipotassium phosphate are both soluble in cold water; the former gives a solution acid in reaction, while the latter gives a solution alkaline in reaction. It thus becomes evident why a soluble phosphate obtained from a flour will influence the acidity test.. The effect of varying temperature on solubility of the different phosphates of potassium explains why the percentages are higher at 40° C.

Whether or not these phosphates are present as such in the flour, or produced by the hydrolytic action of the water in the process of extraction, is immaterial as far as these phosphates. influence the acidity value. It is this water extract that is used for the determination of acidity, and in this extract the acid phosphates would be possible. It may be that the greater part of the phosphorus in the flour is present in the organic form. Determinations made in this laboratory seem to point that way, and the hydrolytic action of the water may easily change this condition during extraction.

The relation of these phosphates to the acidity of flour is a very interesting and important problem. This subject will be referred to further.

In the following discussion the figures obtained by treating long-patent flour at room temperature are taken. The discussion would hold if the figures for either of the other flours were taken at either temperature, but these were taken because this flour represents the average family flow, and the treatment corresponds to the usual conditions for the determination of acidity. The average percentage of acidity is .105. This corresponds to 2.33 cubic centimeters of twentieth-normal potassium hydroxide for ten grams of flour. Such a solution would contain ,0065 grams of potassium hydroxide. The per cent of water-soluble phosphorus in a solution representing the same amount of flour and obtained under the same condition is .023. This would correspond to .0023 grams of phosphorus. That is, the water solution which requires .0065 grams of potassium hydroxide to neutralize the acidity contains .0023 grams of soluble phosphorus. Assuming that this phosphorus is in the form of monopotassium phosphate, this amount would be equivalent to .0101 grams of this salt.

Assuming the chemical reaction to take place in accordance with the following equation: $KOH + KH_2PO_4 = K_2HPO_4 + H_2O$, we have the following proportion: $56.1 : 136.1 :: .0065 : X = .0156$. This means that it would take .0156 grams of monopotassium phosphate to neutralize the .0065 grams of potassium hydroxide, while according to the experiment there was only .0101 gram of this salt present, as calculated from the amount of water-soluble phosphorus present. This amount of monopotassium phosphate would require only .0042 grams of potassium hydroxide for its neutralization if we assume the .above reaction to take place. The difference between .0065 and .0042, or .0023 grams of potassium hydroxide, would be neutralized by some other compounds. That there are such compounds present in the form of acid proteins will be shown later.

It was also noticed that there was an increase in acidity somewhat closely related to the increase in ash. Does this ash contain other substances which are acid in reaction in addition to the soluble phosphates, or is the increase in ash percentage simply due to a relatively larger increase in soluble acid phosphates? The three percentages for water-soluble phosphates at room temperature are .017, .023, and .029. Calculated to the monopotassium phosphate, they are equivalent to .073, .101, and .126, respectively. The increase in ash of the long patent over the short patent is .041 per cent, and for the straight there is a further increase of .021. While these differences are small, and would not be considered of much significance in individual cases, these figures are the average of a large number, and only general relationship is taken into account in this discussion. The increase in the content of the monopotassium phosphate of the long-patent flour over the short-patent is .028 per cent, and the increase of the straight over the long patent is .025 per cent. While this increase in soluble phosphate is not quite equivalent to the increase in ash, the figures make it very probable that the increase in ash content does not itself increase the acidity, but because a larger amount of ash is accompanied with a greater percentage of soluble acid phosphates, the acidity is higher. Theoretically it would be more likely that some of the compounds present in the ash would have an alkaline reaction. This subject deserves further investigation.

It is thus seen that while the acidity increases with the poorer commercial grades of flour, this increase in acidity is accompanied by an increase in water-soluble phosphates which, to a large extent, account for the increase in acidity. The acidity which the soluble phosphates do not account for is probably due to acid proteins. To this further reference wiil be made.

TABLE XIII.—Chemical composition of commercial wheats and short patent flours from same. Percentages on air-dry basis.

Serial No.		Moisture.		Protein.		Ash.		Acidity at 40° C.		Total phosphorus.		Water-soluble phosphorus (40° C.).	
Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.
288	287	11.82	11.42	14.23	12.31	2.01	.400	.486	.124	.438	.080	.204	.023
291	289	12.69	12.06	12.43	11.99	2.33	.428	.515	.137	.403	.083	.130	.027
295	294	11.20	12.63	12.40	10.82	2.01	.427	.545	.128	.434	.086	.209	.030
297	296	11.18	12.55	14.14	12.71	1.94	.428	.576	.146	.403	.080	.232	.025
299	298	10.72	11.67	13.68	11.57	2.06	.413	.684	.124	.481	.084	.225	.030
302	300	10.95	12.51	12.59	10.83	1.96	.409	.549	.107	.461	.071	.201	.019
317	315	10.67	12.75	12.89	11.74	2.06	.400	.618	.125	.405	.075	.186	.043
323	321	10.97	12.22	14.74	13.17	2.03	.502	.753	.141	.447	.086	.273	.029
Average,	....	11.28	12.23	13.39	11.89	2.05	.426	.591	.129	.434	.081	.208	.028

TABLE XIV.—Chemical composition of commercial wheats and long patent flours from same. Percentages on air-dry basis.

Serial No.		Moisture.		Protein.		Ash.		Acidity at 40° C.		Total phosphorus.		Water-soluble phosphorus (40° C.).	
Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.
274	272	10.59	12.76	15.33	13.11	1.98	.451	.740	.176	.457	.086	.210	.032
277	275	10.40	12.16	15.08	12.68	1.99	.492	.653	.218	.464	.096	.193	.042
282	281	10.52	12.05	12.35	10.91	1.80	.380	.554	.143	.435	.090	.208	.033
286	285	10.90	12.07	14.88	13.17	2.08	.490	.551	.160	.476	.103	.276	.028
293	292	10.90	12.95	14.34	11.94	2.05	.395	.518	.137	.455	.082	.210	.024
305	303	10.06	13.16	15.76	14.17	2.24	.462	.676	.160	.464	.094	.212	.033
312	310	11.16	12.40	13.00	11.46	2.02	.420	.657	.137	.438	.080	.211	.026
320	318	10.45	12.09	15.42	13.70	2.01	.464	.641	.154	.439	.088	.244	.030
327	325	11.65	13.72	13.51	12.17	2.01	.480	.618	.164	.448	.098	.263	.037
Average,	....	10.74	12.59	14.41	12.59	2.02	.448	.623	.161	.453	.091	.225	.032

TABLE XV.—Chemical composition of commercial wheats and straight flours from same. Percentages on air-dry basis.

Serial No.		Moisture.		Protein.		Ash.		Acidity at 40° C.		Total phosphorus.		Water-soluble phosphorus (40° C.).	
Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.
274	273	10.59	12.56	15.33	13.31	1.98	.577	.740	.197	.457	.090	.210	.038
277	276	10.40	12.71	15.08	13.19	1.99	.507	.653	.201	.464	.104	.193	.046
284	283	10.47	12.93	14.15	12.99	2.09	.413	.540	.142	.457	.090	.209	.025
291	290	12.69	11.80	12.43	12.02	2.33	.454	.515	.159	.403	.095	.130	.033
302	301	10.95	12.22	12.59	11.31	1.96	.459	.549	.185	.461	.087	.201	.027
305	304	10.06	13.50	15.76	14.28	2.24	.536	.676	.167	.464	.112	.212	.048
307	306	10.44	13.31	14.99	13.71	2.06	.470	.662	.120	.466	.085	.218	.036
309	308	11.16	13.29	11.86	10.42	2.00	.438	.763	.160	.454	.098	....	.041
312	311	11.16	12.30	13.00	11.80	2.02	.499	.657	.169	.438	.103	.211	.048
317	316	10.67	12.83	12.89	11.88	2.06	.482	.618	.150	.405	.085	.186	.031
320	319	10.45	12.12	15.42	13.22	2.01	.491	.641	.178	.439	.100	.244	.038
323	322	10.97	12.26	14.74	13.45	2.03	.535	.753	.185	.447	.104	.273	.031
327	326	11.65	13.59	13.51	12.54	2.01	.510	.618	.171	.448	.106	.263	.041
329	328	11.81	14.11	13.60	11.77	1.73	.416	.650	.133	.438	.085	.255	.029
Average,	....	10.96	12.82	13.95	12.56	2.04	.485	.645	.166	.446	.096	.216	.037

TABLE XVI.—Chemical composition of commercial wheats and short patent flours from same. Percentages on moisture-free basis.

Serial No.		Protein.		Ash.		Acidity at 40° C.		Total phosphorus.		Water-soluble phosphorus (40° C.).	
Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.
288	287	16.14	13.90	2.28	.452	.551	.140	.497	.090	.231	.026
291	289	14.23	13.63	2.67	.487	.590	.156	.461	.094	.149	.031
295	294	13.96	12.39	2.26	.489	.614	.147	.489	.098	.235	.034
297	296	15.92	14.54	2.18	.490	.649	.167	.454	.092	.261	.029
299	298	15.32	13.10	2.31	.468	.766	.140	.539	.095	.252	.034
302	300	14.14	12.16	2.20	.459	.617	.120	.518	.080	.226	.021
317	315	14.42	13.45	2.31	.458	.692	.143	.453	.086	.208	.049
323	321	16.55	15.00	2.28	.572	.846	.161	.502	.098	.307	.033
Average..	....	15.09	13.52	2.31	.484	.666	.147	.489	.092	.234	.032

TABLE XVII.—Chemical composition of commercial wheats and long patent flours from same. Percentages on moisture-free basis.

Serial No.		Protein.		Ash.		Acidity at 40° C.		Total phosphorus.		Water-soluble phosphorus (40° C.).	
Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.
274	272	17.14	15.02	2.21	.517	.827	.202	.511	.099	.235	.037
277	275	16.83	14.44	2.22	.560	.729	.248	.518	.109	.215	.048
282	281	13.81	12.40	2.01	.432	.619	.163	.486	.102	.232	.038
286	285	16.70	14.97	2.33	.557	.618	.182	.534	.117	.310	.032
293	292	16.09	13.72	2.30	.454	.581	.157	.511	.094	.236	.028
305	303	17.53	16.32	2.49	.532	.752	.184	.516	.108	.236	.038
312	310	14.64	13.09	2.27	.480	.740	.156	.493	.091	.238	.030
320	318	17.22	15.58	2.25	.528	.716	.175	.490	.100	.273	.034
327	325	15.29	14.12	2.28	.557	.700	.190	.507	.114	.298	.043
Average.	....	16.14	14.41	2.26	.513	.698	.184	.507	.104	.253	.036

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TABLE XVIII.—Chemical composition of commercial wheats and straight flours from same. Percentages on moisture-free-basis.

Serial No.		Protein.		Ash.		Acidity at 40° C.		Total phosphorus.		Water-soluble phosphorus (40° C.).	
Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.	Wheat.	Flour.
274	273	17.14	15.23	2.21	.660	.827	.225	.511	.103	.235	.043
277	276	16.83	15.12	2.22	.581	.729	.230	.518	.119	.215	.053
284	283	15.81	14.93	2.33	.475	.603	.163	.510	.103	.233	.029
291	290	14.23	13.63	2.67	.515	.590	.180	.461	.108	.149	.037
302	301	14.14	12.88	2.20	.523	.617	.211	.518	.099	.226	.031
305	304	17.53	16.51	2.49	.620	.752	.193	.516	.129	.236	.055
307	306	16.74	15.82	2.30	.542	.739	.138	.521	.098	.244	.042
309	308	13.35	12.01	2.25	.505	.859	.184	.511	.113	....	.047
312	311	14.64	13.45	2.27	.569	.740	.193	.493	.117	.238	.055
317	316	14.42	13.63	2.31	.553	.692	.172	.453	.097	.208	.036
320	319	17.22	15.04	2.25	.559	.716	.203	.490	.114	.273	.043
323	322	16.55	15.33	2.28	.610	.846	.211	.502	.119	.307	.035
327	326	15.29	14.51	2.28	.590	.700	.198	.507	.123	.298	.047
329	328	15.42	13.70	1.96	.484	.737	.155	.497	.099	.289	.034
Average..	....	15.67	14.41	2.29	.556	.725	.190	.501	.110	.242	.042

CHEMICAL COMPOSITION OF WHEATS COMPARED WITH THE COMPOSITION OF THE FLOURS FROM THE SAME.

These data are found in tables XIII, XIV and XV. The same data calculated to a moisture-free basis are found in tables XVI, XVII and XVIII. These wheats were analyzed for moisture, protein, ash, acidity, total phosphorus, and water-soluble phosphorus. The figures for acidity were obtained by the same method as the acidity in flour. The solution for acidity was used for the determination of water-soluble phosphorus.

Moisture in Wheat and Flour.

In all cases but two the wheat has a lower per cent of moisture than the flour made from it. These are wheats Nos. 288 and 291, and in the latter both the short-patent and the straight flours have a lower percentage of moisture than the wheat. The increase in moisture is largely due to the tempering water. Whether or not the inside of the kernel contains more water naturally than the bran coat is not known. It would be reasonable to asume that the endosperm was higher in water content than the bran coat. The short-patent flours average .95 per cent more moisture than the wheats from which they were made, and the long patents and the straights have, respectively, 1.85 per cent and 1.86 per cent more. This moisture added in the tempering process compensates, to a large extent, the miller for invisible loss through dust and evaporation of moisture from stock as it passes the different machines. Other things being equal, a hard wheat which takes two and one-half per cent of water in tempering will give a larger yield than a softer wheat which takes only one-half per cent of water or none at all. It should be understood, however, that the water is not added for the purpose of increasing the yield, but because tempering gives a better separation and a higher grade flour. The diminution of the invisible loss is an incidental but valuable result.

In the discussions which follow the figures for the moisture-free substance are used.

Protein in Wheat and Flour.

Without any exception, the protein content of the wheat is higher than that of the flour. The decrease in protein content of the flour as compared with wheat for these three grades is, respectively, 1.57, 1.73 and 1.26 per cents. The portion of the wheat kernel richest in protein is the layer next to the bran.

Therefore, the flour streams which contain more of this layer are richer in protein than those from the interior, and some may even average higher in protein than the whole wheat kernel. It is because of this unequal distribution of protein in the wheat kernel that flours from the same wheat will differ in protein content.

To bring out the relation between the constituents in the wheat and those in the flour, the percentages for the wheats

PLATE V

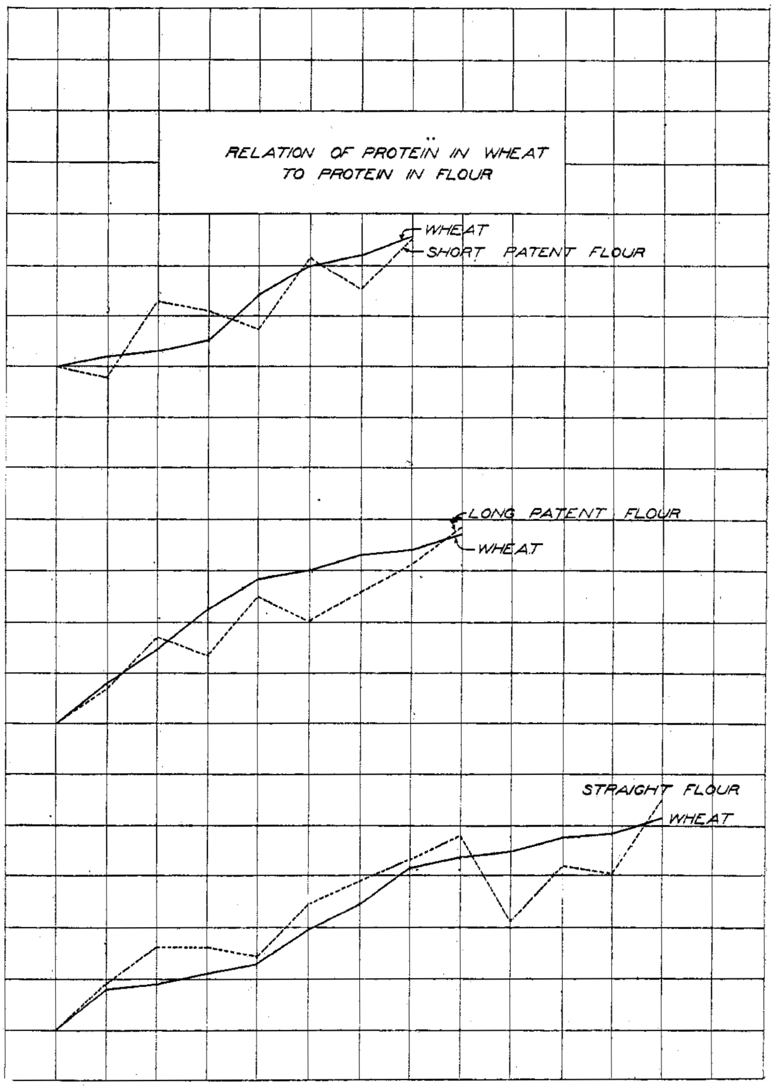
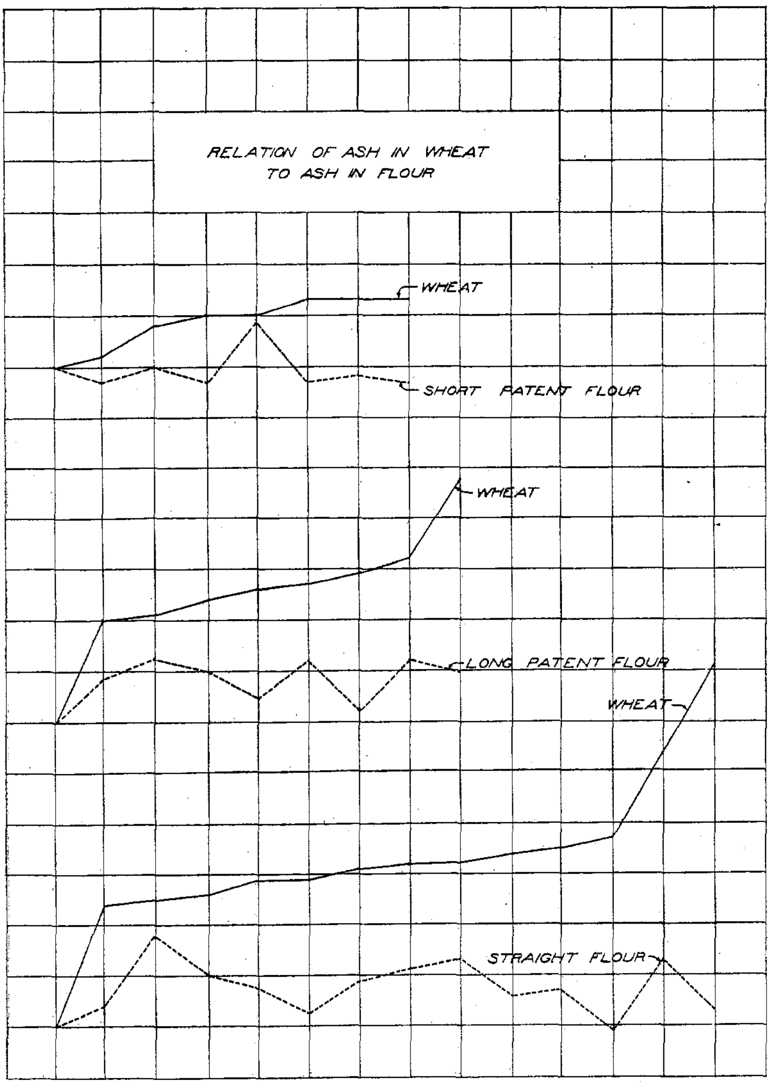


PLATE VI



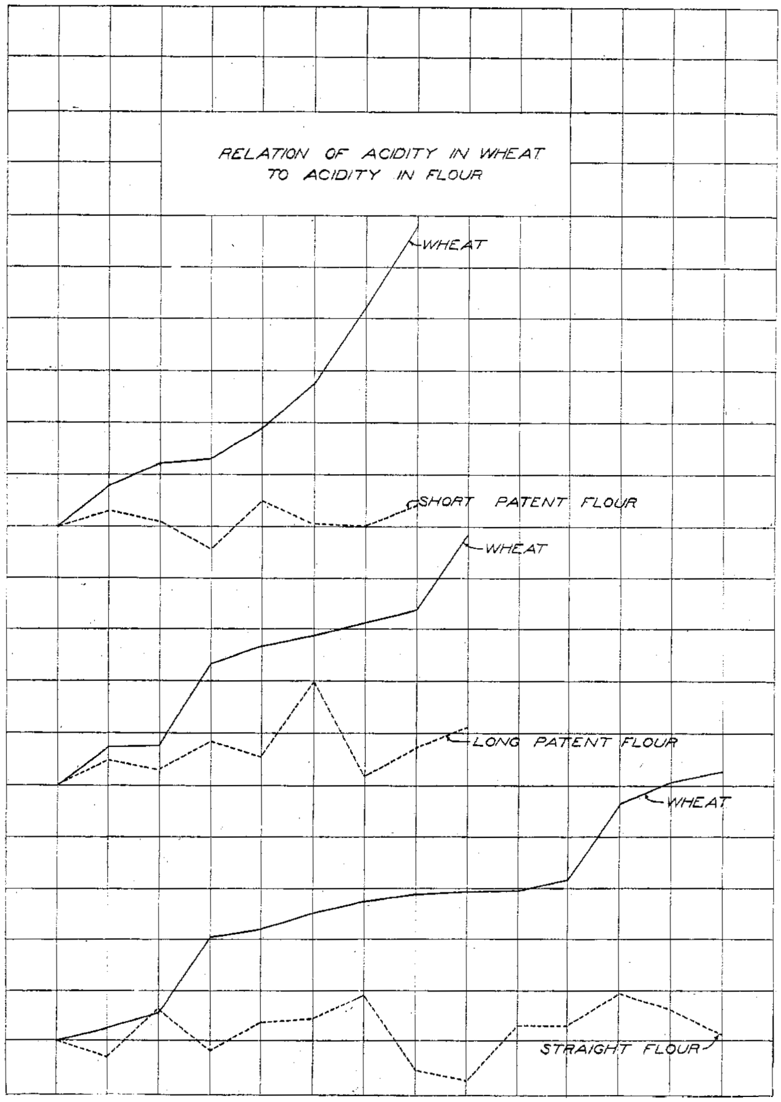
in these three groups were arranged in an ascending series and the corresponding percentage for the flour made from the same wheat put in a parallel column. These values were then plotted on cross-section paper. To have the curves start at the same point, the difference between the smallest value for the wheat and the corresponding value for the flour was added to each one of the flour values. This does not change the form of the curve for the flour values, nor its relation to the curve for the wheat values, except the distance. For example, if the flour curve goes above or below the curve for wheat it does not mean that the actual value is above or below that of the wheat. These curves simply show the relative variation between the wheat and flour values.

