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THE INFLUENCE OF CERTAIN SUBSTANCES UPON THE BAKING QUALITIES OF FLOUR.

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The Baking Qualities of Flour as Influenced by Certain Chemical Substances, Milling By-products and Germination of the Wheat.

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INTRODUCTION.

THE milling tests of wheat and baking-tests of flour conducted by the Department of Chemistry began in 1905, when an experimental reduction mill was purchased. During that year, Mr. W. E. Mathewson, in a research conducted as a part of his work for the master's degree, made very careful analyses of several flours, including determinations of the percentages of each of the distinct proteins present, and compared their chemical composition with their baking qualities as shown by baking-tests made for us in the Department of Domestic Science. At that time the statement was frequently made, and perhaps is even to-day, that the ratio of the gliadin to the glutenin of the flour determines its baking qualities. Mr. Mathewson's results threw grave doubt on this supposition, and all subsequent investigations in the department have confirmed the view suggested at that time, namely, that the chemical factors entering into the baking quality of flour are more complex than that. Flours may be very good in their content of gliadin and in the gliadin-glutenin ratio, and yet be inferior in baking qualities to others with supposedly less favorable composition. Of two flours, essentially the same in respect to these data, one may be very good and the other very poor.

As a result of such observations the department has been conducting numerous experiments designed to throw light on the subject of baking quality in flour. Many of these do not come within the scope of the present report, which is concerned with the effects of the addition of certain chemical substances to the flour. These tests were suggested by the thought that, inasmuch as considerable differences in respect to the gliadin

* Mr. R. C. Thompson, formerly assistant chemist here, now chemist of the Arkansas Experiment Station, performed the baking tests reported in this bulletin.

and the gliadin-glutenin ratio did not in themselves appear to influence the results much, it might easily be true that the difference in baking qualities exhibited may be caused by substances present in very small amounts. It will be recalled that capacity to produce a good loaf depends on the quality of the gluten that a given flour can yield, other conditions being favorable. Gluten does not exist as such in the flour, but is produced, in a manner not altogether understood, from constituents existing in the flour, chiefly the gliadin and the glutenin, when the flour is stirred with water. Gliadin is a gluey adhesive substance which binds the glutenin and other constitutents of the flour together in the dough and produces the well-known condition so essential to the production of good bread, in which the carbon dioxide produced by yeast is held in small bubbles that give the loaf its lightness. If the gluten is too weak the partitions between the globules break, and globules coalesce with the production of coarse-grained bread. A weak gluten will yield under the weight of the loaf, and instead of rising in a well-rounded form will flatten out and run over the edge of the pan if possible. The production of a good loaf depends on the physical properties of the gluten. It is well-known that small percentages of substances may cause very great differences in the physical properties of mixtures. It is therefore quite reasonable to expect that the physical properties of gluten may be profoundly affected by small quantities of associated substances. This would be a purely physical phenomenon. It is, however, also possible that small quantities of substances may influence the character of the loaf in an entirely different manner by favoring or inhibiting, as the case may be, the growth of the yeast.

It is well-known that Graham flour lacks the power to yield as round and light a loaf as does white flour produced from the same wheat. This fact suggested experiments to ascertain the effect of substances in the bran and shorts, the action of which is excluded from white flour. These effects were tested in different ways which will be detailed later, using bran, extracted bran, extract from bran, extract from wheat scourings, etc.

Recent research has shown that the protein substances consist in large part of nuclei derived from a considerable number of amino-acids. It is highly probable that, in the growth of the yeast in the flour, hydrolysis of the proteins takes place, with the liberation of some of these amino-acids, and it is possible that they play an important part in the development of the yeast, or affect the physical properties of the gluten. A part of our study in this connection, then, has been to ascertain what effect, if any, the addition of small amounts of amino-acids has on the character of the loaf produced. As but few of the amino-acids represented in proteins are to be purchased in the market, our experiments in this line are not completed as yet. It is planned to import as complete a list of these substances as can be obtained for continuation of this investigation.

A considerable number of observations were made with each baking-test. Where individual loaves were baked in testing different flours, 31 sets of figures were recorded for each loaf. In these studies only the important factors, such as would he affected by the test, are presented. A short description of the method used in making the baking tests is given first. Then follow tables giving the most important results of each test together with remarks and deductions made. The summary tables give the results for individual factors obtained in all the tests under all the conditions involved.

Method of Making the Baking-Tests.

In making these baking-tests the method of procedure was in general the same as that usually employed in this laboratory, with a few modifications to suit special cases.

The baking-tests were carried out as described below. It should be remembered that in all baking-tests, not all the conditions are under the operator's control, and, further, that a skilled operator can often tell, by the way the dough handles, many things in regard to the test which he can not put into words or figures. However, in making a series of tests it is necessary to eliminate the personal equation as much as possible, in order that the results may be comparable to the extent demanded by scientific accuracy. For this reason it is desirable to obtain as many measured factors as possible, and this has been kept in view in the adoption of the details of the method. Further, in making a baking-test a loaf should be secured which conforms to standards for good bread, rather than one which is at once subject to criticism by bread-bakers in general.

Yeast. The yeast is one of the most important factors in making a baking-test, and one which is very difficult to control. For this reason a check loaf was always baked under conditions identically the same as obtained in baking the other loaves. The yeast used for these tests was of the Fleischmann brand and bought from a local baker. It was received fresh once a week from Kansas City. As soon as the yeast arrived in the laboratory it was stored in a tin pail in a dry refrigerator cooled by ammonia. Yeast stored in an ordinary refrigerator where the air is very damp will not keep well unless securely protected from moisture. The portion of the yeast used for the day was cut into small pieces about the size of rice grains and thoroughly mixed. Ten-gram portions were weighed out, placed in small glass-stoppered bottles, and put in a cool place until ready for use.

Flour. The flour used in these tests was obtained from the Manhattan Milling Company and was an unbleached, straight grade. The flour for the day's use was weighed out in small baking-pans and placed in the sponge case until it had a temperature of 35° C. On cool days it was sometimes necessary to heat the flour in the electric oven for a short time before putting it in the sponge case. Five grams of lard were weighed into the flour for shortening. The flour used in each test was 300 grams.

Water, Sugar, Salt, or Chemicals. In these tests the same amount of water was used for each loaf except in a few special cases. The requisite amount was found to be 165 cc. The weighed portion of the chemical to be used, with 15 grams of sugar, was dissolved in this amount of water in a beaker. If the chemical or chemicals were in solution, correspondingly less amounts of water were used. This solution was heated to 35" C. and placed in the sponge case.

Preliminary Fermentation. Thirty minutes before the doughing commenced, the yeast was mixed with the above solution and allowed to ferment in the sponge case at 35° C. for thirty minutes.

Making the Dough. About 200 grams of the warmed flour were placed in the dough-kneader and the above fermenting yeast liquor added. The kneader is of the Koelner make, and connected with a one-fourth horse-power motor. The motor has a speed regulator, and the kneader was allowed to work at its highest speed for just five minutes, when the rest of the 300 grams of flour was added. With a spatula all or nearly all the flour was worked into the dough. This last kneading also occupied five minutes. If a continuous series of bakings. is kept up, it is necessary to start the preliminary fermentations ten minutes apart.

Proving the Dough. As soon as the dough was taken from the machine it was placed in a tall cylinder, and pressed down firmly. This cylinder is about 30 centimeters high, and of such a diameter that one centimeter in height equals very nearly 100cc. volume. All doughs in these tests had a volume of about 550 cc., and the dough was allowed to rise for the first time until the volume measured very nearly 1650 cc. When this point was reached the time was noted and the dough was worked lightly in the hands, and allowed to rise again. This time the rising was allowed to go as far as it would. This has to be watched very carefully if the time element in a test is to have any value. When the dough would rise no more, or showed signs of falling, it was again worked in the hands and placed in a greased baking-can, the weight of which was known. The can and dough were weighed and the dough was again allowed to rise a standard amount. These baking-cans are the same as described in a previous publication and are so constructed that when the dough is ready for the oven it presses against, and raises, a circular disk attached to a shaft which extends through the cover. The amount of rise on this shaft was made the same for all the loaves. This plan gives a uniform rise before baking, and is an important consideration if difference of texture and volume are to be attributable to the flour and other ingredients in the dough, and not to the handling just before baking.

Baking. The loaves were baked 35 minutes at 240° C. This temperature is somewhat. high but was found necessary in the style and kind of oven used. At the end of 35 minutes the loaf was taken from the oven, the rise or spring in the oven measured on the shaft, and the loaf removed from the pan. After cooling 30 minutes, it was weighed.

Volume. The volume was taken by placing the loaf in a circular can of known volume and filling the empty space with flaxseed. The seed was allowed to flow loosely over the loaf in such a way that it was not packed and the top stroked off level. The seed used was then poured into a glass measuring cylinder by means of a large funnel. It is very important that the seed be allowed to run around the loaf, and fill the empty space in the same manner each time, and flow from the funnel from the same height and at the same rate each time. If this is not done grave errors are introduced in taking the volume.