In plate V we have the relation between the protein content of the wheat and the protein content of the flour. In all these three grades we see that as the protein content of the wheat increases, the protein content of the flour also tends to increase. That the relation is not more regular is in a large measure due to different methods of milling and the variation in these grades among themselves. Then it is also true that some wheats with a definite protein content will give a flour of a higher protein content than another wheat of the same protein content. In other words, two wheats may have the same protein content and yet the seventy per cent patent flour from these wheats will have a different protein content. (See table 30, page 118, Bull. 177, Kansas Experiment Station.)

The Relation Between the Ash Content of the Wheat and the Ash Content of the Flour.

The average ash content of these respective groups of flour is .484, .513, and .556 per cents, while the corresponding values for the wheats in the same groups are 2.31, 2.26 and 2.29 per cents. Thus, as far as the averages go, the higher ash content of the lower grades of flours is not due to the higher ash content of the wheats from which these were made, but to variation in method of milling and the mill stream from which the flours are made. In plate VI are given the curves for the ash content of the wheats and the flours made from them. It can readily be seen that as the ash content of the wheats increases there is no corresponding tendency for the ash of the flour to increase. That the ash content of a wheat may influence the ash content of the flour is probably true, as was previously suggested, but these curves show that the ash content of a flour is more dependent on the method of milling than the variation in ash content of the wheat. The difference between the highest and lowest ash percentage in these wheats is .71 per cent, while the largest difference in ash content of the flours is .228 per cent. A wheat with a high ash content may give a

PLATE VII



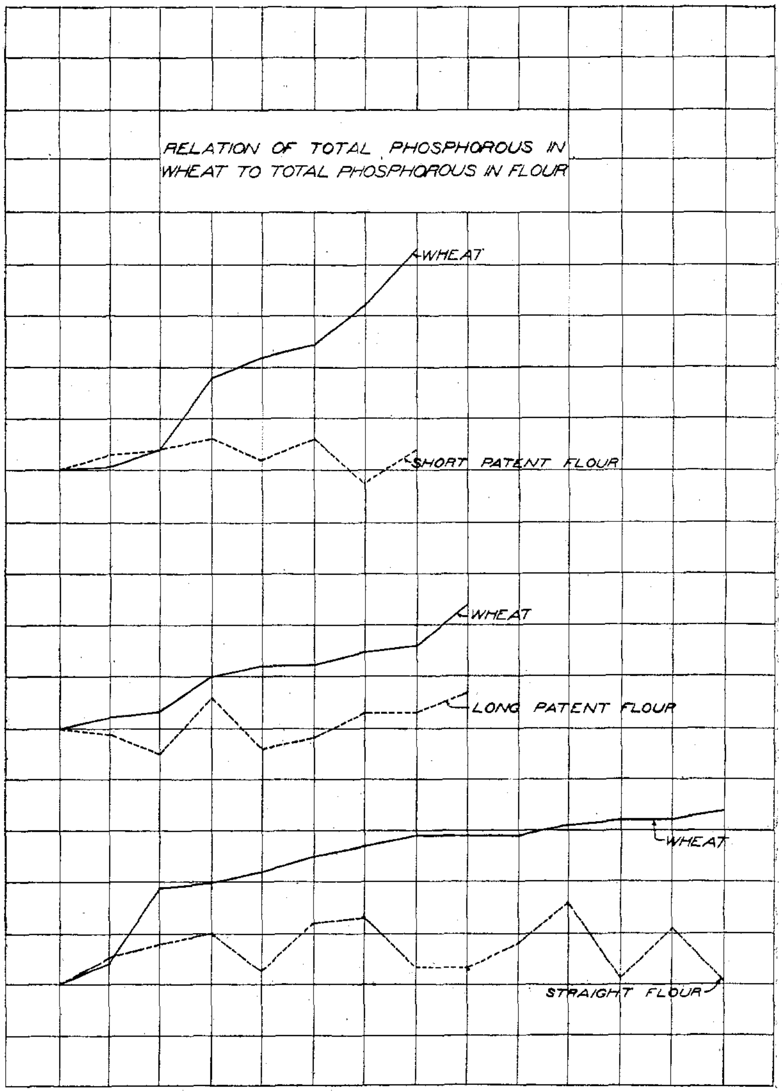
flour with a low ash content, and a wheat with a low ash content may give a flour with a high ash content. The ash content of the wheat averages between four and five times that of the flour. How much the larger part of the ash of the wheat goes into the feed can be seen from the following calculation. Suppose that from one hundred pounds of wheat are milled seventy pounds of straight flour and that the ash content of the wheat is 2.30 per cent and that of the flour is .6 per cent. Then in the seventy pounds of flour there are .42 pound ash and 1.88 pounds in the thirty pounds of feed, or 81.74 per cent of the ash in the wheat goes into the feed and 18.26 per cent into the flour, while the ash content of this flour is .6 per cent and that of the feed is 6.26 per cent, or the ash content of the feed is over ten times that of the flour. From this it is easy to see that the ash content of the flour is more influenced by the presence of bran particles than by the variation of ash content in the wheat.

Relation Between the Acidity of Wheat and the Flour Made from the Same.

The average acidity values for these three groups of flours are .147, .184 and .190 per cents, respectively, and for the wheats similarly grouped the figures are .666, .698 and .725 per cents. The acidity of the wheat averages about four times that of the flour. That portion of the wheat kernel next to the bran has a higher per cent of acidity than the average for the whole wheat kernel. Thus as flour contains a larger per cent of this portion of the wheat kernel the higher the acidity. The highest acidity in any of these wheats is .859 per cent and the lowest .551 per cent; the highest in flour is .248 per cent and the lowest is .120 per cent. A high acidity in wheat does not necessarily give a high acidity in flour. This is brought out by the curves in plate VII. The flour from a wheat high in acidity may be lower in acidity than another flour from a wheat which is low in acidity. This is because the portion of the wheat kernel next to the bran and the germ is high in acidity value. Consequently, in proportion as this portion is incorporated into the flour the acidity value rises in a greater ratio than any increase in acidity value due to the high acidity of the wheat. The curves show that several of the wheats high in acidity give a flour as low in acidity as the wheats lowest in acidity. As far as this investigation goes, acidity value depends more on the method of milling and the percentage grade of flour than on variation in the wheats from which the flours are made.

A simple calculation will make the above clear. Suppose that the wheat gives an acidity value of .72 per cent and the flour made from the same shows .18 per cent acidity, and that 70 per cent flour and 30 per cent feed are made. The total quantity of acidity in the wheat would be represented by the figure .72 and that of the flour by .126, leaving .594 for the 30 per cent feed. This would give an acidity value of 1.98 per cent for the feed, or eleven times that of the flour. Manifestly it would not take much of this substance so high in acidity value to influence the acidity value more than it would

PLATE VIII



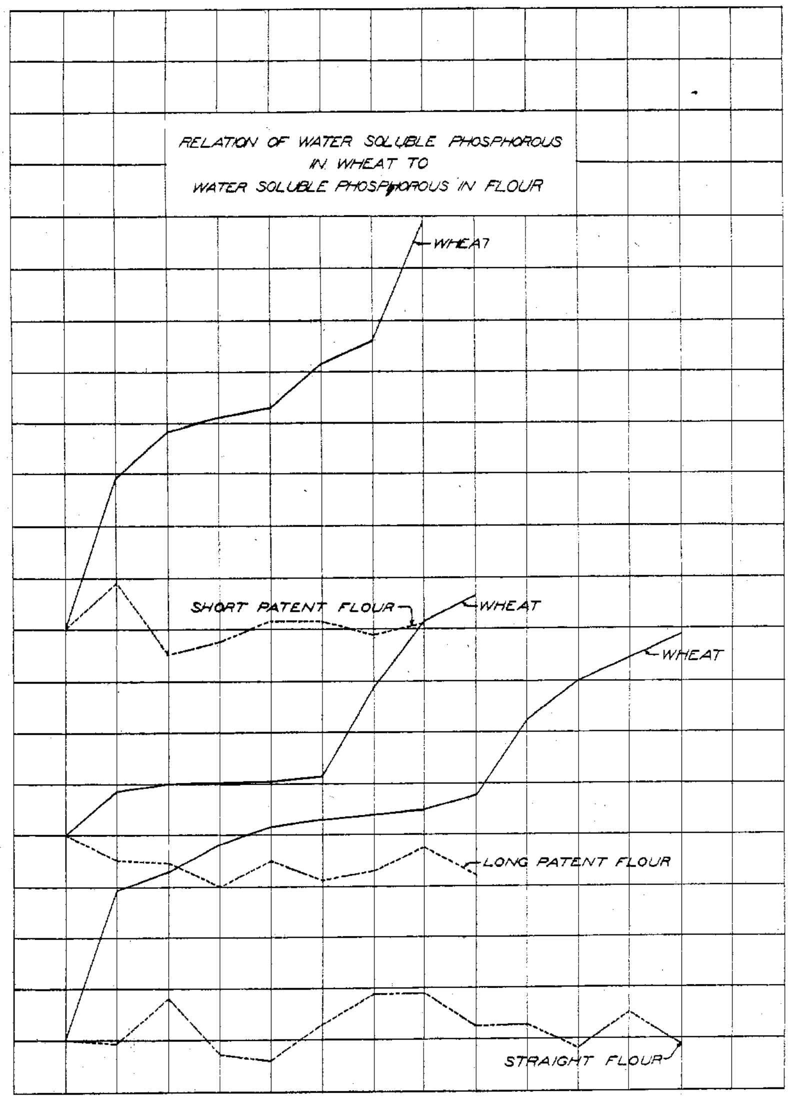
be influenced by the variation in acidity values of the wheats. An important question for investigation arises right here: If two wheats differ in acidity value, what will be the acidity values of the flour made from them, provided that exactly the same process of milling is used on each? This question can be answered only by the use of an experimental mill, the equipment of which is scientifically accurate, and so complete that the results are commercially comparable.

Relation of Total Phosphorus in the Wheat to the Total Phosphorus in the Flour.

The average per cents of total phosphorus in these three groups of wheats are, respectively, .489, .507 and .501, and for the corresponding flours the percentages are .092, .104 and .110. The total per,cent of phosphorus in wheat will average about five times that of the flour. The highest phosphorus content of all these wheats is .539 per cent, and the lowest is .453 per cent. The highest phosphorus content of the flours is .129 per cent and the lowest is .080 per cent. A wheat with a high phosphorus content does not necessarily give a flour with a high phosphorus content. The larger part of the phosphorus is found in the bran coat and in the layer near the bran coat. That phosphorus in the wheat does not necessarily influence the phosphorus content of the flour can be seen from the curves in plate IX. A wheat with a high phosphorus content may give a flour which is as low in phosphorus as flour from one which has a small per cent of phosphorus. The relative amount of phosphorus in the wheat, the flour, and the feed may be seen from the following calculation : Suppose the per cent of phosphorus in the wheat is .5 and that of the flour .1 per cent. In 100 pounds of wheat there would be .5 pound phosphorus; in the 70 pounds of flour made from the wheat there would be .07 pound, leaving .43 pound of phosphorus for the 30 pounds of feed. Of the total present in the whole wheat kernel only about one-seventh is in the flour, and the rest of it is found in the feed which would, under the conditions named, contain 1.43 per cent of phosphorus.

The relation of phosphorus in the whole wheat to the phosphorus in the flour forms an important chapter in soil fertility. As only one-seventh of the phosphorus of the wheat

PLATE IX



is in the flour, it is evident that if only the flour was sold off the farm, wheat farming would not exhaust the soil more than one-seventh as fast as when the whole wheat is sold. In a permanent system of agriculture enough live stock should be kept so that all of the bran and shorts can be fed on the farm. A few figures will enforce this point. Assume a maximum production of fifty bushels, or 3000 pounds, per acre, and that 70 per cent of this is ground into commercial flour; also, that the wheat contains .5 per cent phosphorus, and the flour .1 per cent; there would be 2100 pounds of flour and 900 pounds of feed. In the 3000 pounds of wheat there would be 15 pounds of phosphorus, and in the flour there would be 2.1 pounds. That means that we would have 13.9 pounds of phosphorus in the feed.

An average fertile Kansas soil contains about 1000 pounds of phosphorus per acre to the depth of seven inches, or enough for sixty-six 50-bushel crops of wheat, while the phosphorus removed in the flour would be sufficient for 476 such crops. As the average production is less than half this amount in good years, it follows that if only the phosphorus found in the flour is removed from the soil, practically there would be equilibrium, as the rate of gentle erosion would more than offset this removal of plant food.

Relation of the Water-Soluble Phosphorus in Wheat to the Water-Soluble Phosphorus in Flour.

Nearly one-half of the total phosphorus in wheat is soluble in water at 40° C., while in flour only a little more than one-third of the total present is soluble under the same conditions. The phosphorus in that portion of the wheat kernel which goes into the flour is less soluble than the phosphorus in the bran and portions near the bran. The average water-soluble phosphorus in all these wheats is .243 per cent, while the average of the total phosphorus is .496 per cent. For the flours, these figures are .037 per cent, and 0.102 per cent, respectively. In 100 pounds of wheat so blended as to have the composition of the average of these wheats there would be .496 pound of phosphorus, of which .243 pound would be soluble. The 70 pounds of flour from this wheat would contain .0714 pound of phosphorus, of which .0259 pound would be soluble. The proportion of the water-soluble phosphorus in the wheat to the water-soluble phosphorus in the flour made from that wheat is .243 to .026, or very nearly ten to one.

In other words, whole wheat contains nearly ten times as much water-soluble phosphorus as the flour made from that wheat. Of all the water-soluble phosphorus present in the wheat, only one-tenth is found in the flour, the other nine-tenths remaining in the bran and shorts. Thus it becomes evident that the method of milling will have a larger influence on the percentage of soluble phosphorus in the flour than the variation in the percentage of water-soluble phosphorus in the wheat from which the flour is made. Flour from a wheat high in water-soluble phosphorus may give a flour low in water-soluble phosphorus. (See plate IX.)

Part III.

Chemical Composition and Baking Qualities of Flours from Different Mill Streams.

Two sets of samples of flours from the several mill streams were obtained, one from a four break, 1200-barrel mill, and the other from a five break, 1500-barrel mill, The data on the flours from the four break mill will be given first.

The results on acidity in relation to other constituents in flour were so interesting that it was thought worth while to work on flours from different mill streams. The advantage of such flours is that their origin in relation to the different portions of the wheat kernel is better known. Furthermore, such flours differ from each other to such an extent that small variations in results due to the experimental error have less influence. In fact, the differences in such flours are so great that the experimental error can in no way influence the main results. The description of the flours is given below. The serial numbers are the ones used throughout the discussion.

FLOUR FROM THE FIVE BREAK MILL.

DESCRIPTION OF THE MILL-STREAM FLOURS.

Serial No.
367 The whole cleaned wheat from which these flours were made.
368 First break flour.
369 Second break flour.
370 Third break flour.
371 Fourth break flour.
372 Short-patent flour, 65 per cent. Sizings flour from first, second, and third middlings.
373 Long-patent flour, 80 per cent. Sizings flour from first, second, third, fourth, fifth, sixth and seventh middlings; also, second and third break flour.
374 Straight flour, 98 per cent. Contains the flour from all the streams except 2 per cent low grade.
375 Flour from fourth and fifth middlings.
376 Flour from sixth and seventh middlings.
377 Flour from eighth middlings.
378 First clear flour 33 per cent. Contains first, second, third and fourth break flour; also, fourth, fifth, sixth, seventh and eighth middlings, and reel flour.

Serial No.
379 Second clear, 18 per cent. Contains first and fourth break flours; flours from eighth middlings; flour from reels, dust collectors, bran dusters, etc.
380 Low-grade flour, 1½ per cent to 2 per cent. Flour from the tail end of the mill.

EXPLANATION OF TERMS.

The sample of whole wheat was taken just before it entered the rolls. This was cleaned, tempered, and would contain all the constituents which go into the different streams. The first break flour is made by the first break rolls. This is the first treatment of the wheat by the milling process proper. Bran dust and any other impurity such as crease dirt clinging to the wheat kernel thus gets into this flour. For this reason, the first break flour is inferior to the flour made in the second and third breaks.

The second and third break flours come more from the interior of the wheat kernel. But for the presence of some bran powder, which injures the color, these two flours would be very good. The fourth break flour comes from the portion of the wheat kernel next to the bran. The floury portion is literally shaved off from the bran. For this reason, the fourth break flour is more nearly like the flour from the sixth and seventh middlings.

The sixty-five per cent short-patent flour is made from the best and purest middlings. One purpose of making the breaks is to take off the coarsest part of the outside bran. In doing this some flour is produced, but the greater part of the interior of the wheat kernel is left in a granular condition. These particles of the endosperm are of various grades and sizes. Some resemble the well-known breakfast foods "Cream of Wheat" and "Vitos," and others are coarser or finer than these. These are what are known as middlings. Because of their coarse granular state, the middlings can, by means of purifiers, be freed from such fine dust as can not be removed by sieves. Because of their purity, they can be made into the very finest flour. The process of producing flour from the middlings consists of a series of crushing operations. These operatons are known as reductions. Each time they are crushed some flour is produced and the middlings are reduced in size. Before they are reduced again they are repurified. It is this process of crushing and repurifying which produces the granular flour.

The middlings are not made up of material such that all can be reduced to flour. As the wheat kernel is broken in the break rolls, larger or smaller pieces of bran are also broken off in connection with the portions of the endosperm which make up the middlings. If it were not for these bran particles the middlings could at once be reduced to flour. Each time the middlings are reduced some flour is produced, and the middlings which remain to be reduced again are relatively richer in those portions of the wheat kernel which are part of the bran or come next to the bran. When no more good flour can be crushed from these middlings they correspond to what is sometimes sold as a feed under this name. This is very much like the material from which the eighth-middlings flour in this series is made. If such middlings are further reduced a low-grade flour is produced. When no more flour can be obtained from the middlings, what remains goes into the shorts. By itself this is sometimes called white shorts. From this it follows that the flour gets poorer as the number designation of the middlings becomes higher.

TABLE XIX.—Chemical composition of flours from different mill streams, four-break mill. Percentages on air-dry basis.

Serial number.	Mill stream.	Moisture.	Ash.	Protein.	Gluten.		Acidity.	Amino compounds.	Phosphorus.		
					Wet.	Dry.			Water-soluble.	Total.	Per cent of total phosphorus soluble in water.
367	Wheat	11.48	1.97	12.77	....	....	.399	.456	.154	.430	35.81
368	First break	11.65	0.61	11.57	32.9	11.1	.200	.240	.073	.144	50.69
369	Second break	11.77	0.54	11.57	31.9	10.9	.157	.185	.060	.119	50.42
370	Third break	11.78	0.59	13.68	40.9	13.8	.170	.185	.058	.116	50.00
371	Fourth break	11.49	0.75	15.88	44.9	15.3	.240	.237	.093	.175	52.90
372	Short patent, 65 per cent	11.20	0.41	11.09	29.8	10.3	.107	.171	.026	.090	28.89
373	Long patent, 80 per cent	9.70	0.51	12.29	36.3	12.1	.127	.194	.037	.106	34.90
374	Straight, 98 per cent	9.58	0.49	12.08	37.0	12.2	.137	.166	.039	.109	35.77
375	Fourth and fifth middlings	10.52	0.59	12.89	38.5	12.5	.182	.240	.059	.135	43.70
376	Sixth and seventh middlings	9.89	0.83	13.08	36.9	12.1	.271	.291	.093	.196	47.45
377	Eighth middlings	10.18	1.44	15.39	36.2	13.5	.504	.533	.193	.324	59.71
378	First clear, 33 per cent	11.14	0.71	13.00	36.1	12.1	.212	.254	.085	.162	52.47
379	Second clear, 18 per cent	9.73	0.88	14.31	39.6	13.4	.300	.311	.105	.315	33.41
380	Low-grade flour, 1½ to 2 per cent	10.27	1.55	15.34	37.3	12.8	.493	.579	.200	.364	54.95

TABLE XX.—Chemical composition of flours from different mill streams, four-break mill. Percentages on moisture-free basis.

Serial number.	Mill stream.	Ash.	Protein.	Gluten.		Acidity.	Amino compounds.	Phosphorus.		
				Wet.	Dry.			Water-soluble.	Total.	Per cent of total phosphorus soluble in water.
367	Wheat	2.22	14.43	....	....	.451	.515	.174	.486	40.50
368	First break	0.69	13.10	37.24	12.6	.226	.272	.083	.163	57.38
369	Second break	0.62	13.11	36.14	12.3	.178	.210	.068	.135	57.13
370	Third break	0.67	15.51	46.38	15.6	.193	.210	.066	.132	56.70
371	Fourth break	0.85	17.94	50.74	17.3	.271	.268	.105	.198	59.78
372	Short patent, 65 per cent	0.46	12.49	33.55	11.6	.120	.193	.029	.101	32.53
373	Long patent, 80 per cent	0.56	13.61	40.18	13.4	.141	.215	.041	.117	38.63
374	Straight, 98 per cent	0.54	13.36	40.92	13.5	.152	.184	.043	.121	39.56
375	Fourth and fifth middlings	0.66	14.40	43.00	14.0	.203	.268	.066	.151	48.81
376	Sixth and seventh middlings	0.92	14.52	40.96	13.4	.301	.323	.103	.218	52.67
377	Eighth middlings	1.60	17.13	40.29	15.0	.561	.593	.215	.361	66.46
378	First clear, 33 per cent	0.80	14.63	40.61	13.6	.239	.286	.096	.182	59.03
379	Second clear, 18 per cent	0.98	15.86	43.88	14.8	.332	.345	.116	.349	37.02
380	Low grade, 1½ to 2 per cent	1.73	17.10	41.59	14.3	.550	.646	.223	.406	61.27

Chemical Composition of Flour from the Streams of the Four-break Mill.

The chemical composition of the flours from the different mill streams described above is given in table XIX. This table gives the percentages of the air-dry sample. In table XX these percentages have been calculated to the moisture-free basis. This makes all the samples more comparable. The headings for the different columns in these two tables have the same meaning as in tables IX, X and XI, giving the chemical composition of commercial flours.

The straight and the long-patent flours were obtained from stock flours made a few days before these samples were taken. This explains why these flours do not fit in with the others in composition as well as would be expected.

Ash.

The short patent has the lowest per cent of ash, while the low grade has the highest. The ash content is lowest in those streams which come from the interior of the kernel, while it is highest in these streams which are taken from that portion next the bran. Thus the ash contents in the first three breaks differ but very little from each other, but in the fourth break the ash is notably higher. The short patent, which is made from the cleanest middlings, those which are almost entirely from the interior of the kernel, is lowest in ash percentage. From the fourth up to the seventh middlings there is a gradual increase in ash, and the eighth middlings, which comes mostly from the portion of the wheat next to the bran, is almost as rich in ash as the low grade. There is an apparent inconsistency in the ash content of the long patent and the straight flour. From the way these flours are made up, the straight ought to have a larger ash percentage than the long patent. The small difference found is easily due to the way the sample was taken in the mill, as just explained. This small difference does not invalidate the general tendency noted.

Protein.

The protein content follows almost the same law of variation as the ash. The short patent has the lowest per cent of protein while the eighth middlings flour has the highest. The first- and second-break flours, the short- and the long-patent and the straight flours all have a smaller percentage of protein than the wheat from which they are made, while the fourth to the seventh middlings have nearly the same protein content as the wheat. The other streams are all higher in protein content than the wheat. These come from that portion of the kernel next to the bran, and the nearer to the bran the flour is taken the richer it is in protein. It should be recalled that some of these streams which are very rich in protein yield a small percentage flour, and so their effect on the total protein content of the long-patent and the straight flours with which they are incorporated is relatively small.

Gluten.

The conclusions made in the preceding part of this bulletin in regard to quality and quantity of gluten are borne out by the figures in tables XIX and XX. The short-patent flour has the smallest amount of gluten in regard to quantity, yet we know that this is one of the best in quality. The fourth-break flour has the largest quantity of gluten, yet it is of a rather inferior quality as shown by the baking test.

Acidity.

The acidity figures show very plainly what portion of the wheat kernel the flour comes from. There is a gradual increase in acidity in the flour streams in proportion as they contain material next to the bran. These acidity figures represent the maximum; that is, they were determined at 40° C. and with two hours' extraction. The average acidity values given above for the short patent, long patent and straight were, respectively, .128, .163, and .166. Here they are .120, .141, and .152. If the flour is made from the same wheat, the long patent will have a larger acidity value than the short patent, and the straight will have more than the long patent. And the same general relationship holds when we take the average acidity value of a large number of these commercial grades. But for the fact that different wheats will themselves have different acidity values when treated in the same manner as for the determination of acidity in flour, acidity would show exactly from what portion of the wheat kernel the flour comes. As has been shown in the previous tables, one wheat may have over 50 per cent more acidity than another under the same conditions. This fact affects the figures for acidity somewhat in determining the grade of flour. The relation of acidity in flour to that in the wheat will be referred to later.

The Amino Compounds.

Amino compounds were determined in the following way: Eleven grams of flour were placed in a 600 cc. Erlenmeyer flask and 400 cc. of a 1 per cent solution of sodium chloride added. The whole was thoroughly shaken and the shaking repeated every ten minutes for one hour. It was then allowed to settle for thirty minutes, when a little over 200 cc. were filtered off. To 200 cc. of the filtrate were added 20 cc. of a 10 per cent solution of phosphotungstic acid. It was then allowed to stand over night and then filtered. This filtrate was perfectly clear. Two hundred cubic centimeters of this clear filtrate were placed in a Kjeldahl flask, 5 cc. sulphuric acid added, placed over a burner, and the solution evaporated to 25 cc. Next, the rest of the sulphuric acid was added and the nitrogen determination finished in the regular way. To prevent bumping during digestion glass beads were used.

There is a close relationship between the amino compounds and the acidity values. With the exception of the long-patent flour, the acidity values and the amino compounds vary almost in the same proportion. See the curves for these values in plate X. The amino compounds may be products of protein decomposition, or cleavage. When proteins break down they form amino compounds. On the other hand, when proteins are built up there is a synthesis of amino compounds. It was shown in bulletin No. 177 that when wheat germinates, amino compounds are formed very rapidly. The relation of these amino compounds to the baking qualities of the flour is a very important subject for investigation.

Water-soluble Phosphorus.

The phosphorus in compounds soluble in water was determined under the same conditions for extraction as the acidity determination. It was shown previously in connection with the commercial flours that there is a very close relationship between the water-soluble phosphorus and acidity, and that the water-soluble phosphorus does not account for all of the acidity. The close relationship between the amino compounds and acidity accounts for this difference, at least in part. We shall not have a thoroughly satisfactory test for acidity in flour until we can distinguish between true acidity and acidity influenced by soluble phosphorus compounds natural to the flour.

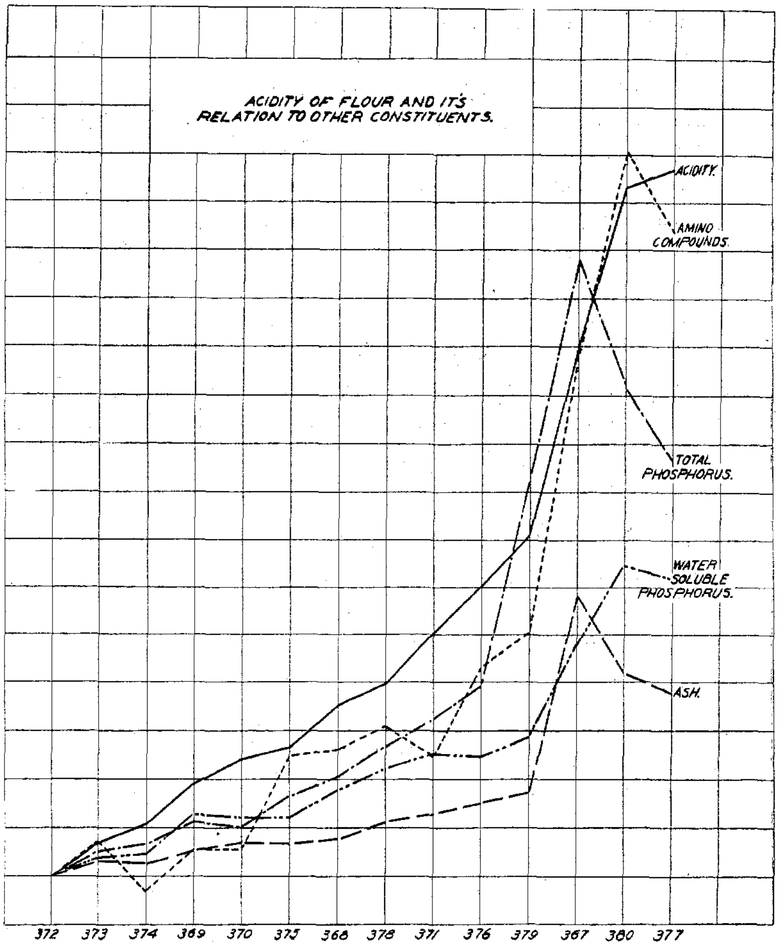
Total Phosphorus.

The figures for total phosphorus show a very close relation to the figures for acidity, even closer than the water-soluble phosphorus. The wheat has the highest percentage of phosphorus, while in proportion as the flour stream contains more bran or comes from the portion of the wheat kernel near the bran, the phosphorus content increases.

Percentage of Total Phosphorus Which is in Compounds Soluble in Water.

Of the total phosphorus in this wheat 40.5 per cent is soluble in water. The phosphates show the least solubility in the short-patent flour and the greatest in eighth-middlings flour. The

Plate X



short patent, the long patent and the straight flour all have a lower percentage of water-soluble phosphorus than the wheat, while all the other streams are higher. Those flour streams which are high in total phosphorus have a very high per cent of soluble posphorus, but increase in total phosphorus is accompanied by a larger increase in the water-soluble. The phosphorus in the portion of the wheat kernel near the bran is more soluble than in the main part of the endorsperm.

Acidity of Flour and Its Relation to Other Substances.

From the composition of these mill-stream flours it is plain that acidity is very closely related to the amino compounds, total phosphorus, water-soluble phosphorus, and ash. The figures for acidity were arranged in an ascending series and the figures for the other constitutents were put in parallel columns. The results as plotted are given in plate X. To have the lines start at the same point, the differences between the highest figure at the beginning of the series and lower figures were added to these so as to have all the first figures of the same magnitude. This does not change the relation of the curves to each other except as to distance. The advantage of this arrangement is that the curves are brought closer together and their relations to each other stand out more conspicuously.

BAKING TESTS ON MILL-STREAM FLOURS FROM FOUR-BREAK MILL.

The results of the baking tests are found in table XXI. The headings have the same meaning as in the tables for the baking tests on commercial flours.

Percentage Absorption.

The break flours, as a class, are lowest in absorption. Next follow the flours largely made from the pure middlings, while the flours taken from streams near the tail end of the mill have the highest power of absorption.

Amount of Flour and Water Used for the Loaf.

The weight of flour used for each loaf depends on the moisture content. The higher the moisture percentage the larger the weight of flour, and the lower the moisture percentage the smaller the weight of flour. The amount of flour used for each loaf corresponds to 297½ grams of dry matter. This gives each loaf the same amount of all materials except the water, which depends for its amount on the absorption. The higher the percentage of absorption, the more water is used.

Fermentation Period.

The fermentation period is longest in those flours which are low in water-soluble phosphates, while the period is short in comparison in those flours which themselves are high in water-soluble phosphates or contain streams high in these soluble phosphates. The fermentation period is longest in the two patents and the straight flours, notably shorter in the break flours and the fourth and the seventh middlings, while it is shortest in the clears and low grade which contain streams very high in soluble phosphates. It should be noted that the figures for the fermentation period can not have the same accuracy as the figures for several of the other measurements, but the correspondence between the water-soluble phosphates and the fermentation period is so manifest that it can not be accidental. The question arises: Do these phosphates furnish food for the yeast cells, and so shorten the fermentation period, or is the presence of the soluble phosphates an indication of such a quality of gluten that it ripens faster? This question is being further investigated.

Maximum Expansion of Dough, Loaf Volume and Gluten Quality Factor.

With the exception of the fourth break, sixth, seventh and eighth middlings, and low grade, these flours are equal to the average of good flours in maximum expansion and loaf volume. The first and second break and the first clear have the largest loaf volume. This again emphasizes the fact that loaf volume alone does not of itself indicate the strongest or best flours; but it shows, also, that these streams, when blended with the rest of the flour as in the straight, would add to and not diminish the loaf volume.

The gluten quality factor shows very plainly that the flour which comes from the portion of the wheat kernel next to the bran has a poor gluten, although large in quantity. The gluten quality factor shows, moreover, that these streams, weak in themselves, when blended with other streams as in the straight and first clear, result in a flour well suited for bread making where texture and color are not of first importance.

TABLE XXI.—Baking tests. Mill-stream flours, four-break mill.

Serial No.	Mill Stream.	Percentage moisture	Percentage absorption	Flour for loaf, grams	Water for loaf, cc	Time for proving, minutes. 1st rise.	2d rise.	3d rise.	Total.	Maximum expansion of dough, cc	Rise in oven, cm	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Pounds of bread per barrel of flour	Volume of loaf, cc	Gluten quality factor	Texture of crumb, 100 = perfection	Color of loaf, 100 = perfection
368	First break	11.65	55.0	340	187	55	87	29	171	2,400	4.7	15	46	500	287	1,925	3,095	96	95
369	Second break	11.77	55.0	340	187	55	80	32	167	2,350	4.8	17	51	494	287	1,950	3,116	98	98
370	Third break	11.78	56.6	340	193	60	76	29	165	2,350	4.5	20	45	502	290	1,850	2,826	95	96
371	Fourth break	11.49	56.6	339	192	64	73	28	165	2,200	3.3	19	45	502	290	1,750	2,041	93	89
372	Short patent, 65 per cent	11.20	58.3	338	197	75	89	31	195	2,400	4.7	23	40	507	293	1,820	2,927	100	100
373	Long patent, 80 per cent	9.70	60.0	333	200	72	85	29	186	2,550	4.6	21	42	505	297	1,890	3,181	100	100
374	Straight, 98 per cent	9.58	60.0	333	200	65	91	26	182	2,400	4.7	23	38	507	297	1,880	3,023	99	100
375	Fourth and fifth middlings	10.52	60.0	335	201	57	91	25	173	2,300	4.3	21	44	506	297	1,830	2,652	98	98
376	Sixth and seventh middlings	9.89	61.6	333	205	60	82	25	167	2,100	3.3	25	38	511	300	1,810	2,015	89	93
377	Eighth middlings	10.18	63.3	334	212	58	76	26	160	1,750	1.4	19	42	520	303	1,500	893	84	94
378	First clear, 33 per cent	11.14	61.6	338	208	56	71	27	154	2,350	5.1	36	41	514	306	1,940	3,237	96	96
379	Second clear, 18 per cent	9.73	60.0	333	200	53	69	28	150	2,250	4.4	12	40	516	297	1,840	2,650	90	90
380	Low grade, 1½ to 2 per cent	10.27	66.6	334	223	74	50	25	149	1,550	fell .8	24	44	524	310	1,220	227	76	76
	Average	10.68	59.6	336	200	62	78	28	168	2,227	3.8	21	43	508	296	1,785	2,453	93	94

Texture and Color.

These figures show that flours which have a good quality of gluten from the standpoint of expansion and loaf volume will not make a bread having the desired texture and color. Yet when these streams are blended with all the other streams, as in the straight flour, the texture and color of the bread is equal to the very best flours.

Photographs of Bread from Mill-Stream Flours from Four-break Mill.

These are shown in plates XI to XIV. Plate XI shows the four loaves from the break flours, the figures under the loaf corresponding with the break number. Plate XII shows the loaves from the short patent, the long patent, and the straight flours, the loaves being numbered from left to right in the order given. In plate XIII are shown the loaves made of the middlings flours. Loaf No. 8 is from the fourth and fifth middlings, loaf No. 9 from the sixth and seventh middlings, and loaf No. 10 from the eighth middlings. Plate XIV shows the loaves from the first clear, second clear and the low grade. The numbers under the loaves are in the order given.

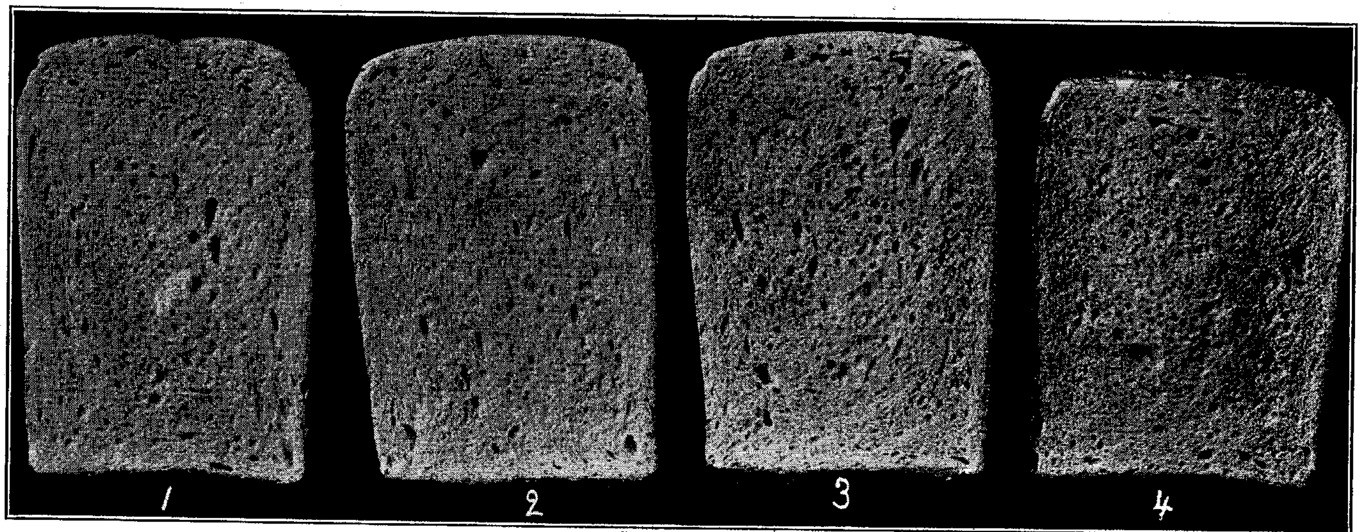


PLATE XI.