Judging the Bread. The loaves in these tests were judged on condition of crust, and texture of crumb, 100 being taken as perfection.

SUMMARY OF PROCEDURE.

1. Weigh the flour and shortening and heat the flour to 35° C.
2. Measure the requisite amount of water, weigh out the sugar and the various chemicals to be used for each loaf, and mix. No common salt was used in these tests.
3. Weigh out the separate portions of yeast.
4. Thirty minutes before doughing commences mix 10 grams of the yeast with the water solution of the sugar and chemicals, and allow to ferment thirty minutes.
5. Make the dough and note time.
6. Allow to rise until volume has trebled, work down, and note time.
7. Allow to rise as high as it will, read volume, and note time.
8. Work, and place in baking-pan, weigh, and allow to rise a standard amount.
9. Note time and bake 35 minutes.
10. Measure spring or rise in the oven, remove from can, allow to cool 30 minutes and weigh.
11. Take volume of loaf; cut and judge bread,

From the data noted the summaries following were obtained. As a rule the quantities of the chemicals were used in a geometrical ratio, the smallest amount being 0.1 gram and the largest 1.6 grams. If it was shown that these amounts were too large or too small, the trial was repeated using larger or smaller amounts, and the second trial is the one usually reported, as the results were such as to show the effects if there were any. When solutions were used the same general plan was followed;

the amount of solution used represented the extract from a definite amount of wheat substance, and this amount was varied in a geometrical ratio.

The time for the first rise was counted from the moment the yeast liquor was mixed with the flour and the kneading commenced, to the point when the dough had trebled its volume. The time for the second rise was figured from the first turning, or knocking down for the first working, until the moment when the dough rose no more, or showed signs of falling. The time for the third rise was counted from the time the dough was placed in the baking-pan until ready to place in the oven as shown by a definite rise of the shaft. The maximum second rise was read direct. The loss of materials is the difference between the weight of the dough as placed in the baking-pan and the weight of all the ingredients used in its making. The loss is mostly water; some loss is due to materials sticking to the kneader and expansion cylinders, but this amount is comparatively small. 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 cooled loaf. The loss of weight, during the third rise of the dough is so small as to be negligible. The loss during cooling is greater as a rule than the loss during baking. This loss is greatest while the loaf is hot and becomes comparatively small as soon as the loaf is cool. The rapid escape of moisture in the form of steam can easily be seen by its effect in wetting the crust if the loaf is so placed that this steam can not readily escape. The expansion during baking or the spring in the oven is the difference between the height of the shaft before baking and its height after baking. This is measured with a caliper. The spring in the oven is due to the expansion of the carbon dioxide, air, and water vapor contained in the dough. This spring is most rapid during the first period of the baking process. As soon as the temperature rises high enough to kill the yeast the evolution of carbon dioxide ceases and the rate of expansion begins to wane. Further increase in volume is due to formation of more steam or water vapor, and the expansion of gases and vapor by reason of higher temperature. A very rapid formation of a crust on top interferes with the expansion in the oven. Differences in baking temperture will also give a difference in the spring of the loaf. Extension of the time for the rising and the amount of the rise of the dough before baking lessens the spring in the oven. The volume of the loaf, the weight of the loaf, the condition of the crust and the texture of the crumb, are data obtained as described above.

Tests with Chemicals.

Peptones were first tried in the usual amounts, beginning with 0.1 gram. These small amounts had no pronounced effects, and not until the amount was 0.8 and 1.6 grams were the effects noticeable. The test was repeated, using larger quantities. There was a regular decrease in the length of time for proving. This was most clearly manifest in the time for the third rise; and when it is remembered that this period is capable of more exact measurement than the other two the result can not be accidental. There was also a regular decrease in total expansion. The oven spring and the loaf volume showed no pronounced results with the smaller amounts, and the decrease for the larger amounts was slight. The texture was poorer with the larger amounts of peptones. The most pronounced effect was on the dough. This was exceedingly sticky, especially with the larger amounts of peptones. The dough handled in a manner similar to taffy, and like dough which contains flour from germinated wheat. The poorer texture of the loaves, and the other effects where larger amounts were used, were obtained in two successive trials.

The influence of glycocoll was very pronounced. There was a slight shortening of the total fermentation period and a decrease of expansion is evident. The decrease in the oven spring was proportionate to the amounts of the chemicals used. The slightly larger spring for loaves four and five can be accounted for by the larger holes in the loaves, especially in number five. The volume showed a regular decrease and in the smaller loaves was accompanied by poorer texture. The dough was of poor handling quality and this was in proportion to the amount of glycocoll used. It was sticky, runny and stringy. The quality of the dough was somewhat similar to that which contains flour from germinated wheat. It would stretch like taffy, and had very little elasticity or spring.

The effect of leucin was somewhat similar to that of glycocoll except that there was no decrease in oven spring or loaf volume, nor was the impairment of texture so pronounced.

TABLE I.—Baking results as affected by the addition of peptones to the flour.

Grams of peptones used per loaf...	None	0.4	0.8	1.6	3.2	6.4
Time for first rise, min...........	75	70	75	73	75	80
Time for second rise, min........	75	75	65	62	55	50
Time for third rise, min..........	30	27	26	23	23	19
Total time for proving, min.......	180	172	166	158	153	149
Maximum amount of second rise, cm.,	21	21	20	19.5	18.5	18.5
Loss of materials before baking, grams	22	19.4	14.8	17.6	19.2	21.4
Loss of materials in baking and cooling, grams	43	39	49	47	44	45
Spring in oven, cm..............	4.4	4.8	4.6	3.9	3.9	4.2
Volume of loaf, cc...............	1380	1390	1370	1280	1300	1320
Weight of loaf, grams...........	430	437	432	432	435	435
Condition of crust, per cent......	95	95	95	95	95	95
Texture of crumb, per cent.......	95	95	95	85	85	90

TABLE II.—Baking results as affected by the addition of glycocoll, aminoacetic acid, $CH_2(NH_2)\cdot COOH$, to the flour.

Grams of glycocoll used per loaf..	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min...........	70	70	70	80	73	75
Time for second rise, min.........	75	70	65	60	62	62
Time for third rise, min..........	27	24	25	26	30	25
Total time for proving, min.......	172	164	160	166	165	162
Maximum amount of second rise, cm.,	21	20	20	18	18	18
Loss of materials before baking, grams	18.0	12.1	14.2	14.4	15.8	13.6
Loss of materials in baking and cooling, grams	47	50	49	44	41	43
Spring in oven, cm..............	4.3	3.9	2.5	3.1	3.5	1.8
Volume of loaf, cc...............	1380	1330	1270	1240	1180	1180
Weight of loaf, grams...........	430	433	432	437	439	440
Condition of crust, per cent......	95	95	95	95	95	95
Texture of crumb, per cent.......	95	85	80	80	75	80

The most pronounced result from the use of this chemical was the development of a very disagreeable odor in the dough and bread.

The presence of aspartic acid was on the whole beneficial. The period of fermentation was slightly decreased and was accompanied by a somewhat larger expansion. The loaf volume showed an increase and the texture a slight improvement with the larger amounts of aspartic acid. However, on the whole the influence of this chemical was less than that of any of the other purely organic compounds.

TABLE III.—Baking results as affected by the addition of leucin, alpha-aminoisocaproic acid, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH(NH_2)\cdot COOH$, to the flour.