PLATE XII.

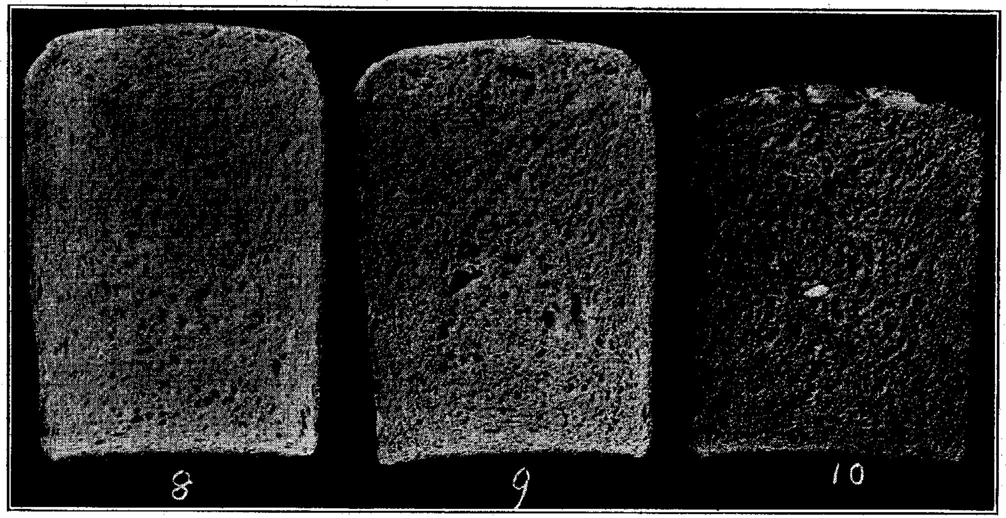


PLATE XIII.

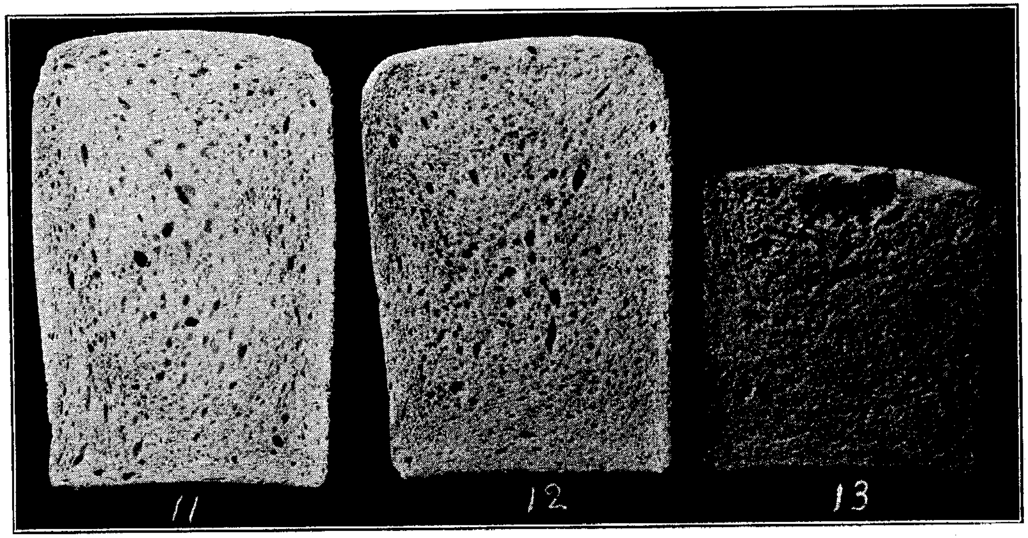


PLATE XIV.

FLOUR FROM THE FIVE-BREAK MILL.

The results secured on the tests made on the nineteen different mill-stream flours from a four-break mill proved to give such valuable data that it was decided to obtain as full a set as possible from a large five-break mill. Samples of the flours from twenty-six different separations were secured.

DESCRIPTION OF MILL-STREAM FLOURS.

SOURCE OF SAMPLE.

Serial No.

389 Wheat from which the following twenty-six flours were made.

390 Patent flour, 70 per cent. Sizing flour from first, second, third, fourth and fifth middlings, also the first reduction of chunks and first sizing. The clear purified middlings are passed between the smooth rolls so set that as the middlings pass between them they are reduced to a smaller size and the flour is produced in the process. The flour thus first crushed off is the purest and best. When the middlings have been treated several times this way they become more fibrous, and their further reduction yields a flour of lower grade. For further description of the milling process see bulletin No. 177, Kansas Experiment Station.

391 Clear flour, 27 to 27½ per cent. Contains all the flour from the five breaks and the flour made in the reduction of the sixth and seventh middlings; also the flour made from second sizings, B middlings, and first and second tailings.

392 Low-grade flour, 2½ to 3 per cent. This is made up of various streams described below.

393 First break flour. Sifted through 12XX flour silk. The sieves used for dressing flour are made of silk bolting cloth. They are usually numbered from 10 to 15. The sign XX refers to a standard size. The fineness increases with the higher numbers. No. 10 is the coarsest, 109 meshes per inch, and No. 15 is the finest, 150 meshes per inch. Sometimes sieves coarser or finer than these are used for dressing or sifting flour. The sieves used to sift out the bran and the shorts are numbered in a different series, usually from twenty, nineteen meshes, to seventy, sixty-eight meshes, and are called grit gauzes. The flour from the first break is produced in the first breaking or grinding of the wheat and by the sifter. The sifting of any stock produces flour dust. Thus each one of the streams mentioned contains flour dust made by the sifting processes used in its separation. The first break flour contains crease dirt and some fibrous materials broken from the bran. This flour goes to the clear.

394 Second break flour. Sifted through 12XX 125 meshes. Goes to the clear flour. Contains the flour made in the second breaking of the kernel and by the sifting processes. This flour is

better than the first break flour. It contains less fiber and dirt, and could go into a long patent.

395 Third break flour. Sifted through 12XX. Goes to the clear flour. This is the cleanest of the break flours. It comes more from the center of the wheat kernel than any of the others. The object of making the breaks is to make middlings and separate them from the bran. In doing so, flour is produced. This flour is sifted out after each break. Naturally, any dirt present on the wheat kernel or any bran powder made fine enough to pass the silk bolting cloth gets into the flour. It is for this reason that the first break flour contains more dirt and fibrous material from the bran than the second, and also that there arc more of these materials in the second break flour than in the third.

396 Fourth break flour. Sifted through 13XX, 129 meshes, and 14XX, 139 meshes. This goes to the clear flour. Fourth-break flour comes from a portion of the wheat kernel nearer the bran than the first three break flours.

397 Fifth break flour. Sifted through 14XX. It goes to the clear flour. The flour from this last break comes from that portion of the wheat kernel next to the bran. After the larger portions of the endosperm have been loosened from the bran in the first three breaks, the action of the corrugated rolls is that of shaving the bran. This shaving action is more intensified in the fifth break. Thus nearly all of the flour from the fifth break comes from the layer of endosperm immediateIy under the bran coat.

398 First middlings flour. Sifted through 10XX and 11XX. Goes to the patent flour. There are four grades of these middlings known as first middlings. One comes from the reduction of the sizings. The sizings are coarse materials produced in the breaks, particles of the wheat kernel having both bran and endosperm, the amount of bran being proportionally smaller than the endosperm. As these sizings are passed between the rolls, the greater portion of the endosperm is separated from the bran, and this product is one of the grades of the first middlings. The other three are the purified middlings from the first, second and third breaks. As any of the middlings are passed between the rolls they are reduced to a smaller size, and in this reduction flour is made. This statement should be understood in connection with the description of the different middlings flour.

399 Second middlings flour. Sifted through 11XX and 12XX. Goes to the patent flour. Some of these middlings come from the residue of the reduction of the first middlings. It is the coarse material remaining from the first reduction of the first middlings after the first middlings flour has been sifted out. This material has passed the smooth rolls once. The second middlings also contain fine purified middlings from the first, second

and third breaks. These middlings from the breaks are of a smaller-size than those classed as first middlings from these breaks.

400 Third middlings flour. Goes to the patent. Sifted through 12XX and 13XX. Some of the third middlings are the residue from the reduction of the second middlings. In this residue is found material which has passed the smooth rolls twice and some which has passed them once. The third middlings also contain fine purified middlings from the fourth break and the second sizings.

401 Fourth middlings flour. Sifted through 12XX, 13XX and 14XX. Goes to the patent. Part of these middlings are made up of residue from the reduction of the third middlings. In this residue will be found material which has passed the smooth rolls once, twice or three times. They also contain fine purified middlings from the fourth break. These middlings from the fourth break are finer than those used in the third middlings. The fourth middlings also contain fine scalped stock from second sizings and fine scalped products from first tailings. Scalping means separating, by means of sieves, coarse branny material from such stock as can be used in the production of good flour.

402 Fifth middlings flour. Flour sifted through 13XX and 14XX. Goes to the patent flour. These middlings are made up of the residue from the fourth middlings entirely. Some of these have passed the smooth rolls once, twice, three or four times. In the production of flour from middlings, the pure middlings can not be reduced to flour by one operation. In the middlings is found a more or less branny material. This branny material is tougher than the adhering floury portion. The action of the rolls is to crush off a portion of this. As the reductions proceed less and less of the floury material adheres to the branny particles. Each reduction results in the production of flour and finer middlings containing more fibrous material. As less and less of the floury portion remains, the rolls are set closer together, and their action becomes so severe that some of the bran will be reduced to such a fine state that it will pass the flour sieves. Also, the flour is taken from the portion of the wheat kernel nearer the bran. It is for this reason that the character of the flour changes as the number of the reductions to which it has been subjected increases, and after the fifth reduction no flour is obtained which is put into a short patent.

403 Sixth middlings flour. Sifted through 14XX. Goes to the clear flour. A portion of these middlings comes from the residue of the fifth middlings reduction. Portions of this residue have passed the smooth rolls two, three, four and five times. These middlings also contain the fine scalped product from B middlings. This latter term is of local use and will be explained further on.

404 Seventh middlings flour. Sifted through 14XX. Goes to the clear flour. A portion of these middlings comes from the residue of the sixth middlings. Parts of this residue have passed the rolls from one to six times. The seventh middlings also contain fine scalped products from the second tailings. This last term is explained further on. The seventh middlings flour is also known as first low grade.

405 First sizings flour. Sifted through 10XX and 11XX. Goes to patent flour. These come from the purified middlings of the first, second and third breaks which are too large to pass 30-mesh wire. The flour is made in reducing them down to pass 36-mesh wire. Very little flour is made. The first sizings are like the first middlings in quality of the floury portion. They contain larger branny particles, When these sizings are reduced they produce one of the four grades which make up the first middlings. See under first middlings.

406 Chunks flour. Sifted through 13XX. Goes to the patent flour. They are middlings from the breaks which have been separated from the clear middlings in the process of purification. They differ from first sizings in that they have more and larger particles of bran fiber adhering to them. In appearance they look quite branny as compared with the first sizings. They have been scalped over 32-mesh wire. The floury portions of the chunks are of the same quality as that in the first middlings. The flour is made in sizing them down and the amount is small.

407 Second sizings flour. Sifted through 13XX. Goes to the clear flour. These sizings come from the cut-offs on the purifier handling sizings middlings. These middlings are made in sizing down coarse products such as have a comparatively large amount of fiber adhering to them. The flour is made in the reduction of the second sizings.

408 B middlings flour. Sifted through 14XX and 15XX. Flour goes to the clear. These come from the fibrous stock produced by the reduction of first tailings and second sizings. The flour is made by the reduction of B middlings.

409 First tailings flour. Sifted through 14XX. Goes to the clear. This is mostly fibrous matter removed from the break middlings by the purifier, and also fibrous matter from the sizing reductions. Flour is made in the reduction of these tailings.

410 Second tailings flour. Sifted through 14XX and 15XX. Goes to the clear. The second tailings come from the first tailings, and fibrous middlings from the fifth break. The flour is made in the reduction of these tailings.

411 Second low-grade flour. Sifted through 14XX. Goes to the low-grade flour. This low-grade flour, is made by the further reduction of the seventh middlings; part of this reduction is done on a roll and part on a scroll. The first low grade is made by the first reduction of the seventh middlings. (See under this head.) Second low-grade flour also contains other products from the tail end of the mill.

412 Bran-duster flour. Sifted through 14XX. Goes to the low-grade flour. This flour is brushed off from the bran.

413 Ship-duster flour. Sifted through 13XX. Goes to the low grade. Flour is brushed off from the shorts by the ship duster.

414 Roll-suction stock. Sifted through 12XX. Goes to the low grade. The rolls in grinding generate a great deal of heat. For this reason air must be continually drawn through the roll housing. This air current carries off more or less fine flour dust.

415 Stock going to fourth middlings from second sizings. Some flour made from this stock is found in the fourth middlings and in the second sizings flour. This sample is not a true flour, but one of the finer middlings used in the production of flour.

TABLE XXII.—Baking test. Mill-stream flours, five-break mill.

Serial No.	Mill-stream flours.	Percentage moisture	Percentage absorption	Flour for loaf, grams	Water for loaf, cc.	Time for rising, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc.	Gluten quality factor	Texture of crumb, 100 = perfection	Color of loaf, 100 = perfection
						1st rise.	2d rise.	3d rise.	Total rise.									
390	Patent, 70 per cent	12.16	60.0	342.0	205.5	60	85	28	173	2,650	4.75	16.2	64.5	499.0	1,845	2,322	100	100
391	Clear, 27 to 27½ per cent	12.10	60.0	341.3	204.8	57	65	24	146	2,350	5.20	16.1	63.5	501.5	1,875	2,291	88	85
392	Low grade, 2½ to 3 per cent	11.40	61.6	342.4	211.2	54	66	23	143	2,175	3.65	9.6	59.0	515.0	1,665	1,321	78	70
393	First break	13.00	55.0	348.8	191.8	57	82	24	163	2,700	5.90	7.6	69.0	494.0	1,980	3,154	86	80
394	Second break	12.97	55.0	348.8	191.8	68	81	26	175	2,500	4.50	16.6	59.5	495.0	1,845	2,076	93	86
395	Third break	12.72	55.0	343.6	189.0	56	86	28	170	2,475	4.70	14.6	56.5	491.5	1,845	2,146	94	88
396	Fourth break	12.86	55.0	344.2	189.3	55	80	26	161	2,400	4.35	15.0	53.5	495.0	1,840	1.920	93	84
397	Fifth break	12.48	56.6	343.0	194.4	59	78	26	163	2,350	3.15	18.4	50.0	499.0	1,700	1,258	75	67
398	First middlings	12.10	60.0	341.3	204.8	60	80	31	171	2,575	4.50	19.6	54.5	502.0	1,845	2,137	98	100
399	Second middlings	12.26	60.0	342.0	205.2	58	85	31	174	2,800	4.90	19.7	60.5	507.0	1,910	2,620	99	99
400	Third middlings	11.82	61.6	340.1	209.7	55	82	27	176	2,675	4.85	12.8	61.5	505.5	1,888	2,471	100	100
401	Fourth middlings	11.81	63.3	340.1	215.7	59	77	23	159	2,575	5.10	16.8	60.0	509.0	1,885	2,475	98	99
402	Fifth middlings	11.53	61.6	339.0	209.0	59	74	24	157	2,550	5.05	12.0	60.0	506.0	1,885	2,427	99	99
403	Sixth middlings	11.33	61.6	338.3	203.0	63	69	23	155	2,475	4.65	19.6	52.0	505.0	1,805	2,077	100	99
404	Seventh middlings	11.32	60.0	338.3	208.6	61	69	25	155	2,200	2.75	19.1	52.5	505.0	1,660	1,004	90	82
405	First sizings	12.35	58.3	342.0	199.5	62	71	30	163	2,400	4.20	16.5	56.5	501.0	1,775	1,789	96	94
406	Chunks	12.09	58.3	341.3	199.1	55	71	31	157	2,375	4.65	16.4	57.5	501.5	1,885	2,081	80	76
407	Second sizings	11.78	60.0	340.0	204.0	60	69	29	158	2,375	4.15	15.5	59.0	499.5	1,825	1,798	95	90
408	B middlings	11.69	60.0	339.7	203.8	55	74	23	152	2,375	4.05	13.5	60.5	499.5	1,770	1,702	96	92
409	First tailings	11.98	60.0	340.9	204.6	54	74	24	152	2,350	4.05	13.0	59.0	503.5	1,770	1,684	79	74
410	Second tailings	11.68	60.0	339.8	203.9	58	68	20	146	2,200	3.15	16.7	55.5	501.5	1,700	1,178	77	71
411	Second low grade	11.08	58.3	337.4	196.8	57	64	26	147	2,150	3.15	15.2	51.5	498.5	1,665	1,127	82	80
412	Bran duster	11.06	60.0	337.4	202.5	63	55	26	144	1,875	2.40	17.6	47.0	502.0	1,585	713	75	66
413	Ship duster	11.32	60.0	338.3	203.0	63	56	25	144	1,850	1.00	15.8	52.5	503.0	1,483	274	70	60
414	Roll-suction stock	11.57	58.3	339.0	198.0	68	52	26	146	1,950	3.70	28.0	56.0	494.0	1,710	1.233	77	69
415	Stock going to fourth middlings from second sizings	12.17	55.0	341.7	188.0	61	66	29	156	2,625	4.30	12.7	53.0	494.0	1,795	2,026	99	97

Photographs of Bread from Mill-Stream Flours from Five-break Mill.

These are shown in plates XV to XX. The loaves are numbered from left to right in the same order as the description of the flours from which they were made.

PLATE XV. Loaves from 70 per cent patent, 27½ per cent clear, and 2½ per cent low grade.

PLATE XVI. Loaves from first, second, third, fourth and fifth break flours.

PLATE XVII. Loaves from first, second, third, fourth and fifth middlings flours.

PLATE XVIII. Loaves from sixth and seventh middlings, first sizings, and chunk flours. The last loaf to the right is from the stock going to the fourth middlings from second sizings.

PLATE XIX. Loaves from second sizings, B middlings, first tailings, and second tailings flour.

PLATE XX. Second low grade, bran duster, ship duster and flour from roll-suction stock.

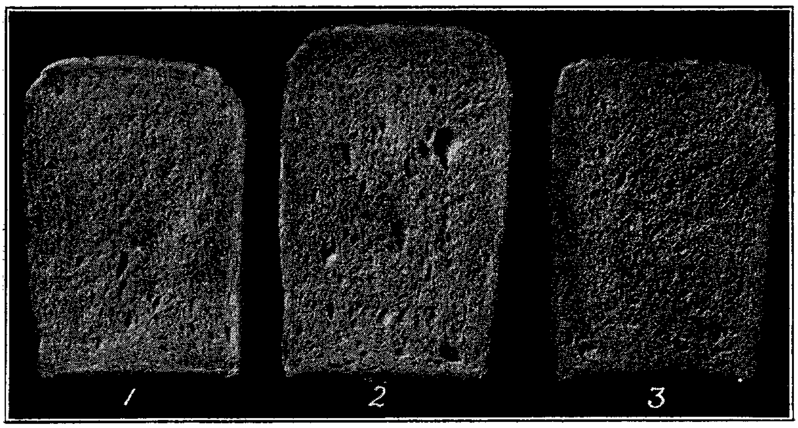


PLATE XV.

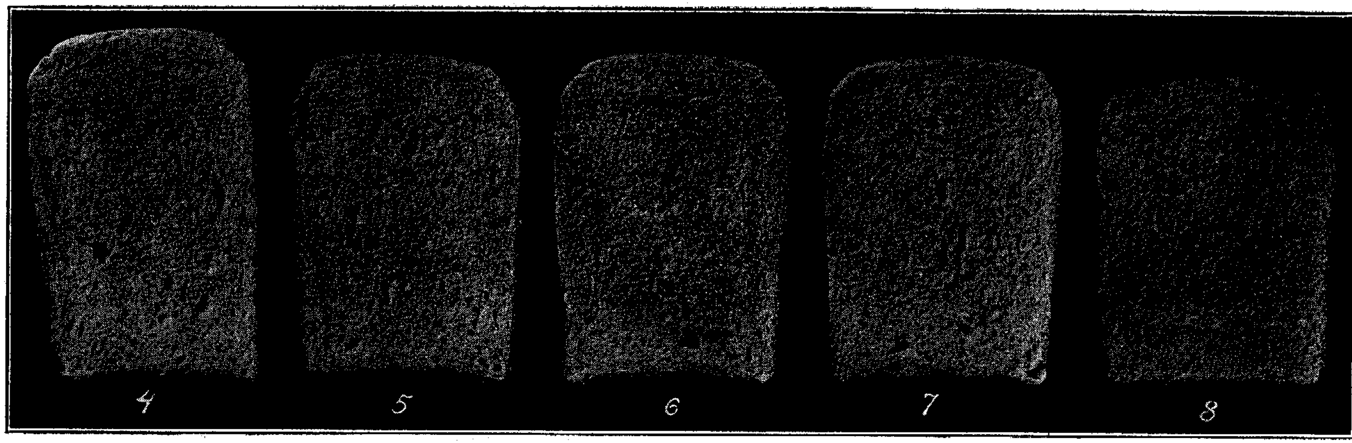


PLATE XVI.

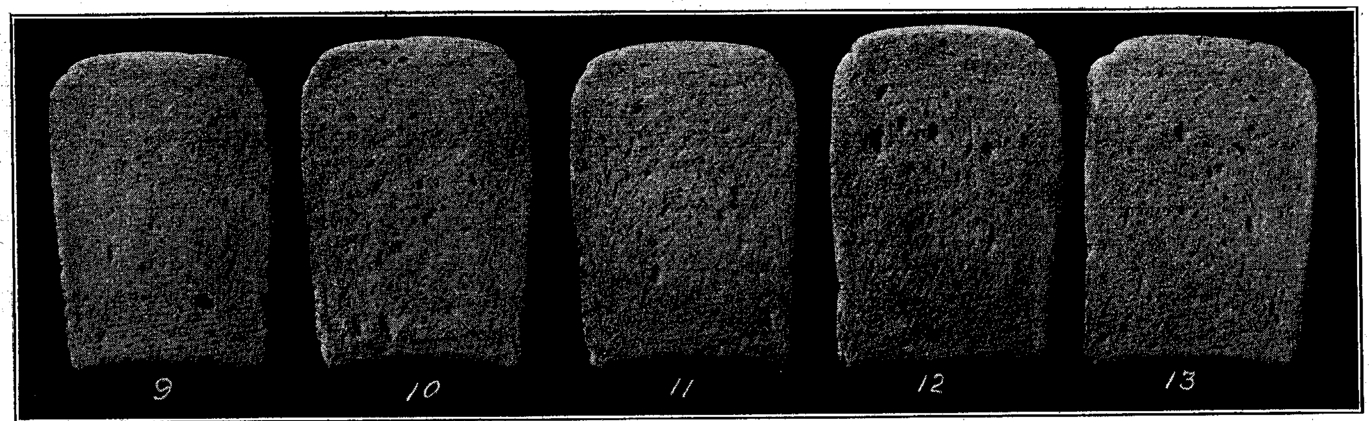


PLATE XVII.

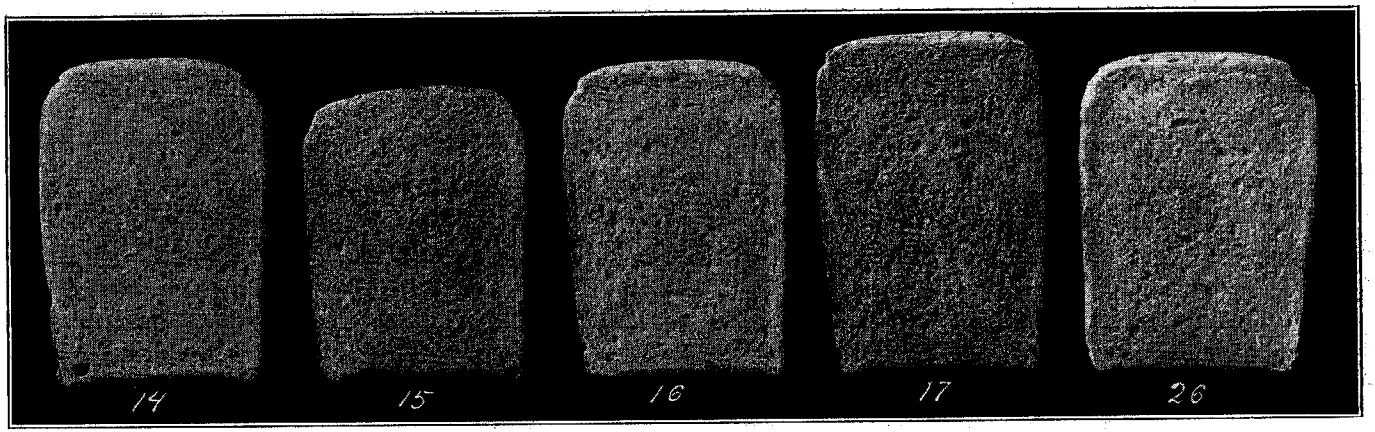


PLATE XVIII.

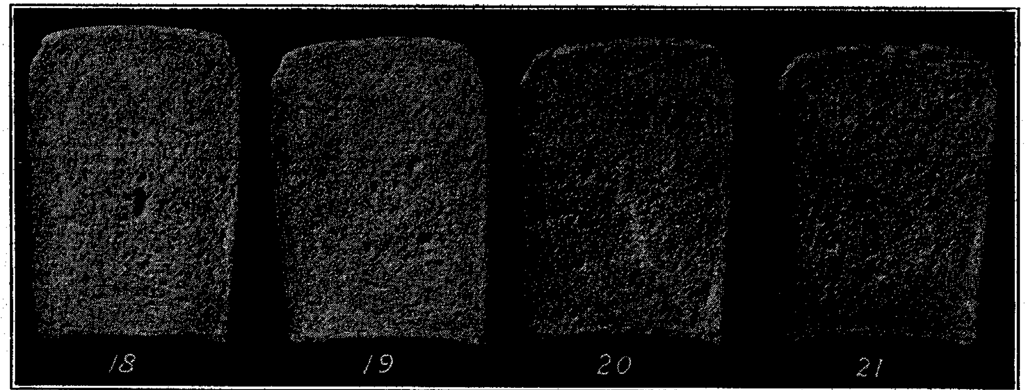


PLATE XIX.

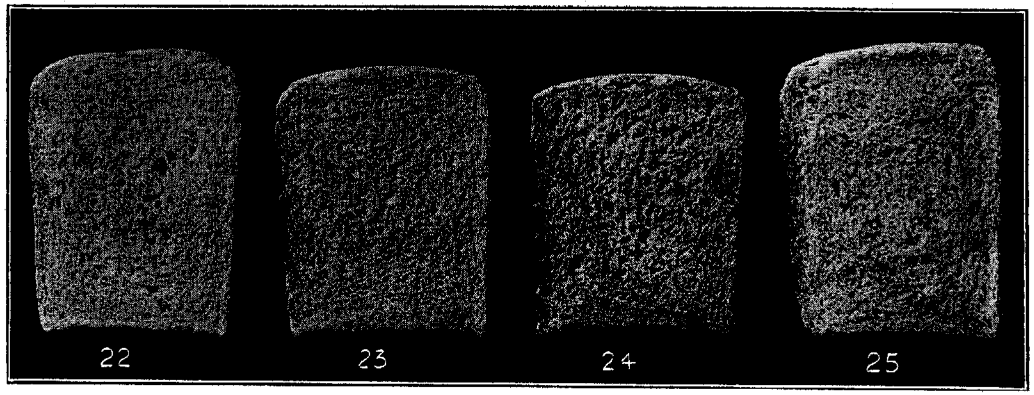


PLATE XX.

THE BAKING TESTS OF MILL-STREAM FLOURS FROM FIVE-BREAK MILL.

The baking tests were carried out as described in the first part of this bulletin, The results of these tests are tabulated in table XXII, and the appearance of the loaves is shown in plates XV to XX.

Absorption, or the Relative Amounts of Flour and Water Used in Baking.

The break flours as a class show the lowest power of absorption. This is probably due to the fact that as a class they are higher in moisture content than the others. However, as the break flours are blended with some other streams to produce the clear, the absorptive power is equal to the patent. The middlings flours have the highest absorption. Some of the streams which go into the low grade are low in absorptive power, yet the blend in the low grade gives a high absorption.

Time for Proving.

The total time for proving is longer in the patent than in the clear and the low grade. This same relative variation holds true in the three periods of riding. Of the break flours, the second and third have a longer period of proving than the others. In the description of the samples it was stated that these two could go into a long patent. Their fermentation period closely approaches that of the patent. The first, second, and third middlings flours have an average period approximating that of the patent, while the fourth and fifth middlings flours which are put in the patent have a distinctly shorter period. The first sizings and chuncks flours also have a fermentation period almost equal to that of the fourth and fifth middlings. Those flours which are blended to make the low grade have the shortest fermentation period. Strong flours have a longer fermentation period than weak ones. The time of proving bears an intimate relation to certain ash constituents, as will be noted further on.

Maximum Expunsion of Dough.

The patent flour has the highest expansion, the low grade has the lowest, while the expansion of the clear is almost an average of the two. The break flours, as a class, have a high expansion. This indicates a quality of gluten such that they could be blended with the patent where the color will allow. As the middlings decrease in quality or as the number of reductions increase, with, consequently, a larger per cent of the material from the portion of the wheat kernel next to the bran, the maximum expansion decreases. Those flours which make up the low grade have the lowest expansion. This total expansion depends on the quality of gluten in the dough. Ordinarily a good gluten will give the highest expansion. However, there are cases where high expansion is not accompanied by other qualities, and so it is sometimes found that a flour classed as second has a higher expansion than one classed as first.

Rise in Oven and Loaf Volume.

The rise in the oven and the loaf volume are closely related, as was pointed out before. The streams near the tail end of the mill give the lowest rise in the oven and the smallest loaf volume. These have a large amount of gluten, but it is of poor quality. It is also very probable that the presence of fibrous material may also have such an effect on the gluten that the loaf volume is lessened.

Gluten Quality Factor.

The gluten quality factor, as was previously shown, is simply a summary of the qualities indicated by maximum expansion, rise in the oven, and loaf volume. Those streams which have a large amount of gluten because they come from that portion of the wheat kernel rich in gluten have a low gluten quality factor, while streams low in gluten because they come from the portion of the wheat kernel low in gluten have a high gluten quality factor. Is it because the gluten in some portions of the wheat kernel is actually inferior in quality as compared with that in the other portions, or is it because of the presence of accessory materials which have a deleterious effect on the gluten? As the reduction treatments beome more severe, portions of the fibrous, branny material will find their way into the flour. A bran extract will materially affect the baking qualities of a flour. Is it possible that some of the extract is actually squeezed out from the bran and so finds its way into the flour, or do the fibrous materials become so intimately mixed with the gluten that they affect the quality? That the addition of accessory materials influences the properties of the dough has been amply shown. (See Bull. 190, Kansas Experiment Station.) It should also be remembered that the physical properties of those streams near the tail end of the mill are very different from those near the head. The flours from the middlings up to the sixth are granular; the middlings beyond this, as well as some other streams, give a flour which is very fine and impalpable. The feel of the flours is different. That this difference in physical properties has an influence on the baking qualities is no doubt true, and is a line of investigation which would bring profitable results.

Texture and Color.

While the first and fourth break flours make a good showing in those measurements which make up the gluten quality factor, the figures for texture and color show that these flours are inferior to the second and third break as well as the middlings flour. This emphasizes again the statement that any one figure alone will not determine the quality of a flour. The quality of a flour is made up of a combination of properties. Some of these will show themselves in total expansion; some in oven rise and loaf volume; some in fermentation period; some in absorption, and others in texture and color. In a good flour these properties are balanced, and a flour must make a good showing in all these respects. The middlings flours meet these requirements better than any others. They are good in all the properties measured. The flours which go into the low grade make a poor showing both in regard to texture and color, as well as the other properties which are measured.

Arrangement of Mill-Stream Samples According to Color, Together with the Color Scow for Bread.

The flours from the different mill streams were placed on glass slides with a slick according to the method of practical millers. The slides were then placed under water, as in the Pekar test. The flours were then arranged in the order of their color values, placing the best one first. This arrangement was made independently by the laboratory workers and a practical miller who kindly volunteered his services. This miller has had experience in milling in Germany, France, and the United States. The color score of the bread is also given opposite the name of the flour from which it was made. The two arrangements differ only in minor details. The arrangement is shown in the accompanying tabular form:

MILL-STREAM FLOUR SAMPLES.

Arrangement according to color with the color score for the bread.

Serial No.	By the laboratory workers.	Color of loaf.	Serial No.	By a practical miller.	Color of loaf.
398	First middlings	100	398	First middlings	100
399	Second middlings	99	399	Second middlings	99
400	Third middlings	100	390	Patent	100
390	Patent	100	400	Third middlings	100
401	Fourth middlings	99	401	Fourth middlings	99
402	Fifth middlings	99	402	Fifth middlings	99
407	Second sizings	90	403	Sixth middlings	99
403	Sixth middlings	99	407	Second sizings	90
405	First sizings	94	408	B middlings	92
408	B middlings	92	405	First sizings	94
414	Roll suction	69	396	Fourth break	84
395	Third break	88	414	Roll suction	69
394	Second break	86	395	Third break	88
391	Clear	85	394	Second break	86
404	Seventh middlings (First low grade).	82	404	Seventh middlings (First low grade).	82
396	Fourth break	84	391	Clear	85
411	Second low grade	80	393	First break	80
406	Chunks flour	76	392	Low grade	70
393	First break	80	411	Second low grade	80
412	Bran duster	66	406	Chunks flour	76
410	Second tailings	71	409	First tailings	74
409	First tailings	74	412	Bran duster	66
397	Fifth break	67	410	Second tailings	71
392	Low grade	70	397	Fifth break	67
413	Ship duster	60	413	Ship duster	60

Chemical Composition of Flour from Different Mill Streams from Five-break Mill.

The figures for the chemical composition of the flours from different mill streams are given in table XXIII. The figures calculated to a moisture-free basis are found in table XXIV. In the following discussion the latter figures will be used,

TABLE XXIII.—Chemical composition of flour from different mill streams—Air-dry percentages.

No.	MILL STREAM	Moisture.	Ash.	Protein.	Fat.	Gluten.		Acidity.		Amino compounds.	Phosphorus.			
						Wet.	Dry.	25° C.	40° C.		Water-soluble at 25° C.	Water-soluble at 40° C.	Total.	Per cent of total phosphorus soluble in water at 40° C.
389	Wheat	12.08	1.70	13.04	1.86	......	....	.137	.420	.466	.058	.192	.424	45.5
390	Patent, 70 per cent	12.16	.46	11.17	1.01	36.4	11.33	.065	.114	.142	.018	.025	.097	25.7
391	Clear, 27 to 27½ per cent	12.10	.73	13.65	1.40	47.2	14.33	.149	.215	.237	.062	.086	.164	52.4
392	Low grade, 2½ to 3 per cent	11.40	.96	14.06	1.67	49.9	14.43	.190	.300	.348	.086	.135	.238	56.7
393	First break	13.00	.72	11.50	1.12	40.4	13.23	.118	.208	.240	.046	.071	.141	50.3
394	Second break	12.97	.70	12.66	1.96	42.6	12.73	.120	.184	.208	.052	.072	.144	50.0
395	Third break	12.72	.70	13.77	1.17	48.6	15.03	.110	.192	.207	.054	.073	.150	48.6
396	Fourth break	12.86	.77	14.88	1.29	49.4	15.06	.139	.220	.249	.061	.090	.178	50.5
397	Fifth break	12.48	1.12	18.10	1.73	66.8	20.20	.206	.324	.318	.100	.164	.259	63.3
398	First middlings	12.10	.46	10.97	0.92	33.2	10.73	.062	.089	.171	.015	.020	.083	24.1
399	Second middlings	12.26	.44	11.12	0.83	34.8	10.56	.059	.096	.175	.015	.022	.082	26.8
400	Third middlings	11.82	.48	11.53	0.92	32.9	10.80	.061	.110	.182	.023	.029	.094	30.8
401	Fourth middlings	11.81	.51	12.14	1.07	38.2	9.95	.071	.125	.177	.023	.037	.104	35.5
402	Fifth middlings	11.53	.55	11.97	1.00	39.1	12.25	.077	.131	.192	.027	.039	.106	36.8
403	Sixth middlings	11.33	.55	12.21	1.21	40.1	17.92	.083	.145	.202	.035	.047	.118	39.8
404	Seventh middlings	11.32	.84	13.67	0.97	50.4	14.18	.146	.244	.297	.071	.091	.191	47.6
405	First sizings	12.35	.56	10.80	1.10	37.2	11.11	.080	.141	.170	.037	.045	.111	40.5
406	Chunks	12.09	.90	11.67	1.47	41.7	12.10	.140	.254	.274	.074	.104	.198	52.5
407	Second sizings	11.78	.78	11.41	1.35	36.5	11.11	.128	.208	.245	.048	.080	.164	49.4
408	B middlings	11.69	.64	11.41	1.05	41.6	12.35	.114	.184	.215	.050	.068	.151	22.5
409	First tailings	11.98	1.01	13.33	1.57	48.9	14.43	.150	.277	.279	.067	.128	.230	55.6
410	Second tailings	11.68	1.20	14.59	2.19	47.1	14.96	.164	.349	.392	.083	.155	.289	53.6
411	Second low grade	11.08	.90	12.65	1.50	44.2	12.48	.161	.271	.302	.058	.108	.204	52.9
412	Bran-duster flour	11.06	1.13	15.62	1.72	58.6	16.25	.196	.329	.359	.072	.143	.268	53.3
413	Ship-duster flour	11.32	1.40	13.44	2.14	40.9	12.50	.212	.413	.448	.062	.169	.331	51.0
414	Roll-suction flour	11.57	.70	10.83	1.40	35.1	10.66	.115	.413	.211	.060	.069	.145	47.5
415	Stock going to fourth middlings from second sizings	12.17	.40	10.99	1.13	41.4	11.85	.057	.117	.067	.020	.069	.099	69.6

TABLE XXIV.—Chemical composition of flour from different mill streams—Moisture-free percentages.