Grams of leucin used per loaf.....	None	0.025	0.050	0.10	0.2	0.4
Time for first rise, min..........	70	70	67	75	75	82
Time for second rise, min.........	73	70	68	67	63	54
Time for third rise, min..........	27	26	22	25	24	24
Total time for proving, min.......	170	166	157	167	162	160
Maximum amount of second rise, cm.,	21.0	21.0	20.0	20.0	19.0	19.0
Loss of materials before baking, grams	16	15	10	11	20	12
Loss of materials in baking and cooling, grams	34	42	47	46	41	45
Spring in oven, cm..............	4.5	4.5	4.0	3.5	5.1	4.5
Volume of loaf, cc...............	1380	1340	1280	1270	1360	1330
Weight of loaf, grams...........	435	438	438	438	434	438
Condition of crust, per cent......	93	93	93	93	93	93
Texture of crumb, per cent.......	92	92	90	90	88	88

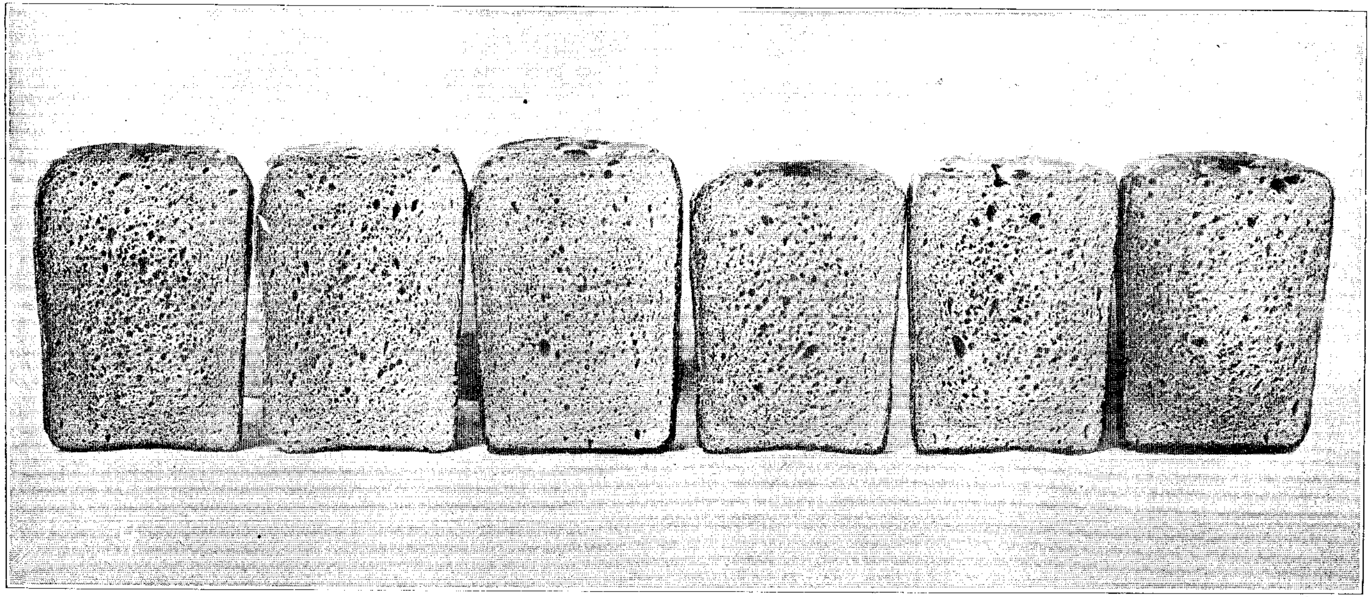

PLATE I. Showing the effect of the use of peptones. Loaves arranged from left to right in the order of quantities used: 0.0 g., 0.4 g., 0.8 g., 1.6 g., 3.2 g., 6.4 g.

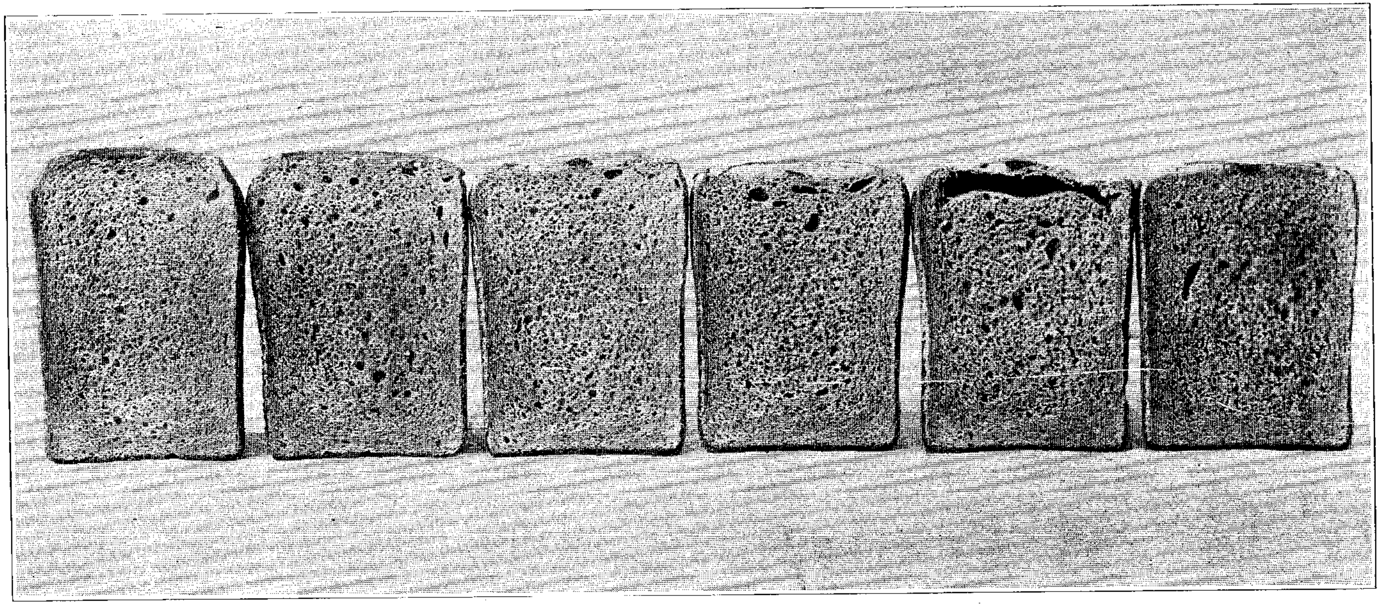

PLATE II. Showing the effect of the use of glycocoll. Loaves arranged from left to right in order of quantities used: 0.0 g., 0.1 g., 0.2 g., 0.4 g., 0.8 g., 1.6 g.

TABLE IV.—Baking results as affected by the addition of aspartic acid, aminosuccinic acid, $COOH{\cdot}CH_2{\cdot}CH(NH_2){\cdot}COOH$, to the flour.

Grams of aspartic acid used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min.	53	52	50	52	55	59
Time for second rise, min.	80	73	65	53	55	54
Time for third rise, min.	25	26	27	20	20	22
Total time for proving, min.	160	151	142	125	130	135
Maximum amount of second rise, cm.	22.0	21.5	21.0	21.0	22.5	23.0
Loss of materials before baking, grams	23.0	20.1	8.2	9.4	19.2	17.6
Loss of materials in baking and cooling, grams	46	49	63	60	50	45
Spring in oven, cm.	5.5	5.3	4.9	4.9	5.5	5.5
Volume of loaf, cc.	1460	1470	1460	1420	1500	1530
Weight of loaf, grams	426	426	414	426	426	434
Condition of crust, per cent.	95	95	95	95	95	95
Texture of crumb, per cent.	98	98	98	98	99	99

The effect of asparagin showed itself in three ways: the shortening of the time of fermentation, the decrease of oven spring and the poorer texture. The decrease in the time for proving was regular and proportional to the amount of asparagin used. This statement is also true of the total expansion. The oven spring and the loaf volume also decreased regularly with the exception of the loaf with which 0.8 gram was used, which showed the greatest decrease. Asparagin evidently stimulates the activity of the yeast, thus shortening the time of rising, but it weakens the gluten as shown by the smaller total rise and diminished oven expansion and loaf volume. As will be seen below, these effects are similar to those produced by compounds formed in the germination of wheat, and asparagin is known to be one of these compounds.

The influence of ammonium acetate was clear and distinct. The second and third periods of fermentation were uniformly shortened, the rise in the oven and the loaf volume were uniformly increased, corresponding to the larger amounts of the salt. In these respects the influence of ammonium acetate is similar to that of ammonium chloride only in less degree. The result is different in that the larger amounts of ammonium acetate produced poorer texture, while larger amounts of ammonium chloride produced a better texture.

Ammonium tartrate seemed to shorten the period of fermentation, especially towards the last, and had a slight influence in increasing the total expansion. The spring in the oven and the loaf volume showed an increase except in the case of the use of the largest amount. This salt had a detrimental effect on the texture, like the ammonium acetate.

In the first trial with ammonium chloride the amounts used were 0.1, 0.2, 0.4, 0.8, and 1.6 grams respectively. The effects

TABLE V.—Baking results as affected by the addition of asparagin, aminosuccinamic acid, $CO(NH_2)\cdot CH_2\cdot CH(NH_2)\cdot COOH+H_2O$, to the flour.

Grams of asparagin used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min	70	62	62	65	75	65
Time for second rise, min	83	78	63	60	50	58
Time for third rise, min	23	21	24	24	19	19
Total time for proving, min	176	161	149	149	144	142
Maximum amount of second rise, cm	22.5	23.0	21.0	20.0	20.5	21.0
Loss of materials before baking, grams	21	17.1	13.2	13.4	17.8	17.6
Loss of materials in baking and cooling, grams	40	44	48	44	40	44
Spring in oven, cm	5.1	5.2	5.1	4.8	3.8	4.6
Volume of loaf, cc	1440	1410	1380	1380	1300	1370
Weight of loaf, grams	434	434	434	438	438	435
Condition of crust, per cent	95	95	95	95	95	95
Texture of crumb, per cent	97	97	95	93	88	88

TABLE VI.—Baking results as affected by the addition of ammonium acetate, $CH_3\cdot COONH_4$, to the flour.

Grams of ammonium acetate used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min	67	60	58	57	57	64
Time for second rise, min	80	80	74	70	67	59
Time for third rise, min	27	21	18	17	12	15
Total time for proving, min	174	161	150	144	136	138
Maximum amount of second rise, cm	23.5	23.5	23.5	23.5	23.5	22.5
Loss of materials before baking, grams	21	18.1	18.2	17.4	14.8	17.6
Loss of materials in baking and cooling, grams	48	49	52	49	51	49
Spring in oven, cm	4.4	5.2	5.4	5.5	5.5	5.3
Volume of loaf, cc	1440	1490	1490	1500	1520	1500
Weight of loaf, grams	429	429	428	432	433	433
Condition of crust, per cent	95	95	95	95	95	95
Texture of crumb, per cent	90	88	88	85	85	85

of the smaller amounts were so pronounced that the use of less quantities for some loaves was necessary in order to get results comparable with the check loaf. Instead of 0.1 gram, 0.025 gram was taken. This small amount, less than one thousandth part of an ounce, was sufficient to make a pronounced change in the texture and the spring in the oven. Fifty milligrams, 0.050 gram, had no increased effect corresponding to the additional amount of chemical used. The effects were clear and unmistakable when 100, 200, and 400 milligrams were used. The second and third periods of rising were shortened, and the spring in the oven increased, with a correspondingly larger loaf volume. This increase in oven rise and loaf volume was accompanied by an improvement in texture of crumb. Large loaf volume with poor texture is not desirable. Ammonium chloride in very small amounts, from 1/300 ounce to 1/75 ounce per loaf, will show very marked results when used in baking. These amounts correspond very closely to the medicinal dose of this salt.

Does the ammonium chloride act as a stimulant to the yeast or as a food giving the yeast increased vigor? Does any of the ammonium chloride remain as such in the bread? As this salt is one having a definite and distinct medicinal effect, its use in bread-making would be strictly prohibited, but as these studies were undertaken to find out if possible some of the causes which affect a baking-test, the results with ammonium chloride were extremely gratifying. It is hoped that these studies may be carried further.

TABLE VII.—Baking results as affected by the addition of ammonium tartrate, $NH_4OOC{\cdot}CHOH{\cdot}CHOH{\cdot}COONH_4$, to the flour.

Grams of ammonium tartrate used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min.	68	63	61	63	70	63
Time for second rise, min.	80	78	74	65	65	72
Time for third rise, min.	21	18	14	15	15	12
Total time for proving, min.	169	159	149	143	150	147
Maximum amount of second rise, cm.	24.0	24.0	24.0	24.0	25.0	25.0
Loss of materials before baking, grams	16	21.1	21.2	20.4	16.8	17.6
Loss of materials in baking and cooling, grams	45	42	43	45	43	41
Spring in oven, cm.	4.7	5.0	4.8	5.2	5.6	4.4
Volume of loaf, cc.	1460	1470	1450	1520	1550	1400
Weight of loaf, grams	433	431	430	429	435	437
Condition of crust, per cent	95	95	95	95	95	95
Texture of crumb, per cent	90	90	90	90	90	90

TABLE VIII.—Baking results as affected by the addition of ammonium chloride, NH_4Cl, to the flour.

Grams of ammonium chloride used per loaf	None	0.025	0.05	0.10	0.2	0.4
Time for first rise, min.	60	60	62	60	63	62
Time for second rise, min.	75	75	73	71	63	62
Time for third rise, min.	22	20	20	17	16	14
Total time for proving, min.	157	155	155	148	142	138
Maximum amount of second rise, cm.	24	24.5	22	23	23	22.5
Loss of materials before baking, grams	20	19	21	18	15	16.4
Loss of materials in baking and cooling, grams	43	49	50	43	44	42
Spring in oven, cm.	3.3	4.2	3.8	5.3	6.1	6.1
Volume of loaf, cc.	1300	1420	1260	1520	1600	1610
Weight of loaf, grams	432	437	424	434	436	437
Condition of crust, per cent	93	93	93	93	93	93
Texture of crumb, per cent	96	97	96	95	98	99

The use of ammonium phosphate showed no noticeable affect. This is remarkable since the ammonium chloride had such a marked influence. These six loaves were as uniform, in all respects as it is possible to get in a baking-test. They showed the possibilities of the test; that uniform condition with no variation of materials will bring comparable results and that the results are not accidental; that when a chemical is introduced, any change in the result is due to it.

Sodium phosphate showed no pronounced results with the usual amounts for these tests, and larger amounts were tried, starting with 0.4 gram or four times as much. Even these increased amounts showed no marked results. The small differences in the different measurements showed no uniform relationship and were accidental.

TABLE IX.—Baking results as affected by the addition of ammonium phosphate $(NH_4)_2HPO_4$, to the flour.

Grams of ammonium phosphate used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min.	65	70	65	70	75	75
Time for second rise, min.	80	70	71	62	63	63
Time for third rise, min.	17	19	16	18	18	18
Total time for proving, min.	162	159	152	150	156	156
Maximum amount of second rise, cm.,	24.5	23.5	22.5	23.5	23.0	20.0
Loss of materials before baking, grams	17	15.1	15.2	14.4	17.8	13.6
Loss of materials in baking and cooling, grams	42	44	51	51	43	41
Spring in oven, cm.	5.0	5.4	5.5	5.4	5.4	5.4
Volume of loaf, cc.	1470	1470	1470	1470	1440	1430
Weight of loaf, grams	436	436	429	430	435	442
Condition of crust, per cent	95	95	95	95	95	95
Texture of crumb, per cent	94	94	94	94	94	94

TABLE X.—Baking results as affected by the addition of sodium phosphate, $Na_2HPO_4 + 12H_2O$, to the flour.

Grams of sodium phosphate used per loaf	None	0.4	0.8	1.6	3.2	6.4
Time for first rise, min.	62	62	54	59	62	62
Time for second rise, min.	82	77	77	70	73	83
Time for third rise, min.	26	27	24	25	26	25
Total time for proving, min.	170	166	155	154	161	170
Maximum amount of second rise, cm.,	22.0	21.5	21.5	22.0	21.5	21.0
Loss of materials before baking, grams	28	22.4	16.8	16.6	17.2	15.4
Loss of materials in baking and cooling, grams	45	41	46	47	46	39
Spring in oven, cm.	4.4	4.5	4.7	4.2	4.5	4.6
Volume of loaf, cc.	1430	1450	1460	1400	1410	1420
Weight of loaf, grams	422	432	433	433	435	447
Condition of crust, per cent	95	95	95	95	93	93
Texture of crumb, per cent	95	92	93	95	96	96

Sodium bicarbonate showed a detrimental effect. The time for proving was longer with the larger amounts of the salt. This was particularly true in the third period. The maximum rise showed a decrease as the quantities of the salt became larger. The spring in the oven also grew less. This showed itself in a lessened loaf volume. The condition of the crust and the texture of the crumb showed a decrease in quality. This detrimental effect of sodium bicarbonate is somewhat remarkable as this salt, in connection with some organic acid, or acid salt, is often used instead of yeast for raising bread. The detrimental effect must be due to the alkaline condition caused by the presence of this salt. Its effect is cumulative. The greatest retardation in the time of rising was in the third period. The conditions of the test are such that the measurement here can be made more exactly than with the other two periods. This is also true of the spring in the oven and the loaf volume. These measurements are the least influenced by the personal equation and the contingencies of the test and when such uniform variations are obtained they are most assuredly due to the substances added.

The influence of sodium formate for the amounts used was not very pronounced or regular. The irregularities may be due to the unavoidable difficulties in attaining uniformity in making baking-tests. Whatever influence was manifest was detrimental, particularly in prolonging the period of fermentation with no corresponding benefits in loaf volume and texture.

TABLE XI.—Baking results as affected by the addition of sodium bicarbonate, $NaHCO_3$, to the flour.

Grams of sodium bicarbonate used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min.	63	68	68	68	70	66
Time for second rise, min.	88	83	77	89	85	81
Time for third rise, min.	25	24	25	29	29	33
Total time for proving, min.	176	175	170	186	184	180
Maximum amount of second rise, cm.	22.0	21.5	21.5	19.0	19.5	18.5
Loss of materials before baking, grams	24	25	22	24.4	20.8	19.6
Loss of materials in baking and cooling, grams	41	42	47	32	37	34
Spring in oven, cm.	4.0	4.5	4.0	2.6	2.5	2.0
Volume of loaf, cc.	1330	1370	1350	1210	1170	1170
Weight of loaf, grams	450	455	453	462	465	468
Condition of crust, per cent	90	90	90	88	88	80
Texture of crumb, per cent	95	95	92	90	90	85

TABLE XII.—Baking results as affected by the addition of sodium formate $H{\cdot}COONa + H_2O$, to the flour.