No.	MILL STREAM.	Ash.	Protein.	Fat.	Gluten.		Acidity.		Amino compounds.	Phosphorus.			
					Wet.	Dry.	25° C.	40° C.		Water-soluble at 25° C.	Water-soluble at 40° C.	Total.	Per cent of total Phosphorus soluble in water at 40° C.
389	Wheat	1.93	14.83	2.11	....	....	.156	.478	.530	.066	.218	.482	51.73
390	Patent, 70 per cent	.52	12.68	1.15	41.42	12.89	.074	.130	.162	.021	.028	.110	29.25
391	Clear, 27 to 27½ per cent	.83	15.53	1.59	53.71	16.31	.170	.245	.270	.071	.098	.187	59.64
392	Low-grade, 2½ to 3 per cent	1.08	15.87	1.89	56.34	16.29	.215	.339	.396	.097	.152	.269	64.01
393	First break	.93	13.21	1.29	46.42	15.20	.136	.239	.276	.053	.082	.162	57.79
394	Second break	.80	14.55	2.52	48.95	14.62	.137	.211	.239	.060	.083	.165	57.45
395	Third break	.80	15.79	1.34	55.78	17.24	.126	.220	.237	.062	.084	.172	55.74
396	Fourth break	.88	17.07	1.48	56.66	17.27	.160	.252	.286	.071	.103	.204	78.34
397	Fifth break	1.28	20.67	1.98	76.29	23.07	.235	.370	.363	.114	.187	.296	72.29
398	First middlings	.52	12.48	1.05	37.78	12.21	.071	.101	.195	.017	.023	.094	27.43
399	Second middlings	.50	12.68	.95	39.67	12.04	.067	.109	.200	.017	.025	.093	30.55
400	Third middlings	.54	13.08	1.04	37.31	12.25	.069	.125	.206	.026	.033	.107	34.93
401	Fourth middlings	.58	13.77	1.21	43.32	11.28	.081	.142	.201	.026	.042	.118	40.26
402	Fifth middlings	.62	13.53	1.13	44.18	13.84	.087	.148	.217	.031	.044	.120	41.58
403	Sixth middlings	.62	13.77	1.36	45.23	20.21	.094	.164	.229	.039	.053	.133	44.89
404	Seventh middlings	.95	15.42	1.09	56.85	16.00	.164	.275	.335	.080	.102	.215	53.69
405	First sizings	.64	12.32	1.26	42.45	12.68	.091	.161	.194	.042	.051	.127	46.21
406	Chunks	1.02	13.28	1.67	47.45	13.77	.159	.289	.312	.082	.118	.225	59.74
407	Second sizings	.88	12.94	1.53	41.39	12.60	.145	.236	.278	.054	.091	.186	56.02
408	B middlings	.72	12.92	1.19	47.09	13.98	.129	.208	.243	.057	.077	.171	25.47
409	First tailings	1.15	15.14	1.78	55.55	16.39	.170	.304	.317	.076	.145	.261	63.16
410	Second tailings	1.36	16.52	2.48	53.32	16.93	.186	.395	.444	.094	.175	.327	60.68
411	Second low grade	1.01	14.23	1.69	49.73	14.04	.181	.305	.340	.065	.122	.230	59.51
412	Bran-duster flour	1.27	17.56	1.93	65.87	18.27	.220	.370	.404	.080	.161	.301	59.91
413	Ship-duster flour	1.58	15.16	2.41	46.14	14.10	.239	.466	.505	.070	.191	.373	57.53
414	Roll-suction stock	.79	12.25	1.58	39.70	12.06	.130	.467	.239	.068	.078	.164	53.72
415	Stock going to fourth middlings from second sizings	.46	12.51	1.29	47.11	13.49	.065	.133	.076	.023	.079	.113	79.20

Ash Content.

There is a regular increase in ash percentage in proportion as the flour contains fibrous branny material or as the flours are taken from the portion of the wheat kernel next to the bran. Of the break flours the fifth has the highest percentage, followed by the first. The relatively high ash percentage of the first break flour is no doubt due to the incorporation of bran fibers with the flour when the flour is made, but in the fifth break the high ash probably results from two causes: (1) the incorporation of bran fiber as in the first break, and (2) the material from the wheat kernel next to the bran contains more mineral matter than the interior of the kernel. This assumption is based on the composition of these mill streams in general. The middlings flours are lowest in ash. The flour from the chunks has a very high ash percentage for a stream which goes into a patent, while the sixth middlings, which is not put with the patent, has no higher ash percentage than the fifth middlings which makes up part of the patent flour. From the standpoint of general chemical composition there seems to be no reason why the sixth middlings flour should not go into the patent, and besides it also made a good showing in the baking test.

The percentage of ash furnishes a very good indication in regard to the quality of a flour as far as that is related to the method of milling. It has been pointed out that the feed contains ten times as high a percentage of ash as the flour. Consequently, the presence of fibrous materials in the lower mill streams influences the ash content more than any other factor. The composition of the ash is also important in judging the baking qualities of a flour. This is discussed later.

Protein Content.

The patent has a lower percentage of protein than the wheat, while both the clear flours and the low-grade flours have a higher percentage. The break flours have a regular increase in protein percentage corresponding to the break number, the fifth break being the highest in percentage of protein in all these flours, while the bran-duster flour and the fourth break have the next highest percentages. In the middlings there is almost the same regular increase in protein content corresponding with the number of reductions. This is because of the well-known fact that the portion of the endosperm next the bran is richest in protein.

Fat or Ether Extract.

While the increase or decrease in fat content is not as regular as that of protein, yet the fat percentages show distinctly the influence of the method used in separation. The germ is richer in fat than any other portion. Wherever the stock containing germ is subjected to close grinding, there is an increase in fat content. The coarse middlings as they come from the breaks contain practically all of the germs. The method of separating these germs from the middlings consists in flattening them by the smooth rolls in such a way that they can be sifted out from the rest of the material. In this way the middlings, which are used for the production of patent flour, are made relatively free from germ. Hence, these streams are lowest in fat. But in order to separate nearly all the floury portions from the smaller bran particles in the middlings beyond the seventh, it is necessary to give these quite severe treatment, and while the greater portion of the germ has been separated out, still some will remain, and therefore the streams near the tail end of the mill are richer in fat. The relatively high fat content of the break flours is due to the action of these rolls on the germ. The objection to a high fat content in the flour is that the fat has poorer keeping qualities than any other ingredient. A high fat content is likely to impart a rancid flavor to a flour when it is kept a long time, especially in warm weather. This is the greatest objection to a high percentage of fat.

Gluten.

The percentage of dry gluten averages a little higher than the protein. Dry gluten contains about 85 per cent of the total crude protein of the flour. The other 15 per cent is made up of soluble nitrogenous substances. These are washed away in freeing the gluten from the starch. Gluten is not pure protein. It contains crude fiber, some fat, starch and other compounds. However, the loss of soluble proteins from the gluten is in most cases more than made up by compounds not proteins, so that the figures for dry gluten are usually a little higher than those for total protein.

The fact that the quality rather than the quantity is the important consideration in regard to gluten is borne out by the figures in the table. The middlings flours which, from all standards of measurements, have the highest qualifications for good bread-making flours, have the lowest average per cent of gluten both wet and dry; and those flours which have the highest per cent of gluten, such as the fifth break and the bran-duster flours, have very poor baking qualities, and those with an average amount of gluten have fair baking qualities.

When dough ferments under the action of the yeast, gluten undergoes profound changes. Of these changes very little is known, and until more is known about these changes many obscure problems will remain unsolved. What these changes are and how they affect the chemical composition of the gluten is now being investigated at this Station. The following notes on the quality of gluten were taken at the time of washing it from the flour:

Gluten Quality—Mill-Stream Samples.

Gluten from flours numbers 398, 399, 400, 401, 405, 390, 402, 403 and 407 is of good quality and average amount.

414 Good quality but small amount.
396 Large amount, rather hard, tough, elastic.
395 Large amount, good quality, elastic.
394 Large amount, good quality, elastic, a little hard.
391 Small amount, good quality, elastic, soft.
393 Small amount, good quality, elastic, soft.
409 Small amount, good quality, elastic.
406 Small amount, quite hard.
404 Medium amount, a little hard.
411 Brittle, lacking elasticity, very hard to wash.
412 Soft, elastic.
410 Soft, weak.
413 Soft, flabby, lacking coherence, very poor.
397 Somewhat soft, elastic.
392 Fairly good, somewhat lacking in coherence and elasticity.
415 Very Good.

Acidity.

The acidity was determined under two conditions as in the commercial flours. The acidity at 25° C. was determined in order to have figures comparable with the usual figures for acidity. That the figures for 40° C. and two hours' extraction are more reliable in comparing flours, one with another, will be shown further on. The acidity values at 40° C. show very plainly what portion of the wheat kernel the flour comes from. The first break flour has a slightly higher acidity than the second, but from this there is a regular increase corresponding with the break number, showing that the nearer the bran the flour comes from, the higher the acidity. The first middlings flour has the lowest percentage of acidity, and the acidity increases with the reduction number, for the same reason as in the break flours. The relatively low acidity in the first sizings as compared with the chunks is due to the difference in fiber content of these two, the former having a much smaller amount of fiber than the latter. The large acidity values for the streams near the tail end of the mill is due, in a large measure, to the fact that these flours contain a great deal of bran fiber. The relatively simple process of determining acidity would indicate that this determination could be used by the miller in testing his flour streams. The figures for acidity show as close a relation to the grade of the flour and its baking qualities as any other figures. The very high acidity in the roll-suction stock is no doubt due to the method of making this flour. Any volatile compounds would be found in this flour in a larger percentage than in any of the others.

Amino Compounds.

The amino compounds are described under the mill-stream flours of the four-break mill. The amino compounds vary almost identically as the acidity. These amino compounds are in all probability amino acids, and as such they have the power to neutralize the alkali used in the determination of acidity. That only a part of the acidity is due to these amino acids is probable; phosphates, which also vary as the acidity, doubtless contribute to it.

Percentage of Phosphorus.

Three determinations of phosphorus were made: Total; soluble at 40° C., two hours' extraction; soluble at 25° C., half an hour's extraction. The total and water-soluble phosphorus show the same law of variation as the acidity taken, As has been intimated, part of the acidity, probably the greater portion, is due to acid phosphates. A quantitative study of these phosphates would yield valuable results. What relation have these phosphates to the gluten? What portion of the phosphorus is in organic and what portion is in inorganic combination? That there is an intimate relation between the ash, phosphates, acidity and amino compounds is established by the facts shown in the table giving the chemical composition of these flours.

Relation of Total Phosphorus to Other Constituents.

The constituents which show more or less close relationship to phosphorus are: amino compounds, acidity, and ash. There is also a relationship between protein and these compounds, but not as close. The water-soluble phosphorus, both at 40° C., two hours' extraction, and at 25° C., half an hour's extraction, vary with the total phosphorus, but not in the same proportion. This is seen in the column headed "Per-cent of total phosphorus soluble in water at 40° C." The first middlings has the lowest percentage of water-soluble phosphorus, followed closely by the patent flour, the second and the third middlings. The amount of water-soluble phosphorus in the middlings increases as the number designation of the reduction increases. In the first break flour 57.79 per cent of the phosphorus is soluble, and the amount increases in the fourth and fifth breaks. In all the lower streams the percentage of water-soluble phosphorus is high as compared with the middlings flours.

If a comparison is made between the figures for total expansion, the fermentation period, and the percentage of water-soluble phosphorus, it is found that those flours which have a high percentage of water-soluble phosphorus have a short fermentation period, and a low total expansion. It is not only that the lower grade flours have a high percentage of total phosphorus, but this phosphorus is more soluble. Thus, in the patent and the middlings flour, less than one-third is soluble, while in the low grade, and the streams near the tail end of the mill, two-thirds and more is water-soluble. Not only the total amount of phosphorus, but the percentage of it that is water-soluble, has a close relationship to the baking qualities of the flour.

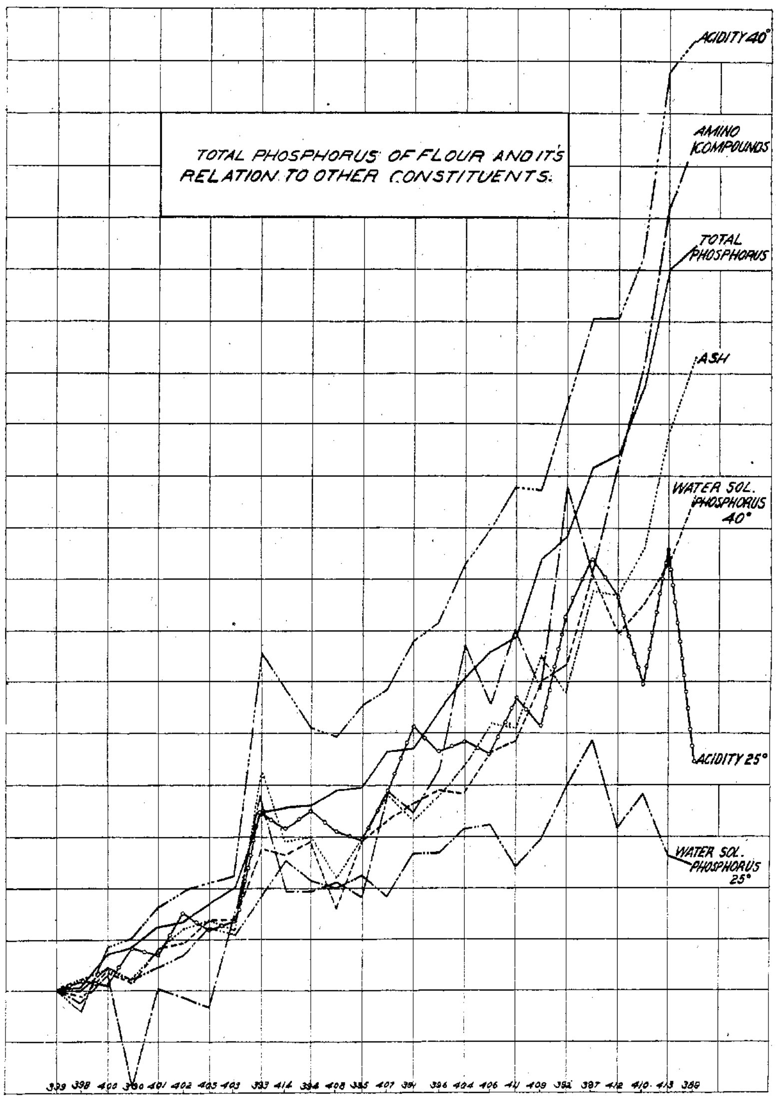
The figures for total phosphorus given in table XXIV were arranged in an ascending series and the figures for the other constituents placed in parallel columns. The results are presented in table XXV. It is at once apparent that the percentages for these other constituents vary almost as the percentage for total phosphorus. These figures were plotted in a manner similar to those represented in plate X. The result is found in plate XXI. The percentages for acidity at 40°, two hours' extraction, amino compounds, total phosphorus, ash and water-soluble phosphorus at 40°, show a very close relationship. The acidity at 25°, half an hour's extraction, and the water-soluble phosphorus under the same conditions, do not show the same uniformity as under the conditions of higher temperature and longer time, The extraction at the higher temperature and for the longer time gives results more comparable and reliable. In plotting the curve for acidity in plate XXI, the figures for the acidity of roll-suction flour were left out, as this flour was abnormal in comparison with the others.

The close relationship of these constituents points to a profitable line of investigations, not only on flour but on the dough in its various stages of fermentation. What causes the gluten to form in flour, and why does it disappear as the dough ferments? What changes take place in the solubility of the phosphorus as the dough ferments, and what are the changes in acidity? What have the amino compounds to do with the quality of the gluten? These are some of the questions suggested by the present investigation.

TABLE XXV.—Relation of total phosphorus to other constituents—percentages arranged in ascending series.

Serial number	Total phosphorus	Water-soluble phosphorus at 40° C.	Water-soluble phosphorus at 25° C.	Percentage of total that is soluble in water at 40° C.	Amino compounds	Acidity, 40 °C.	Acidity, 25° C.	Ash	Protein
399	.093	.025	.017	30.55	.200	.109	.067	.50	12.68
398	.094	.023	.017	27.43	.195	.101	.071	.52	12.48
400	.107	.033	.026	34.93	.206	.125	.069	.54	13.08
390	.110	.028	.021	29.25	.162	.130	.074	.52	12.68
401	.118	.042	.026	40.26	.201	.142	.081	.58	13.77
402	.120	.044	.031	41.58	.217	.148	.087	.62	13.53
405	.127	.051	.042	46.21	.194	.161	.091	.64	12.32
403	.133	.053	.039	44.89	.229	.164	.094	.62	13.77
393	.162	.082	.053	57.79	.276	.239	.136	.93	13.21
414	.164	.078	.068	53.72	.239	.467	.130	.79	12.25
394	.165	.083	.060	57.45	.239	.211	.137	.80	14.55
408	.171	.077	.057	25.47	.243	.208	.129	.72	12.92
395	.172	.084	.062	55.74	.237	.220	.126	.80	15.78
407	.186	.091	.054	56.02	.278	.236	.145	.88	12.94
391	.187	.098	.071	59.64	.270	.245	.170	.83	15.53
396	.204	.103	.071	78.34	.286	.252	.160	.88	17.07
404	.215	.102	.080	53.69	.335	.275	.164	.95	15.42
406	.225	.118	.082	59.74	.312	.289	.159	1.02	13.28
411	.230	.122	.065	59.51	.340	.305	.181	1.01	14.23
409	.261	.145	.076	63.16	.317	.304	.170	1.15	15.14
392	.269	.152	.097	64.01	.396	.339	.215	1.08	15.87
397	.296	.187	.114	72.29	.363	.370	.235	1.28	20.67
412	.301	.161	.080	59.91	.404	.370	.220	1.27	17.56
410	.327	.175	.094	60.68	.444	.395	.186	1.36	16.52
413	.373	.191	.070	57.53	.505	.466	.239	1.58	15.16
389	.482	.218	.066	51.73	.530	.478	.156	1.93	14.83

PLATE XXI


TOTAL PHOSPHORUS OF FLOUR AND IT'S RELATION TO OTHER CONSTITUENTS.
ACIDITY 40°
AMINO COMPOUNDS
TOTAL PHOSPHORUS
ASH
WATER SOL. PHOSPHORUS 40°
ACIDITY 25°
WATER SOL. PHOSPHORUS 25°
398 400 401 402 403 393 414 408 407 396 404 406 409 397 412 410 413 389

Part IV.

Effect of Storage on Flour.

All of the work on storage of flour was planned, and the greater part finished, before the work described in the previous part of this bulletin was begun. These storage experiments were continued over two years' time, duing which the methods were changed somewhat, and there were also changes in the personnel of the workers.*

Loss in Weight of Ordinary Forty-eight-Pound Sacks When Stored in a Steam-heated Room.

This part of the experiment was undertaken at the suggestion of Dr. S. J. Crumbine, chief food inspector, secretary of the State Board of Health.

For this work twenty-seven 48-pound sacks of straight flour were used. They were weighed at the mill and should have contained forty-eight pounds of flour each. They were taken immediately to the laboratory, where they were again weighed on a balance sensitive to one-eighth of a pound. This same balance was used for all the subsequent weighings. The twenty-seven sacks were stored in a small steam-heated room in the Physical Science building, This room has windows to the north and west. It is a light, airy room, well ventilated, and protected from fumes. The sacks were placed on the floor in the form of a rectangular prism, three sacks each way. Thus one sack in the center was entirely surrounded by other sacks and the other twenty-six sacks were exposed either on the sides, top, or bottom. The sacks were all numbered and were made to occupy the same position throughout the experiment. The room was fumigated to kill weevil and no infection was observed for over twelve months. Over and surrounding the sacks was placed a wire screen to protect from mice. The consecutive weighings were made as nearly as possible on the same day of the month.

Record of the Changes in the Weight of Stored Flour.

The complete record of the weight of these sacks taken at different times during the period of a year is found in

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* Credit for assistance in the work covering the first season's experiments is due Prof. R. C. Thompson, formerly assistant chemist here, but now chemist of the Arkansas station.

table XXVI. In the first column are the weights obtained as soon as the flour arrived in the laboratory. This includes the weight of the sack itself, together with the flour. The average weight of empty flour sacks is about one-fourth of a pound. Most of the sacks were full weight, and considering

TABLE XXVI.—Changes in the weight of stored flour—pounds.