Grams of sodium formate used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min.	61	63	64	74	68	70
Time for second rise, min.	77	69	71	67	61	78
Time for third rise, min.	19	19	22	24	19	26
Total time for proving, min.	157	151	157	165	148	174
Maximum amount of second rise, cm.	22.5	22.5	21.5	21.5	22.0	21.5
Loss of materials before baking, grams	27	24.1	16.2	17.4	12.8	12.6
Loss of materials in baking and cooling, grams	38	40	54	52	50	54
Spring in oven, cm.	5.5	5.5	5.3	5.1	5.5	5.5
Volume of loaf, cc.	1550	1530	1500	1470	1550	1500
Weight of loaf, grams	430	431	425	426	433	430
Condition of crust, per cent	95	95	95	95	95	95
Texture of crumb, per cent	95	96	98	97	94	94

The influence of potassium nitrate was very slight. The only noticeable effect was the slight shortening of the time for rising in the third period. The variation of the spring in the oven, loaf volume and texture of crumb showed no quantitative relation to the amounts used. It is difficult to see why 0.2 gram should be apparently detrimental and the larger amounts beneficial, unless the presence of the salt creates two opposing conditions, and a small variation in the amount present determines which shall prevail. The result is, however, probably accidental.

Influence of Substances in By-products of Milling.

Several tests were made to ascertain the effect of soluble substances existing in bran and wheat scourings. The bran used for these tests was pure, being free from scourings or screenings of any kind. Five hundred grams of bran were placed in a glass jar and 2000 cc. of water added. In that ratio the bran soaked up most of the water, and a larger proportion of bran could not be conveniently used without employing some pressure filter to obtain the extract. The bran was allowed to soak over night. It was then placed on a piece of muslin and the extract squeezed out. This extract contained a considerable amount of matter in suspension. The extract was poured into a tall cylinder and most of this matter settled to the bottom. In this first trial with the bran extract, the supernatant liquid was drawn off with a pipette. As 2000 cc. of water were used for 500 grams of bran, each 4 cc. contained the extract from one gram of bran. The amounts of extract used were respectively 10, 20, 40, 84, and 165 cc., representing 2½, 5, 10, 21, and 41 grams of bran.

The use of this extract was advantageous in every way except in the effect on texture. The time for rising was shortened in the second and third periods, and this shortening of the time for rising was not accompanied by any diminution of total expansion. The spring in the oven and the loaf volume showed an almost regular increase. These results show that the extract furnishes a valuable food or stimulant for the yeast, increasing its growth and vigor. This extract may have contained a larger amount of enzymes, the presence of which seems to stimulate yeast activity. The poorer texture may have been the result of a slight overfermentation due to the increased growth and vigor of the yeast plant, or to an alteration in the quality of the gluten through the influence of certain substances upon the physical properties. It would be a very interesting and profitable study to determine what compounds in this bran extract are influential in effecting the changes in results obtained in raising and baking of the dough. It is well known that this bran extract contains the organic phosphorus compound phytin, and that the presence or absence of this compound has a marked influence on the nutrition when bran forms part of the ration of dairy cows. Are the beneficial clinical effects of Graham bread due to this compound, or to the mechanical effect of the bran particles? This question could be studied by conducting nutrition experiments, using bread made with this bran extract, bread made with the untreated bran, and bread made with extracted bran. It is also known that the presence of these bran particles is undesirable for delicate stomachs. Can the good clinical results be secured by the use of bran extract, and the presence of the more or less undesirable bran particles be avoided? This seems to be a question of human nutrition worthy of investigation.

TABLE XIII.—Baking results as affected by the addition of potassium nitrate, KNO_3, to the flour.

Grams of potassium nitrate used per loaf	None	0.1	0.2	0.4	0.8	1.6
Time for first rise, min.	60	65	60	60	61	65
Time for second rise, min.	75	65	70	70	80	75
Time for third rise, min.	26	24	26	22	21	19
Total time for proving, min.	161	154	156	152	162	159
Maximum amount of second rise, cm.	24.5	24.0	23.0	23.5	25.5	25.5
Loss of materials before baking, grams	10.0	10.1	8.2	10.4	10.8	6.6
Loss of materials in baking and cooling, grams	40	38	39	51	47	50
Spring in oven, cm.	5.0	4.8	4.1	4.5	5.1	5.1
Volume of loaf, cc.	1500	1480	1440	1500	1520	1520
Weight of loaf, grams	435	437	436	434	438	440
Condition of crust, per cent	93	93	93	93	93	93
Texture of crumb, per cent	95	90	90	95	93	96

TABLE XIV.—Baking results as affected by the addition of bran extract to the flour. (Extracted cold, unfiltered.)

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Bran extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min.	57	52	52	52	52	55
Time for second rise, min.	81	80	73	73	59	58
Time for third rise, min.	28	24	23	20	17	18
Total time for proving, min.	166	156	148	145	128	131
Maximum amount of second rise, cm.	23.5	23.5	24.0	23.5	23.5	23.5
Loss of materials before baking, grams	30	20	22	20	22	12
Loss of materials in baking and cooling, grams	38	48	48	47	47	48
Spring in oven, cm.	4.9	4.9	4.7	5.3	5.4	5.6
Volume of loaf, cc.	1480	1490	1410	1510	1520	1520
Weight of loaf, grams	427	427	425	428	426	435
Condition of crust, per cent	93	93	93	93	93	93
Texture of crumb, per cent	97	96	94	91	88	85

It would also be interesting to know what other compounds present in the bran extract influence the baking of the dough. What effects have the organic compounds of phosphorus as compared with the effect of the inorganic? These questions will be investigated as soon as opportunity offers.

Another test was conducted in the same manner as the previous one, with the exception that the extract was filtered to

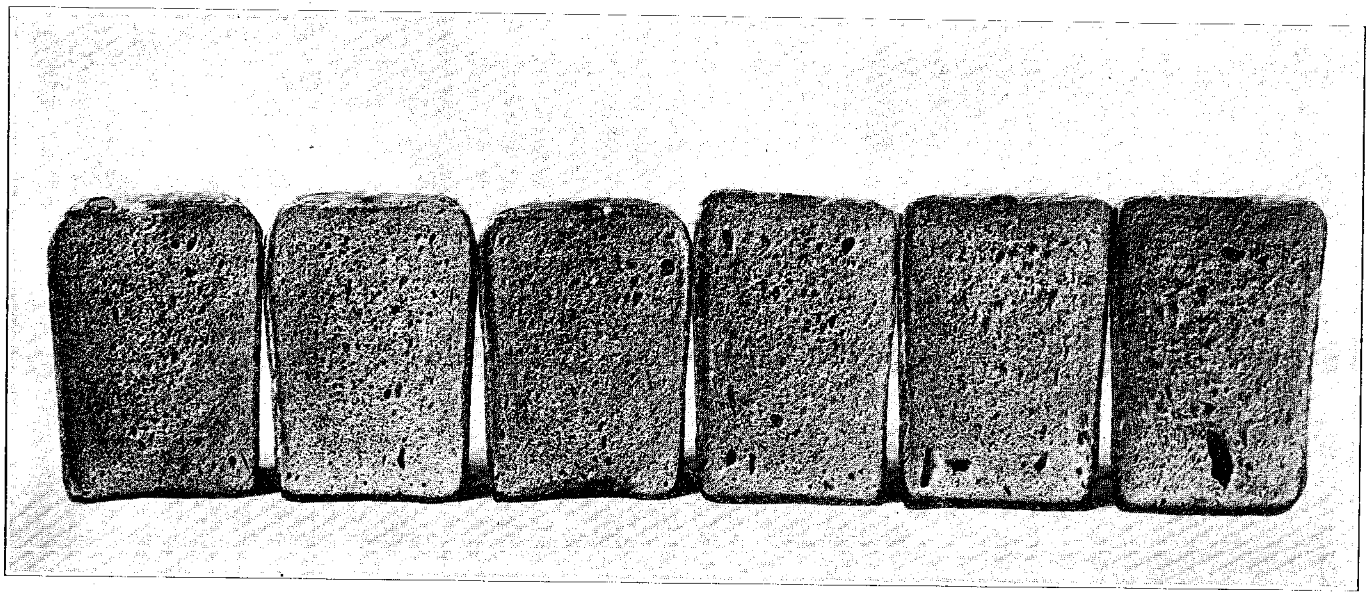

PLATE III. Showing the effect of the use of bran extract, cold extraction, Loaves arranged from left to right in order of quantities of bran extracted: 0 g., 2½ g., 5 g., 10 g., 21 g., 41 g.

rid it of suspended matter, so that whatever effects are noted were due to the soluble matter of the bran extract. The effect of this filtered extract was, in the main, identical with that of the one which was not filtered. The active compounds in bran extract are soluble. The better texture of the crumb noted in this trial was due to the heating of the flour before baking. Repeated trials in this laboratory have shown that heating the flour to a high temperature for a short time before baking produces a finer texture in the bread than is obtained when the flour is not heated. This is particularly true of flour from new wheat. This needs further investigation.