Sack.	Aug. 11.	Sep. 11.	Oct. 11.	Nov. 17.	Jan. 11.	Mar. 11.	Apr. 11.	May 13.	June 14.	Aug. 10.
1	48¼	48¼	48	48	47¾	47⅝	47½	47½	47⅝	47¾
2	48¼	48	47⅞	47¾	47½	47⅜	47¼	47¼	47⅜	47½
3	48¼	48	47⅞	47¾	47½	47½	47⅜	47¼	47⅜	47⅝
4	48	48	47¾	47¾	47¾	47⅝	47⅜	47⅜	47½	47½
5	48	48⅛	48⅛	47⅞	47⅞	47¾	47⅝	47⅝	47⅝	47¾
6	48	47⅞	47⅞	47¾	47⅝	47⅝	47⅜	47⅜	47½	47⅝
7	48¼	48¼	48	47⅞	48	47⅞	47⅝	47⅝	47⅞	47⅞
8	48¼	48	48	47¾	47¾	47¾	47½	47½	47⅝	47¾
9	48¼	48⅛	47⅞	47¾	47¾	47⅝	47⅜	47⅜	47⅝	47¾
10	48¼	48⅛	48	47¾	47⅝	47⅝	47½	47½	47½	47¾
11	48¼	48	47⅞	47¾	47½	47⅜	47¼	47¼	47¼	47⅜
12	48¼	48	47⅞	47⅝	47½	47⅜	47¼	47¼	47⅜	47½
13	48¼	48⅛	48	47⅞	47⅞	47¾	47½	47½	47⅝	47¾
14	48¼	48	47⅞	47¾	47⅝	47½	47½	47½	47⅜	47½
15	48¼	48	47⅞	47¾	47⅝	47½	47⅜	47⅜	47½	47⅝
16	48¼	48¼	48	47¾	47⅞	47¾	47½	47⅝	47¾	47⅞
17	48¼	48⅛	48	47⅞	47¾	47¾	47⅝	47⅝	47¾	47¾
18	48¼	48⅛	48	47¾	47¾	47⅝	47⅜	47½	47¾	47⅞
19	48¼	48⅛	47⅞	47⅝	47½	47½	47⅜	47⅜	47⅝	47⅝
20	48	47⅞	47¾	47½	47¼	47⅛	47⅛	47¼	47¼	47½
21	48¼	47⅞	47⅞	47⅝	47⅜	47¼	47¼	47¼	47⅜	47⅝
22	48⅛	48	47¾	47⅝	48⅜	47⅝	47½	47½	47⅝	47¾
23	48¼	48	47⅞	47⅝	47⅝	47½	47⅜	47½	47½	47⅝
24	48¼	48	47⅞	47¾	47⅝	47½	47⅜	47⅜	47½	47¾
25	48	48	47¾	47⅝	47⅝	47½	47⅜	47½	47¾	47¾
26	48⅛	48	47⅞	47⅝	47⅝	47½	47⅜	47½	47⅝	47¾
27	48⅛	48	47⅞	47⅝	47½	47½	47¼	47¼	47⅝	....
Average,	48.19	48.05	47.90	47.73	47.65	47.55	47.40	47.43	47.55	47.67

the conditions under which flour must be weighed in a mill, the weights were fairly uniform. The results of subsequent weighings are shown in the other columns. The greatest loss occurred during the first two months, and the flour continued to lose throughout the winter. The lowest average weight for all of the sacks was in April, when the average loss had amounted to a little more than three-fourths of a pound per sack. A very large number of the sacks had lost a pound in weight. After April there was a slight increase in the weight of some of the sacks. This was sufficient to raise the average weight a small amount. This increase in weight continued through the summer months. However, none of the sacks regained their original weight. It seems, therefore, that when this flour was fresh it contained more moisture than it would retain under such hygroscopic conditions as were present in this storeroom. It is reasonable to conclude from this experiment that a 48-pound sack of flour will lose three-fourths of a pound or more in weight if stored in a light, steam-heated room. The moisture content of this flour was 10.58 per cent. This is over one per cent lower than the average moisture content of the commercial flours reported in the preceding pages. If these sacks lost nearly a pound under the storage conditions present, it is reasonable to expect that flour with a higher moisture content will lose more. This loss will be governed by two factors: the hygroscopic conditions of the air and the moisture content of the flour. The drier the air and the more moisture the flour contains, the greater will be the loss. Reverse the conditions and the loss will be small, or there may be an actual gain in the weight.

Influence of Different Conditions of Storage on the Weight, Chemical Composition and Baking Qualities of Flour.

The experiment to determine the influence of different conditions of storage on weight, chemical composition and baking qualities was carried on for two successive seasons.

FIRST SEASON'S WORK—1909-'10.

First Part.

Tests on Bleached and Unbleached Flours-Same Conditions of Storage.

To compare bleached and unbleached flours under the same conditions of storage three portions of flour were selected, one not bleached, one ordinary bleached, and one strongly bleached. From each of these portions eleven one-kilo samples were weighed out and placed in small cloth bags. These were piled on the floor in the same room with the larger bags mentioned in the preceding pages. The samples were numbered according to the foIIowing arrangement :

	0	1	2	3	4	5
Ordinary bleached	101	102	103	104	105	106
Strongly bleached	107	108	109	110	111	112
Unbleached	113	114	115	116	117	118

The samples under 0 were for immediate baking and chemical tests. 'The samples under 1, 2, 3, 4, 5 were for tests at the end of approximately one, two, three, five and eight months.

These bags were all weighed at the time the chemical and baking tests were made. The results of these weighings are found in table XXVII. The weight is the average of all the bags representing one portion. The loss or gain is obtained by comparing the average weight at the end of testing with the average weight at the beginning of the experiment. The percentage loss or gain is computed on the above figures; All samples were in duplicate. Thus, when one sample was used for the baking test, the duplicate was reserved for further weighing tests. This makes the series very complete, and the results show what can be expected under the conditions of storage used.

The two bleached flours showed a gain in weight during the first month of storage. After that all samples lost steadily in weight until April; subsequently there was a slight gain. The greatest loss corresponds to the months in which artificial heat was used in the room. The strongly bleached flour showed the largest loss.

The results of the chemical analysis of these flours are found in table XXVIII. As the moisture determinations were made in a hydrogen oven, the data are not as reliable as when these determinations are made in the vacuum desiccator. As the data stand they do not show any difference between the flours such as can be traced to bleaching.

The baking tests made on these flours are reported in table XXIX. The method used in making these baking tests is a modification of the one reported in the latter part of bulletin No. 177, not the one described in the first part of this one. The baking qualities of the unbleached, ordinary bleached, and strongly bleached flours remained as nearly alike after the first

TABLE XXVII.—Average weight of samples at time of making the baking tests—1909-1910.

SET OF SAMPLES. All except those in sealed jars were in cloth bags.		Aug. 10, 1909.	Sept. 10, 1909.	Oct. 10, 1909.	Nov. 17, 1909.	Jan. 11, 1910.	April 11, 1910.	June 6, 1910.
In steam-heated room, ordinary bleached	Average weight, grams	1033.6	1036.8	1028.6	1024.3	1018.8	1014.0	1021.7
	Total loss or gain, grams	....	3.2*	5.0	9.3	14.8	19.6	11.9
	Percentage loss or gain	....	.31*	.48	.90	1.43	1.89	1.15
In steam-heated room, strongly bleached	Average weight, grams	1033.0	1035.7	1027.5	1021.9	1016.5	1012.4	1019.9
	Total loss or gain, grams	....	2.7*	5.5	11.1	16.5	20.6	13.1
	Percentage loss or gain	....	.26*	.53	1.07	1.60	1.99	1.26
In steam-heated room, not bleached	Average weight, grams	1032.8	1031.5	1027.9	1024.1	1020.5	1014.8	1021.6
	Total loss, grams	....	1.3	4.9	8.7	12.3	18.0	11.2
	Percentage loss	....	.126	.47	.84	1.19	1.74	1.08
In sealed jars	Average weight, grams	1446.9	1446.9	1446.9	1446.9	1446.8	1446.7	1446.7
	Total loss or gain, grams	....	....	....	....	.1	.2	.2
In unheated room	Average weight, grams	1029.7	1016.3	1008.2	1014.6	1019.5	1002.5	1010.3
	Total loss, grams	....	13.4	21.5	15.1	10.2	27.2	19.4
	Percentage loss	....	1.30	2.09	1.46	.99	2.64	1.88
In steam-heated room, not bleached	Average weight, grams	1031.7	1026.6	1022.7	1018.5	1014.2	1010.0	1016.7
	Total loss, grams	....	5.1	9.0	13.2	17.5	21.7	15.0
	Percentage loss	....	.49	.87	1.27	1.69	2.10	1.45

*Gain.

TABLE XXVIII.—Bleached and unbleached flours analyzed at different periods of storage—1909-1910 (percentages).

Sample number.	Kind of flour, stored in cloth bags, in steam-heated room.	Time stored.	Moisture.	Protein.	Gliadin.	Gliadin per cent of protein.	Moisture-free basis.		
							Protein.	Gliadin.	Gliadin per cent of protein.
101	Ordinary bleached	16 days	10.29	11.60	6.24	53.79	12.876	6.926	59.707
102	Ordinary bleached	1 month, 5 days	10.62	11.56	6.08	52.59	12.947	6.810	58.901
103	Ordinary bleached	2 months, 5 days	9.84	12.16	6.24	51.31	13.498	6.926	56.954
104	Ordinary bleached	3 months, 13 days	10.09	12.60	6.67	52.93	13.986	7.404	58.752
105	Ordinary bleached	5 months, 11 days	9.60	12.23	6.47	52.90	13.575	7.182	58.719
106	Ordinary bleached	7 months, 4 days	10.13	11.88	6.78	57.07	13.187	7.526	63.348
107	Strongly bleached	16 days	10.44	11.56	6.48	56.05	12.947	7.258	62.776
108	Strongly bleached	1 month, 6 days	10.65	11.88	6.04	50.84	13.306	6.765	56.941
109	Strongly bleached	2 months, 5 days	10.22	12.24	6.23	50.89	13.586	6.915	56.488
110	Strongly bleached	3 months, 16 days	10.14	12.54	6.67	53.18	13.919	7.404	59.030
111	Strongly bleached	5 months, 9 days	9.84	12.09	6.50	53.76	13.420	7.215	59.674
112	Strongly bleached	8 months, 4 days	10.04	11.88	6.21	52.27	13.187	6.893	58.020
113	Unbleached	10 days	10.58	11.58	6.28	54.23	12.970	7.034	60.738
114	Unbleached	1 month, 6 days	10.63	11.60	6.32	54.48	12.992	7.078	61.018
115	Unbleached	2 months, 10 days	10.22	12.20	6.18	50.65	13.542	6.860	56.222
116	Unbleached	3 months, 16 days	10.10	12.51	6.62	52.91	13.886	7.348	58.730
117	Unbleached	5 months, 11 days	10.29	12.14	6.44	53.04	13.475	7.148	58.874
118	Unbleached	8 months, 4 days	10.04	11.76	6.24	53.06	13.054	6.926	58.897

TABLE XXIX.—Bleached and unbleached flours baked at different periods of storage—1909–1910.

Portion number	CONDITION OF FLOUR. Stored in steam-heated room.	Time stored	Percentage moisture at time of baking	Percentage absorption	Water in dough, grams	Total time for proving	First rise, cm.	Second rise, cm.	Loss of materials, grams	Rise in oven, cm.	Volume of loaf, cc.	Texture of loaf, 100 = perfection	Weight of fresh loaf, grams	Weight of loaf 16 hours old, grams
101	Ordinary bleached	16 days.	10.29	56.6	200.87	7h., 31m.	17.65	19.60	25.5	1.90	1080	86	446	409
102	Ordinary bleached	1 month, 5 days.	10.62	58.3	206.86	6h., 5m.	18.40	21.25	24.0	3.90	1265	85	470	428
103	Ordinary bleached	2 months, 5 days.	9.84	56.6	199.52	5h., 49m.	18.75	20.50	27.5	3.00	1260	89	443	427
104	Ordinary bleached	3 months, 13 days.	10.09	58.3	205.27	6h., 26m.	17.75	20.00	23.0	4.20	1295	91	452	423
105	Ordinary bleached	5 months, 11 days.	9.60	58.3	203.80	5h., 55m.	18.85	21.90	21.0	4.20	1290	92	453	428
106	Ordinary bleached	7 months, 4 days.	10.13	58.3	205.39	4h., 39m.	18.00	20.25	16.0	4.40	1320	91	461	437
107	Strongly bleached	16 days.	10.44	58.3	206.32	6h., 11m.	17.60	19.90	26.5	4.10	1260	90	446	419
108	Strongly bleached	1 month, 6 days.	10.65	59.3	209.95	5h., 39m.	19.25	21.40	25.5	2.80	1165	90	459	432
109	Strongly bleached	2 months, 5 days.	10.22	56.6	200.66	5h., 15m.	18.00	20.75	23.0	4.40	1360	93	449	432
110	Strongly bleached	3 months, 16 days.	10.14	58.3	205.42	5h., 50m.	18.50	21.00	21.5	4.45	1370	91	453	428
111	Strongly bleached	5 months, 9 days.	9.84	58.3	204.52	5h., 1m.	17.95	None.	20.0	3.70	1240	92	457	427
112	Strongly bleached	8 months, 4 days.	10.04	58.3	205.12	4h., 16m.	18.00	22.00	12.0	4.15	1330	94	460	440
113	Unbleached	10 days.	10.58	56.6	201.74	7h., 22m.	18.15	19.90	24.0	1.65	1060	86	441	221
114	Unbleached	1 month, 6 days.	10.63	58.3	206.89	5h., 37m.	19.10	20.85	24.0	3.30	1225	90	458	433
115	Unbleached	2 months, 10 days.	10.22	58.3	205.66	5h., 5m.	18.50	21.00	19.0	3.65	1290	91	449	430
116	Unbleached	3 months, 16 days.	10.10	58.3	205.30	5h., 30m.	18.80	21.25	23.0	4.25	1345	94	444	428
117	Unbleached	5 months, 11 days.	10.29	58.3	205.87	5h., 52m.	18.65	21.00	22.0	4.20	1310	92	454	426
118	Unbleached	8 months, 4 days.	10.04	58.3	205.39	4h., 33m.	17.75	21.00	11.5	4.30	1320	91	461	440

test as was possible to determine with the measurements used. In the first test the strongly bleached flour showed the largest oven expansion and loaf volume accompanied with the better texture. It is this improvement in new flour which has given flour bleaching favor with millers. But as this improvement can be obtained by treatments of the wheat before milling by methods which are along the line of true progress and free from the objectionable features of bleaching, the justification for bleaching is not what its advocates claim. The claim is often made that age will bleach flours. In these samples there was a distinct difference between the bleached and the unbleached samples throughout the whole period. The unbleached flour did not acquire the same whiteness as the bleached.

SECOND PART.

Tests on Unbleached Flours, Different Conditions of Storage.

To test the effects of different conditions of storage on flour, a straight unbleached flour was selected. This was of the same grade as the unbleached flour used in the preceding work. There were three storage conditions: the attic of a stone building, the steam-heated room, and sealed cans. The first represents the condition of the unheated warehouse; the second the same conditions as were used for the comparison of the bleached and unbleached flours and would be the condition of the ordinary store; the third gives the conditions of a warm room but without a chance for anychange in moisture content. The bags of flour, both in the attic and the steam-heated room, were placed in tall tin cans having openings on the sides covered by wire gauze.

These samples were numbered and arranged as follows:

Samples in sealed cans.............	120	121	122	123	124
Samples in attic....................	125	126	127	128	129
Samples in steam-heated room.......	130	131	132	133	134

These samples were in triplicate. This left two in reserve when one was used for the baking test. All samples were weighed at the same time as the preceding bleached and unbleached samples. The data obtained are found in table XXVII. All the weighings were made on a balance sensitive to one-tenth of a gram. The sealed cans showed no change except such as can be accounted for in the handling. The samples stored in the attic showed a large loss during September and October. During November part of this weight, was restored. That this gain in moisture continued is shown by the weight in January. The weight in April showed the greatest loss, and the weight in June showed that this loss was partly regained, The season was alternately very wet and very dry, and the result shows that flour is very sensitive to moisture changes in the atmosphere. In the steam-heated room there was a constant loss in the fall and winter, with the maximum loss in April when the steam heat ceased to be used. After this there was certain gain.

These results show that the weight of flour varies with atmospheric conditions. Two per cent may easily be lost when flour is stored in such a room as an attic, or any place which gets very warm in the late summer. Flour will partially regain lost weight when the atmosphere becomes more humid.

The data obtained from chemical tests made on these flours are found in table XXX. The moisture content of the flour stored in the attic or the unheated room varies the most, and those in sealed cans the least. These should not vary any at all, but as will be shown later there is a difference in the ease with which moisture can be driven off from flour. The other chemical determinations do not show any regular change which can be traced to the difference in storage conditions.

The baking results are found in table XXXI. As far as these tests are reliable, there seems to be no evidence which shows that there was either an improvement or a deterioration in the flours stored under the different conditions. It should be stated that the flour was not entirely from new wheat, but a blend of new wheat and wheat several weeks old. This accounts in part for the uniform results.

SECOND SEASON'S STORAGE EXPERIMENTS — 1910-'11.

Condition and Arrangement of Samples.

For the work on stored flour the second season the same storage conditions as the previous year were used; namely, the unheated room, a steam-heated room, and sealed jars. Ordinary bleached and strongly bleached flours were also stored in the steam-heated room. The sealed samples were placed in tin cans and the covers were soldered. All the samples this year were from the same lot of flour. The samples were approxi-

TABLE XXX.—Analysis of flours stored under different conditions—1909-1910 (percentages).

Sample number.	Condition of storage.	Time stored.	Moisture.	Protein.	Gliadin.	Gliadin per cent of protein.	Moisture-free basis.		
							Protein.	Gliadin.	Gliadin per cent of protein.
119	In sealed jar, steam-heated room	6 days	10.56	11.64	7.20	61.85	13.037	8.064	69.272
120	In sealed jar, steam-heated room	1 month, 4 days	10.46	12.28	7.58	61.72	13.754	8.490	69.126
121	In sealed jar, steam-heated room	2 months, 10 days	11.15	12.68	6.48	51.10	14.328	7.322	57.743
122	In sealed jar, steam-heated room	3 months, 10 days	11.39	12.82	6.82	53.19	14.487	7.707	60.105
123	In sealed jar, steam-heated room	5 months, 9 days	11.02	12.31	6.92	56.21	13.787	7.750	62.955
124	In sealed jar, steam-heated room	8 months, 3 days	12.02	12.08	6.41	53.06	13.771	7.307	60.488
125	In cloth bags, unheated room	1 month, 4 days	9.93	12.08	7.58	62.74	13.409	8.414	69.641
126	In cloth bags, unheated room	2 months, 3 days	9.00	12.80	6.61	51.64	14.080	7.271	56.804
127	In cloth bags, unheated room	3 months, 10 days	10.17	13.14	6.95	52.89	14.585	7.715	58.708
128	In cloth bags, unheated room	5 months, 10 days	9.67	12.79	6.90	53.94	14.069	7.590	59.334
129	In cloth bags, unheated room	8 months, 3 days	10.14	12.34	6.87	55.67	13.697	7.626	61.794
130	In cloth bags, steam-heated room	1 month, 5 days	10.21	12.04	7.58	62.95	13.364	8.414	69.875
131	In cloth bags, steam-heated room	2 months, 3 days	9.77	12.80	6.56	51.25	14.208	7.282	56.888
132	In cloth bags, steam-heated room	3 months, 13 days	10.32	13.11	7.01	53.47	14.683	7.851	59.886
133	In cloth bags, steam-heated room	5 months, 10 days	9.40	12.57	6.81	54.17	13.827	7.491	59.587
134	In cloth bags, steam-heated room	8 months, 3 days	10.46	12.28	6.75	54.96	13.754	7.560	61.555

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TABLE XXXI.—Baking tests of flours stored under different conditions—1909-1910.