Another extract was made by mixing 500 grams of pure bran with 2000 cc. of water, heating to boiling, and keeping at this temperature for about 15 minutes. The hot bran mash was then put on linen and the extract squeezed out. The amounts and proportions in all these trials with bran extract were the same. There were some very important differences as well as similarities in the results from the use of cold extraction and the hot extraction. With the latter there was practically no shortening of the first period of rising, and the second period was considerably lengthened, though this was not regular nor in proportion to the amount of extract used. This is in striking contrast with the effect of the cold extract, where both the first and second periods were shortened in time comparably with the amount of extract used. The third period was considerably shortened. This suggests the thought that the enzymes present in the cold bran extract are a direct aid to the yeast, and that when these enzymes are absent the beneficial effects of the extract are due only to the food furnished to the yeast, and that yeast fed by these food principles becomes more vigorous as it grows older. This suggests an important line of study. What is the relation between the yeast in the dough and the enzymes in the dough? As previously stated, it has been shown in this laboratory that heating of the flour to a certain temperature before baking gives a better texture than is obtained with the unheated flour. If this is related to enzyme action it would seem that when enzymes are present, the evolution of gas is so vigorous as to rupture more dough bubbles and thus make a more holey bread, while when these enzymes are absent the evolution of gas is gentler, resulting in a more uniform crumb. The total expansion was slightly greater with the larger amount of extract. It should be noted that the better texture was found in the loaves, not where the largest, or the least, amount of extract was used, but between these extremes. Another important difference was noted in the use of the hot extract as compared with the cold, in that the dough did not fall suddenly when it reached the maximum expansion, but acted as in normal tests where pure water is used. Is the more vigorous action induced by enzymes less persistent? The spring in the oven and the loaf volume were regular in their increase, and became larger with the greater quantities of extract used.

TABLE XV.—Baking results as affected by the addition of bran extract to the flour. (Extracted cold, filtered.)

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Bran extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min.	57	59	52	52	50	50
Time for second rise, min.	78	70	71	70	65	68
Time for third rise, min.	26	23	22	21	20	19
Total time for proving, min.	161	152	145	143	135	137
Maximum amount of second rise, cm.,	22	22	22.5	24	24	22.5
Loss of materials before baking, grams	14	15	14	14	9	11
Loss of materials in baking and cooling, grams	45	44	56	49	46	44
Spring in oven, cm.	5.0	5.2	5.4	5.4	5.6	5.7
Volume of loaf, cc.	1470	1500	1520	1550	1550	1530
Weight of loaf, grams	436	436	425	432	440	440
Condition of crust, per cent.	95	95	95	95	95	95
Texture of crumb, per cent.	100	100	100	100	95	95

TABLE XVI.—Baking results as affected by the addition of bran extract to the flour. (Extracted hot.)

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Bran extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min.	60	57	51	54	55	55
Time for second rise, min.	75	77	69	65	79	90
Time for third rise, min.	32	30	27	25	22	19
Total time for proving, min.	167	164	147	144	156	164
Maximum amount of second rise, cm.,	22.5	23.0	23.5	23.0	24.5	23.2
Loss of materials before making, grams	25	22	19	13	17	16
Loss of materials in baking and cooling, grams	47	48	49	55	47	52
Spring in oven, cm.	4.2	4.5	4.8	5.4	5.6	5.9
Volume of loaf, cc.	1400	1420	1440	1520	1550	1560
Weight of loaf, grams	423	425	427	427	431	427
Condition of crust, per cent.	95	95	95	94	93	91
Texture of crumb, per cent.	97	98	99	99	100	95

An extract was made from wheat scourings such as are ordinarily put into the bran. They were obtained from a dust collector connected with the scourer in a commercial mill. They were quite free from screenings and larger particles. Those used for the test were sifted through No. 44 cloth to remove the few oat hulls and pieces of chaff present. Five hundred grams of these sifted scourings were then soaked in 2000 cc. water over night and the extract obtained by straining through linen in a Buchner funnel. The amounts of extract used for the different loaves were the same as those used with the bran. The dough made with this extract was of a sticky, undesirable nature, and this quality was more pronounced with the larger amounts of extract. The extract shortened the period of fermentation and the total amount of expansion, and lessened the oven spring and loaf volume. This decrease in the oven spring and loaf volume was more pronounced in the duplicate test repeated the next day. (See table XVIII.) The texture of the crumb was also impaired. The effects of extract from scourings are thus in marked contrast to those from bran. These effects from the scourings are wholly undesirable, while those from bran are beneficial. The wheat scourings contain that part of the bran exposed to the weather; also portions of the germ and parts of the bran in close proximity to the germ. Some of the effects of this extract from wheat scourings are very similar to those due to substances contained in germinated wheat and also those produced by peptones. It will be recalled that the bran used in making the bran extract was wholly free from scourings. It is very probable that the undesirable effects of the extract from wheat scourings are due to these compounds closely associated with the germ of the wheat.

The scourings would also, in the nature of the case, contain a varied bacterial flora. This suggests a line of investigation which would be both interesting and profitable.

TABLE XVII.—Baking results as affected by adding a cold filtered extract from wheat scourings to the flour. First trial.

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Filtered extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min.	55	52	51	50	52	53
Time for second rise, min.	56	54	49	52	47	43
Time for third rise, min.	24	21	18	17	19	17
Total time for proving, min.	135	127	118	119	118	113
Maximum amount of second rise, cm.,	24.0	24.0	24.5	24.8	23.0	22.0
Loss of materials before baking, grams	18	15	13	12	10	8
Loss of materials in baking and cooling, grams	58	58	72	54	48	44
Spring in oven, cm.	5.4	5.7	5.4	5.1	5.1	5.1
Volume of loaf, cc.	1450	1480	1500	1520	1540	1490
Weight of loaf, grams	419	422	410	429	437	443
Condition of crust, per cent	95	95	95	95	95	95
Texture of crumb, per cent	95	95	95	94	92	85

TABLE XVIII.—Baking results as affected by adding a cold filtered extract from wheat scourings to the flour. Second trial.

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Filtered extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min.	75	74	74	74	80	89
Time for second rise, min.	70	69	64	58	57	53
Time for third rise, min.	31	28	23	25	21	21
Total time for proving, min.	176	171	161	157	158	163
Maximum amount of second rise, cm.,	20.0	20.0	19.0	19.0	17.5	17.0
Loss of materials before baking, grams	21	15	16	8	17	21
Loss of materials in baking and cooling, grams	49	48	50	50	41	34
Spring in oven, cm.	3.8	4.0	3.1	3.9	3.5	2.9
Volume of loaf, cc.	1360	1460	1280	1360	1260	1190
Weight of loaf, grams	425	432	429	437	437	440
Condition of crust, per cent	95	95	95	95	93	90
Texture of crumb, per cent	95	96	92	91	80	50

Table XVIII gives the results of a second trial with wheat scourings. The results were in the main similar to those given in table XVII, and serve to corroborate the conclusions.

The results obtained in a former trial with flour from germinated wheat (Bulletin No. 177) were so interesting that it was thought worth while to repeat the trial under modified conditions, and also to try the effect of extract from bran and shorts from germinated wheat in a way similar to the trials made with pure bran from sound wheat.

Influence of Substances Produced in Germination.