Portion No.	Condition of Storage.	Time stored.	Moisture percentage at time of baking.	Percentage absorption.	Water in dough, grams.	Total time for proving.	First rise, cm.	Second rise, cm.	Loss of materials, grams.	Rise in oven, cm.	Volume of loaf, cc.	Texture of loaf, 100 = perfection.	Weight of fresh loaf, grams.	Weight of loaf, 16 hrs. old, grams
119	In sealed jar, steam-heated room	6 da.	10.56	55.0	196.68	6 h., 21 m.	17.10	19.85	18.0	4.05	1,245	90	445	416
120	In sealed jar, steam-heated room	1 mo., 4 da.	10.46	55.0	196.38	6 h., 19 m.	16.60	None.	25.5	3.00	1,190	88	446	425
121	In sealed jar, steam-heated room	2 mos., 10 da.	11.15	55.6	203.45	5 h., 20 m.	18.50	21.00	21.0	4.30	1,350	91	449	427
122	In sealed jar, steam-heated room	3 mos., 10 da.	11.39	56.6	204.17	6 h., 26 m.	17.50	19.00	27.5	3.45	1,300	92	448	420
123	In sealed jar, steam-heated room	5 mos., 9 da.	11.02	56.0	201.06	5 h., 14 m.	17.50	None.	26.0	2.80	1,190	88	449	418
124	In sealed jar, steam-heated room	8 mos., 3 da.	12.02	56.6	206.06	4 h., 45 m.	18.00	20.00	21.0	2.80	1,150	90	454	430
125	Cloth bags, unheated room	1 mo., 4 da.	9.93	58.3	204.79	5 h., 57 m.	16.70	None.	22.5	3.45	1,250	89	458	426
126	Cloth bags, unheated room	2 mos., 3 da.	9.00	60.0	207.00	4 h., 28 m.	19.90	20.50	24.0	3.75	1,342	90	448	429
127	Cloth bags, unheated room	3 mos., 10 da.	10.17	58.3	205.51	6 h., 5 m.	17.00	19.00	22.0	3.00	1,270	92	452	422
128	Cloth bags, unheated room	5 mos., 10 da.	9.67	58.3	204.00	5 h., 16 m.	18.60	20.00	24.0	3.25	1,255	90	451	419
129	Cloth bags, unheated room	8 mos., 3 da.	10.14	58.3	205.42	4 h., 24 m.	18.00	20.50	18.0	4.00	1,270	91	458	431
130	Cloth bags, steam-heated room	1 mo., 5 da.	10.21	58.3	205.63	6 h., 38 m.	19.10	20.85	26.5	3.90	1,270	85	458	428
131	Cloth bags, steam-heated room	2 mos., 3 da.	9.77	60.0	209.31	4 h., 32 m.	19.75	21.50	20.5	2.95	1,370	90	453	428
132	Cloth bags, steam-heated room	3 mos., 13 da.	10.32	58.3	205.96	5 h., 42 m.	18.75	19.50	17.0	3.60	1,295	93	451	421
133	Cloth bags, steam-heated room	5 mos., 10 da.	9.40	58.3	203.20	4 h., 51 m.	18.85	21.50	19.5	4.55	1,305	92	453	421
134	Cloth bags, steam-heated room	8 mos., 3 da.	10.46	58.3	206.38	3 h., 4 m.	18.00	20.00	17.0	3.65	1,260	90	460	433

mately one thousand grams each, and they were weighed with the containers. To correct for the changes in weight which the sacks might undergo, ten empty sacks were weighed at the same time, and for the losses and gains due to the sacks corrections were made. The samples were numbered and arranged as follows:

Samples in sealed jars, unbleached......	135	136	137	138	139	140	141	142
Samples stored in unheated room, unbleached	143	144	145	146	147	148	149	150
Samples stored in steam-heated room, unbleached	151	152	153	154	155	156	157	158
Samples stored in steam-heated room, ordinary bleached	159	160	161	162	163	164	165	166
Samples stored in steam-heated room, strongly bleached	167	168	169	170	171	172	173	174

There were thus eight duplicate samples for each storage condition or for flour differently treated. In the weighing all the duplicates were used and the average taken for the final result. The samples in the vertical column were tested at the same time, but as only one of the duplicates was used, the other was kept and weighed throughout the year. The baking tests were made according to the method described in the first part of this bulletin. The chemical work was done with all of the care possible. The same set of reagents was used throughout for all of the tests. The moisture determinations were made in the vacuum desiccator. This, so far, has been found to be the only reliable method of determining moisture in flour.

Average Weight of the Samples Taken at the Time the Baking Tests Were Made.

The weights of stored samples are found in table XXXII. The losses or gains in the sealed samples are not greater than can be accounted for by changes in the moisture condensations on the surface of the cans.

The sacks stored in the unheated room showed a loss of. nearly half a per cent the first thirty days. The moisture content of the flour samples at the beginning was nearly thirteen per cent. The loss, though small, continued during the fall. This loss was partially regained during the winter. A comparatively large loss occurred during the spring months, after which the weight was constant. The season was dry in the fall, wet in February, and dry in the spring and summer.

In the steam-heated room the loss was less than in the attic room during the early fall. The samples stored in the steam-

TABLE XXXII.—Average weight of samples at the date of making the baking tests—grams.

Set of Samples.		Aug. 10, 1910.	Sept. 10, 1910.	Oct. 10, 1910.	Dec. 10, 1910.	Feb. 10, 1911.	April 10, 1911.	June 10, 1911.	Aug. 10, 1911.
In sealed jars, steam-heated room	Average weight	1241.7	1241.8	1241.9	1242.1	1241.9	1241.8	1241.5	1241.7
	Total loss or gain		*.1	*.2	*.4	*.2	*.1	†.2	.0
In cloth bags, unheated room	Average weight	1032.2	1027.3	1026.5	1025.0	1027.2	1021.8	1011.3	1005.2
	Total loss		4.9	5.7	7.2	5.0	10.4	20.9	27.0
	Percentage loss		.47	.55	.70	.48	1.01	2.02	2.62
In cloth bags, steam-heated room, not bleached	Average weight	1031.6	1034.1	1034.3	1011.9	1006.8	1001.2	1008.0	1011.8
	Total loss or gain		*2.5	*2.7	†19.7	†24.8	†30.4	†23.6	†19.8
	Percentage loss or gain		.24	.26	1.91	2.40	2.94	2.28	1.91
In cloth bags, steam-heated room, ordinary bleached	Average weight	1032.4	1034.7	1035.2	1012.7	1006.1	1002.4	1008.5	1013.7
	Total loss or gain		*2.3	*2.8	†19.7	†26.3	†30.0	†23.9	†18.7
	Percentage loss or gain		.22	.27	1.90	2.54	2.90	2.31	1.81
In cloth bags, steam-heated room, strongly bleached	Average weight	1032.0	1033.8	1034.2	1012.9	1006.0	1001.3	1007.6	1013.0
	Total loss or gain		*1.8	*2.2	†19.1	†26.0	†30.7	†24.4	†19.0
	Percentage loss or gain		.17	.21	1.85	2.52	2.97	2.36	1.84

*Gain. †Loss.

TABLE showing pounds of loss per one hundred pounds of flour at the different dates.

DATES OF WEIGHING.	Aug. 10, 1910.	Sep. 10, 1910.	Oct. 10, 1910.	Dec. 10, 1910.	Feb. 10, 1911.	Apr. 10, 1911.	Jun. 10, 1911.	Aug. 10, 1911.
In unheated room..............	....	.47	.55	.70	.48	1.00	2.62	2.62
In steam-heated room, not bleached..................	....	.24	.26	1.91	2.40	2.94	2.28	1.91
In steam-heated room, ordinary bleached..................	....	.22	.27	1.90	2.54	2.90	2.31	1.81
In steam-heated room, strongly bleached..................	....	.17	.21	1.85	2.52	2.97	2.36	1.84

heated room lost most in the winter. This loss was partially regained in the spring and summer.

The above table shows the number of pounds of probable loss in one hundred pounds flour stored under the conditions named. It should be noted that where flour is stored in larger quantities the loss will likely be less. However, as was shown in the experiments with the forty-eight-pound sacks, the loss may be as much as two per cent in flour that was lower in moisture content than the average. A loss of two and one-half per cent is not improbable even from large sacks.

Chemical Composition of Flours Stored Under Different Conditions.

(Table XXXIII.)

The moisture was determined by drying in a vacuum desiccator until constant weights mere obtained. There was a decrease of nearly one per cent of moisture in the flour stored in the sealed cans. The decrease of moisture is not regular throughout the year. It was noticed that as the samples became older, longer and longer time was necessary to obtain constant weights. Some of the older samples were kept in the desiccator for three weeks and a continued slight decrease was noticed. It seems that there is a tendency for a part of the hygroscopic water to combine in some way with the flour so that it is less easily driven off. Other things being equal, it is not possible to obtain as large a per cent of moisture from old flour as from new. These cans had not lost any weight, yet there was a decrease of about one per cent of moisture. This had combined with the flour so that it could not be driven off by the methods used in drying.

Protein Content. The protein content shows more variation than one would expect, especially when these figures are calculated to the moisture-free basis. The same set of standard reagents was used throughout all the tests. The variation is probably due to lack of homogeneity in the samples. Workers in chemical laboratories are familiar with the difficulty. It would seem that this trouble ought to be less in flour than in many other samples. There is also the difficulty of moisture. Although the chemical samples were kept sealed, it is easy to conceive that the exposure which is inevitable would affect the moisture content, and in this way alter the homogeneity of the sample. The data represent what may be reasonably expected on a set of samples analyzed at different periods throughout a whole year.

Acidity. The acidity showed no marked increase or decrease during the year, and the different storage conditions had no perceptible effect on the acidity. The same is also true of the bleached flours as compared with the unbleached.

Nitrites. The bleached flours were quantitatively tested for nitrites. Both of the bleached flours showed a decrease in nitrites, the strongly bleached showing the greatest decrease.

Baking Tests of Flour Stored Under Different Conditions.

(Table XXXIV.)

The greatest change in baking qualities occurs at the end of the first month. After that the changes are very small and not regular. The probability is that the changes noted are as much due to the weather conditions at the time of the test as to inherent qualities of the flour itself. The figures for maximum expansion, the rise in the oven and the loaf volume, and consequently the gluten quality factor, are the smallest in the first test. The flour was as freshly milled from new wheat as it was possible to obtain. The greatest improvement occurs during the first month. If there is any difference in the subsequent tests, those made in the late fall and winter make the best showing. The last test does not make as good a showing as the others. The poorer quality of the yeast in the summer may account for this in part, though it is also probable that the flour had deteriorated somewhat in quality.

Texture and color. There is no marked change in texture corresponding with the different conditions of storage or the season. In color there is a marked improvement in all the samples as the season progresses, the best color being obtained in next to the last test.

TABLE XXXIII.—Chemical composition of flours stored under different conditions—1910-1911—analysis made at time of baking.

Portion number.	CONDITION OF STORAGE.	Preliminary treatment.	Length of time stored, days.	Percentages. Moisture.	Percentages. Protein.	Percentages. Acidity.	Percentages. Nitrites, parts per million.	Percentages. Moisture free. Protein.	Percentages. Moisture free. Acidity.
135	Sealed jars, steam-heated room	Unbleached	......	12.98	12.28	.160	....	14.11	.184
136	Sealed jars, steam-heated room	Unbleached	36	13.01	12.43	.154	....	14.28	.177
137	Sealed jars, steam-heated room	Unbleached	62	13.02	12.36	.150	....	14.20	.172
138	Sealed jars, steam-heated room	Unbleached	125	12.42	12.47	.158	....	14.56	.185
139	Sealed jars, steam-heated room	Unbleached	186	12.65	12.49	.163	....	14.64	.191
140	Sealed jars, steam-heated room	Unbleached	244	12.85	12.18	.164	....	13.98	.188
141	Sealed jars, steam-heated room	Unbleached	305	12.74	12.49	.151	....	14.34	.173
142	Sealed jars, steam-heated room	Unbleached	366	11.99	12.45	.150	....	14.14	.170
143	In cloth bags, attic	Unbleached	......	12.98	12.28	.160	....	14.11	.184
144	In cloth bags, attic	Unbleached	36	12.57	12.40	.148	....	14.19	.169
145	In cloth bags, attic	Unbleached	62	12.77	12.36	.149	....	14.16	.171
146	In cloth bags, attic	Unbleached	125	12.00	12.47	.162	....	14.17	.184
147	In cloth bags, attic	Unbleached	186	12.48	12.49	.148	....	14.26	.169
148	In cloth bags, attic	Unbleached	244	12.20	12.10	.147	....	13.79	.167
149	In cloth bags, attic	Unbleached	305	11.26	12.71	.156	....	14.36	.176
150	In cloth bags, attic	Unbleached	366	10.93	12.78	.150	....	14.35	.168
151	In cloth bags, steam-heated room	Unbleached	......	12.98	12.28	.160	....	14.11	.184
152	In cloth bags, steam-heated room	Unbleached	36	12.96	12.43	.165	....	14.28	.190
153	In cloth bags, steam-heated room	Unbleached	62	13.22	12.23	.150	....	14.09	.173
154	In cloth bags, steam-heated room	Unbleached	125	11.07	12.53	.158	....	14.08	.178
155	In cloth bags, steam-heated room	Unbleached	186	12.77	12.68	.156	....	14.53	.179
156	In cloth bags, steam-heated room	Unbleached	244	10.51	12.68	.169	....	14.16	.189
157	In cloth bags, steam-heated room	Unbleached	305	10.90	12.64	.169	....	14.19	.190
158	In cloth bags, steam-heated room	Unbleached	366	11.75	12.58	.146	....	14.25	.165
159	In cloth bags, steam-heated room	Moderately bleached	......	12.98	12.28	.150	2.0	14.11	.172
160	In cloth bags, steam-heated room	Moderately bleached	36	12.95	12.37	.167	2.0	14.21	.192
161	In cloth bags, steam-heated room	Moderately bleached	62	13.27	12.31	.158	2.0	14.19	.182
162	In cloth bags, steam-heated room	Moderately bleached	125	11.19	12.49	.154	2.0	14.06	.173
163	In cloth bags, steam-heated room	Moderately bleached	186	12.60	12.86	.149	1.5	14.71	.170
164	In cloth bags, steam-heated room	Moderately bleached	244	10.61	12.68	.161	1.5	14.18	.180
165	In cloth bags, steam-heated room	Moderately bleached	305	10.86	12.76	.169	1.5	14.32	.190
166	In cloth bags, steam-heated room	Moderately bleached	366	11.78	12.49	.151	....	14.15	.171
167	In cloth bags, steam-heated room	Overbleached	......	12.96	12.33	.153	4.0	14.17	.176
168	In cloth bags, steam-heated room	Overbleached	36	12.96	12.39	.162	5.0	14.24	.186
169	In cloth bags, steam-heated room	Overbleached	62	13.18	12.28	.154	4.0	14.15	.177
170	In cloth bags, steam-heated room	Overbleached	125	11.26	12.60	.154	3.0	14.53	.177
171	In cloth bags, steam-heated room	Overbleached	186	12.70	12.84	.159	2.0	14.70	.182
172	In cloth bags, steam-heated room	Overbleached	244	10.56	12.74	.158	2.0	14.24	.177
173	In cloth bags, steam-heated room	Overbleached	305	10.85	12.76	.170	2.0	14.32	.191
174	In cloth bags, steam-heated room	Overbleached	366	11.72	12.52	.146	....	14.19	.165

TABLE XXXIV.—Baking tests of flour stored under different conditions—1910-1911.

Portion No.	Condition of Storage.	Preliminary treatment.	Length of time stored, days.	Percentage moisture at the time of baking.	Total time of rising, minutes.	Maximum expansion, cc.	Rise in oven, cm.	Volume of loaf, cc.	Gluten quality factor.	Texture of crumbs, 100 = perfection.	Color of crumb, 100 = perfection.
135	Sealed jars, steam-heated room	Unbleached	......	12.98	211	2,230	5.1	1,635	1,918	95	94
136	Sealed jars, steam-heated room	Unbleached	36	13.01	240	2,630	6.5	1,865	3,188	95	94
137	Sealed jars, steam-heated room	Unlbeached	62	13.02	177	2,380	5.7	1,965	2,666	94	97
138	Sealed jars, steam-heated room	Unbleached	125	12.42	187	2,800	6.7	2,040	3,827	93	96
139	Sealed jars, steam-heated room	Unbleached	186	12.65	214	3,000	6.0	1,970	3,546	93	96
140	Sealed jars, steam-heated room	Unbleached	244	12.85	211	2,900	6.3	1,975	3,608	93	96
141	Sealed jars, steam-heated room	Unbleached	305	12.74	188	2,800	5.9	2,000	3,304	95	100
142	Sealed jars, steam-heated room	Unbleached	266	11.99	195	2,550	5.7	1,915	2,783	95	99
143	In cloth bags, unheated room	Unbleached	......	12.98	211	2,230	5.1	1,625	1,918	95	94
144	In cloth bags, unheated room	Unbleached	36	12.57	224	2,630	6.1	1,880	3,016	95	94
145	In cloth bags, unheated room	Unbleached	62	12.77	179	2,450	6.0	2,000	2,940	95.5	97
146	In cloth bags, unheated room	Unbleached	125	12.00	182	2,850	6.2	1,990	3,516	94	96
147	In cloth bags, unheated room	Unbleached	186	12.48	219	2,630	5.9	1,970	3,057	94	97
148	In cloth bags, unheated room	Unbleached	244	12.20	203	2,950	6.0	2,005	3,549	94	97
149	In cloth bags, unheated room	Unbleached	305	11.26	181	2,900	5.9	1,960	3,354	95	100
150	In cloth bags, unheated room	Unbleached	266	10.93	198	2,550	5.7	1,945	2,827	95	100
151	In cloth bags, steam-heated room	Unbleached	......	12.98	211	2,230	5.1	1,635	1,918	95	94
152	In cloth bags, steam-heated room	Unbleached	36	12.96	209	2,700	5.8	1,870	2,928	95	94
153	In cloth bags, steam-heated room	Unbleached	62	13.22	171	2,430	5.7	1,970	2,729	95.5	97
154	In cloth bags, steam-heated room	Unbleached	125	11.07	178	2,800	6.5	1,990	3,622	94	96
155	In cloth bags, steam-heated room	Unbleached	186	12.77	208	2,680	6.0	1,980	3,184	95	97
156	In cloth bags, steam-heated room	Unbleached	244	10.51	210	2,850	6.4	2,070	3,776	94	97
157	In cloth bags, steam-heated room	Unbleached	305	10.90	175	2,900	5.9	2,040	3,490	95	100
158	In cloth bags, steam-heated room	Unbleached	366	11.75	205	2,480	5.1	1,930	2,441	96	99
159	In cloth bags, steam-heated room	Moderately bleached	......	12.98	220	2,180	5.65	1,610	1,983	95	94
160	In cloth bags, steam-heated room	Moderately bleached	26	12.95	208	2,600	5.6	1,890	2,752	95	94
161	In cloth bags, steam-heated room	Moderately bleached	62	13.27	164	2,400	5.1	1,905	2,332	94	95.5
162	In cloth bags, steam-heated room	Moderately bleached	125	11.19	173	2,800	6.3	1,980	3,493	96	97
163	In cloth bags, steam-heated room	Moderately bleached	186	12.60	203	2,680	6.1	2,000	3,270	95	97
164	In cloth bags, steam-heated room	Moderately bleached	244	10.61	228	2,750	6.4	2,005	3,529	94	97
165	In cloth bags, steam-heated room	Moderately bleached	305	10.86	175	2,800	6.0	2,030	3,410	95	100
166	In cloth bags, steam-heated room	Moderately bleached	266	11.78	202	2,450	4.9	1,875	2,251	96	98
167	In cloth bags, steam-heated room	Over-bleached	......	12.96	220	2,180	5.65	1,653	2,036	94.5	95
168	In cloth bags, steam-heated room	Over-bleached	36	12.96	197	2,530	5.3	1,910	2,561	95	99
169	In cloth bags, steam-heated room	Over-bleached	62	13.18	157	2,480	5.2	1,908	2,461	96	97.5
170	In cloth bags, steam-heated room	Over-bleached	125	11.26	166	2,900	6.2	2,020	3,632	95	98
171	In cloth bags, steam-heated room	Over-bleached	186	12.70	207	2,680	5.8	1,945	3,023	96	98
172	In cloth bags, steam-heated room	Over-bleached	244	10.56	219	2,775	6.2	2,005	3,450	95	98
173	In cloth bags, steam-heated room	Over-bleached	305	10.85	178	2,750	6.4	2,020	3,555	95	100
174	In cloth bags, steam-heated room	Over-bleached	366	11.72	202	2,430	4.8	1,865	2,175	96	97