The wheat was germinated on wet sand, and the process was allowed to go on until the sprouts were about one inch long. A shallow box with a bottom surface of nine square feet, and sides two inches high, was filled with fine sand. The bottom of the box was sufficiently open to allow any surplus water to drain through. Two layers of cheese cloth were placed on top of the sand. On this four kilograms of sound wheat were spread, and the whole covered by several layers of cheese cloth. All the cheese cloth used was soaked in a two per cent solution of formaldehyde as a precaution against mold. None appeared. The whole was then thoroughly wetted. This wetting was repeated several times the first day, until the wheat was thoroughly moist, and it was kept in this condition by frequent additions of water. On top of the cheese cloth large pieces of oiled paper were placed to prevent evaporation. The box was placed near a steam radiator so the temperature was warm. Germination was evident on some kernels at the end of 24 hours, and at the end of 48 hours apparently most of the kernels showed signs of germination. When the sprouts were about one inch long the wheat was taken off from the sand

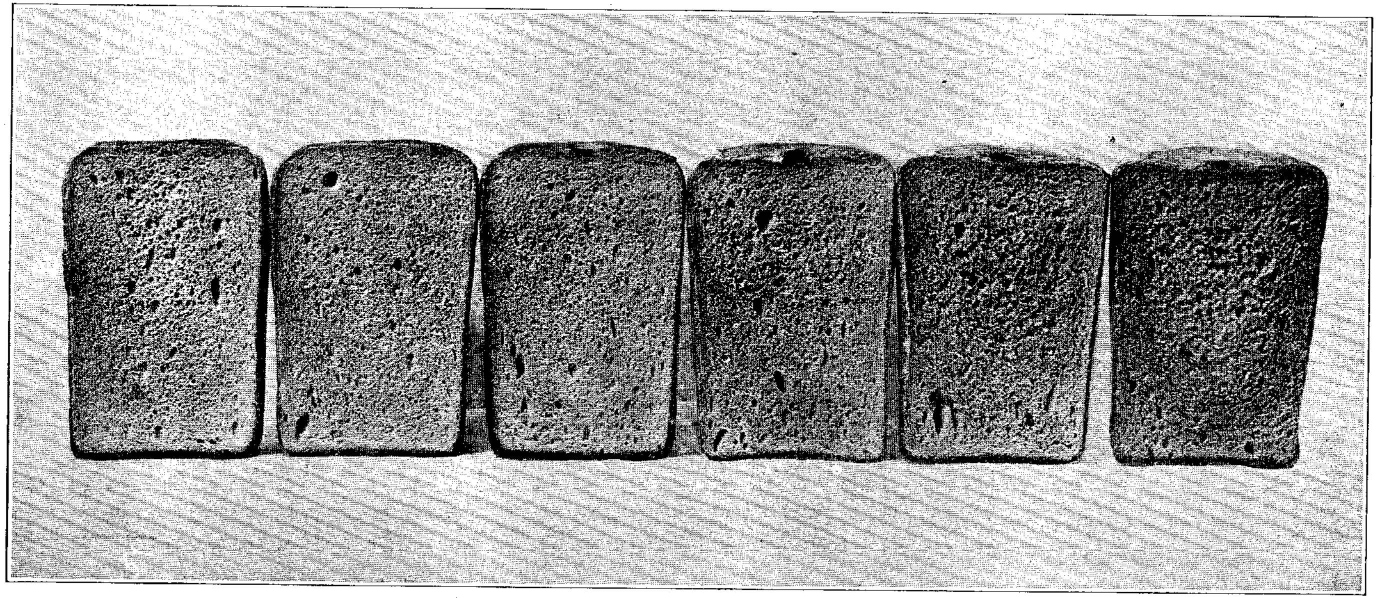

PLATE IV. Showing the effect of the use of filtered extract from ordinary wheat scourings, cold extraction. Loaves arranged from left to right in order of quantities of scourings extracted: 0 g., 2½ g., 5 g., 10 g., 21 g., 41 g.

and spread in a thin layer on the floor of a steam-heated room and allowed to dry. When dry this wheat was ground in the experimental mill, sprouts and all, and separated into bran, shorts and flour. The bran contained all the sprouts.

In the first trial flour from the germinated wheat was mixed with the same kind of flour used in all these trials in such proportion that the check loaf contained good flour only, and one loaf flour from germinated wheat only, while the other loaves contained flour from germinated wheat in the amounts given in table XIX. The total amount of flour used was 300 gram's in each case, as usual. The dough was very sticky, even with small amounts of germinated-wheat flour. Where the larger amounts were used the dough was exceedingly difficult to handle, and in turning the dough and placing it in the baking-can it was necessary to use flour. The dough handled something like putty, with the sticky nature of taffy. The loaf in which flour from germinated wheat only was used rose so slowly and was so difficult to handle that it was given but one rising preliminary to placing in the baking-can. The spring in the oven was increased when 25 grams and 50 grams, respectively, of germinated flour were used. This was due to the larger expansion of the top of the loaf caused by the weakening of the gluten. This weakening of the gluten was shown by the falling in of the top as soon as the loaf was removed from the pan and cooled. With the larger amounts of flour from germinated wheat the spring in the oven was decreased. The baked loaves were so sticky that taking the volume was not attempted. The loaf from the flour from germinated wheat only fell to pieces. See plate V.

The results from the first trial with flour from germinated wheat were so significant that a second trial was made, using smaller amounts of such flour, beginning with nine grams and then increasing in a geometrical ratio. Even nine grams of flour, or three per cent, was enough to make a sticky, undesirable dough. This amount of sprouted wheat is possible when wheat is exposed to unfavorable weather conditions. It should be borne in mind, however, that with this wheat germination had proceeded farther than is ordinarily the case, and, as we have shown before, a small amount of sprouting is not harmful beyond a slight weakening of the gluten. The length of the time for rising was decreased as the amount of flour

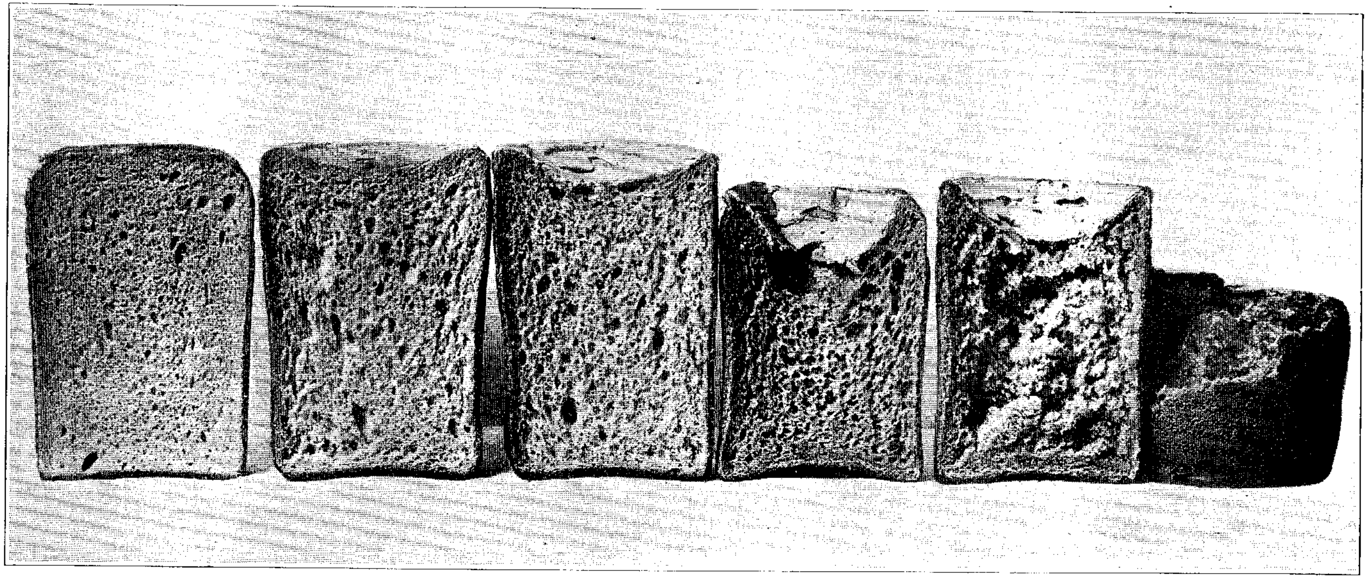

PLATE V. Showing the effect of adding to sound flour different amounts of flour made from germinated wheat. Loaves arranged from left to right in order of quantities of flour made from germinated wheat: 0 g., 25 g., 50 g., 100 g., 200 g., 300 g. (all).

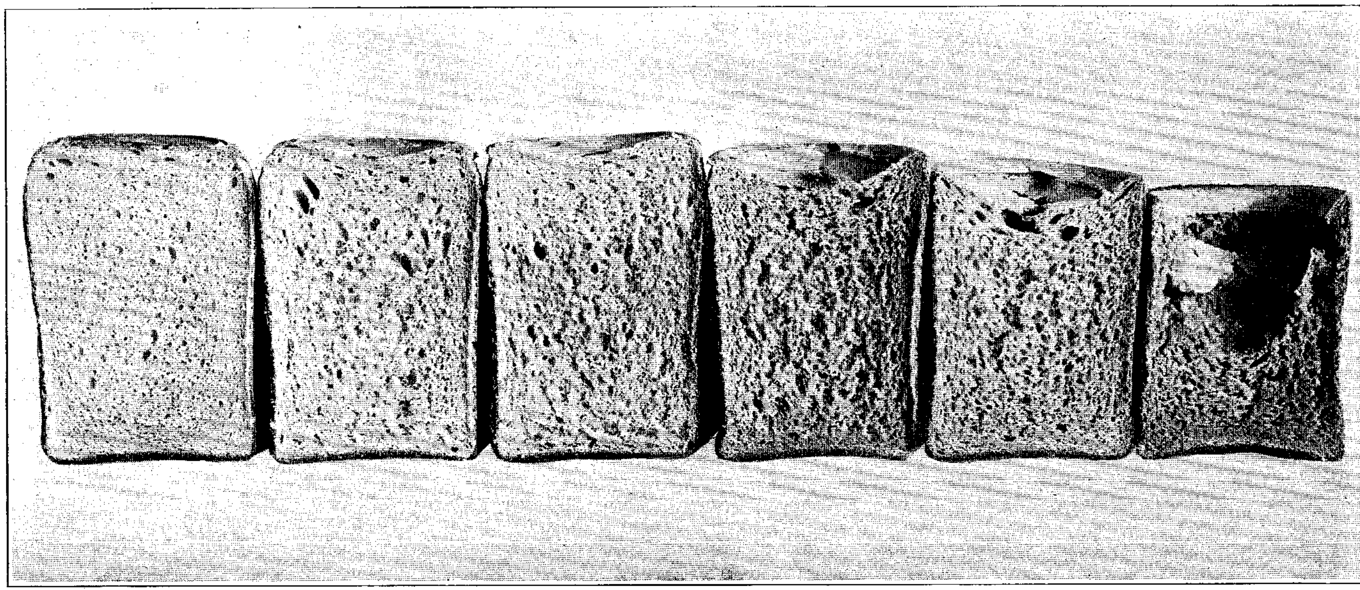

PLATE VI. Showing the effect of adding to sound flour different amounts of flour made from germinated wheat. Loaves arranged from left to right in order of quantities of flour used, made from germinated wheat: 0 g., 9 g., 18 g., 37 g., 75 g., 150 g.

from germinated wheat was increased. The maximum amount of the second rise also grew less. The spring in the oven was not notably decreased until the amounts of flour from germinated wheat reached 25 and 50 per cent. The loaf volume was not taken.

The nature of the dough and the baking factors were similar to those obtained in the use of peptones, but were manifested in a greater degree.

TABLE XIX.—Baking results as affected by adding to sound flour flour made from germinated wheat.

Germinated wheat flour used per loaf, grams	None	25	50	100	200	300
Time for first rise, min.	71	63	55	56	70	113
Time for second rise, min.	68	57	45	39	43	None
Time for third rise, min.	23	20	18	18	20	30
Total time for proving, min.	162	140	118	113	133	143
Maximum amount of second rise, cm.,	24.0	22.0	18.0	16.5	16.5	15.0
Loss of materials before baking, grams	14	18	7	6	....	....
Loss of materials in baking and cooling, grams	54	57	58	54	57	....
Spring in oven, cm.	4.9	5.4	5.6	4.0	4.2	1.1
Volume of loaf, cc.	Too sticky to take					
Weight of loaf, grams	427	420	430	435	495	....
Condition of crust, per cent	....	....	....	....	....	....
Texture of crumb, per cent	95	60	60	40	20	0

TABLE XX.—Baking results as affected by adding to sound flour flour from germinated wheat.

Germinated wheat flour used per loaf, grams	None	9	18	37	75	150
Time for first rise, min.	67	74	71	72	81	48
Time for second rise, min.	73	61	59	52	39	42
Time for third rise, min.	25	25	22	24	24	23
Total time for proving, min.	165	160	152	148	144	113
Maximum amount of second rise, cm.,	20.0	20.5	18.0	17.5	15.0	13.5
Loss of materials before baking, grams	14	10	6	4	7	13
Loss of materials in baking and cooling, grams	46	46	43	52	46	47
Spring in oven, cm.	4.3	4.5	4.7	4.5	3.7	2.7
Volume of loaf, cc.	1440	Too sticky to take				
Weight of loaf, grams	435	439	435	437	435	422
Condition of crust, per cent	95	90	80	60	40	20
Texture of crumb, per cent	95	85	80	50	25	0

The test with cold bran extract from germinated wheat was conducted in the same manner as with bran from sound wheat. The effect of this bran extract was in marked contrast to that. obtained from sound bran. The total time for rising was not decreased by the use of the larger amounts of extract, and the total amount of expansion grew less as the amount of extract used was increased. The oven spring and the loaf volume did not show any decided results. The texture of the bread was proportionately poorer as the amount of extract was increased. This was the very opposite from the results obtained by use of the extract from sound bran. It should be noted that this bran contained all the sprouts. The effect of this extract was very similar to that obtained with the extract from wheat scourings. The fact that the flour from germinated wheat, and the extract of the bran from the same wheat, produced results which are strikingly similar would indicate that the substances which are harmful are soluble, and are of the same general nature whether found in scourings, flour from germinated wheat, or in the extract of the bran from that wheat. We note also that the harmful effects are of the same general nature as those produced by the amino-compounds. It seems, therefore, safe to conclude that the presence of any of these amino-compounds is harmful to the baking qualities of the flour. These amino-compounds are produced by the vital forces inherent in the germ, and these forces are brought into activity by such conditions as are favorable to embryonic development, namely, heat and moisture. It has often been found that flour from exposed wheat will give a larger loaf volume than a loaf from sound wheat. These amino-compounds weaken the gluten, and this within certain limits produces a larger loaf. If this weakening process has gone too far, or when the presence of these amino-compounds in the flour is relatively large, as in flour from germinated wheat, the effect will be harmful, and we have a flour of undesirable qualities. As has been said before, largeness of loaf volume is not of itself an indication of a specially desirable flour.

The results from the extract of the bran from germinated wheat were so marked that the test was repeated, with the difference that the extract was boiled before using. The effects of boiling the extract were marked in several particulars. With the raw extract the total time of rising was not regularly increased or decreased, With the boiled extract the time was increased over one hour with the larger amounts of the extract used. The first rising of the last loaf was so poor that it was given only one rising before it was put into the pan. The oven spring and the loaf volume were increased with the smaller amounts of extracts and decreased with the larger amounts. The most marked result differing from the use of the raw extract was the effect on texture. Here there was very little difference in texture except in the loaf containing the greatest amount. This may be due to the fact that this loaf had one less period of rising, and the less amount of rising before baking. There was also a darkening of the color. This was due, however, to the coloring matter in the extract. Whatever the harmful substances in the bran extract are, they are modified in a marked degree by heat. The influence of the enzymes is, of course, destroyed by boiling, but it is not probable that this is the whole cause. The harmful substances are probably changed chemically in such a way as to render them less harmful. Some very important questions suggested themselves. It is known that wheat which has gone through the sweat will produce flour with better baking qualities than will wheat that has not. Also that old wheat will give better flour for baking than new wheat, and flour from new wheat will become better on standing. What changes have taken place? It is also known, that a short heating of the flour at a high temperature just before baking will improve its baking qualities. The heating of this bran extract from germinated wheat had a fundamental influence on the effects of the extract. Are these compounds in the wheat berry very closely associated with the vital processes, harmful to the baking qualities of the flour? And are these compounds changed by storage and heat? It would be interesting to know how the germination power of perfectly fresh wheat compares with the germination power of stored wheat in good condition for making flour. What are the limits of temperature for treating this wheat so as to make it better for flour-making purposes, and when will the germinating qualities be damaged? Are the different baking qualities due to greater or less amounts of these substances which are present in the wheat berry? The fact that the texture in these loaves was not injured suggests this query: Can the

TABLE XXI.—Baking results as affected by adding to sound flour cold bran extract from germinated wheat.

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Bran extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min.	80	75	74	70	80	94
Time for second rise, min.	67	65	61	58	56	58
Time for third rise, min.	23	23	21	20	23	23
Total time for proving, min.	170	163	156	148	159	173
Maximum amount of second rise, cm.,	21.0	19.5	19.5	18.5	18.5	18.5
Loss of materials before baking, grams	26	23	19	19	15	14
Loss of materials in baking and cooling, grams	46	44	48	49	43	44
Spring in oven, cm.	4.3	3.4	4.0	4.0	4.3	4.5
Volume of loaf, cc.	1350	1290	1310	1360	1320	1350
Weight of loaf, grams	423	428	428	427	437	437
Condition of crust, per cent	90	95	90	90	85	85
Texture of crumb, per cent	95	90	88	65	50	40

TABLE XXII.—Baking results as affected by adding to sound flour boiled bran extract from bran made from germinated wheat.

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Bran extract used per loaf, grams,	None	2½	5	10	21	41
Time for first rise, min...........	50	55	60	55	104	165
Time for second rise, min.........	60	56	55	60	85	1 rising
Time for third rise, min..........	17	17	20	16	19	17
Total time for proving, min.......	127	128	135	131	208	192
Maximum amount of second rise, cm.,	23.5	24.5	22.0	23.0	23.0	12
Loss of materials before baking, grams	15	13	30	14	17	13
Loss of materials in baking and cooling, grams	48	52	49	50	48	39
Spring in oven, cm..............	3.6	5.6	5.1	5.5	5.4	4.8
Volume of loaf, cc...............	1360	1460	1400	1500	1460	1420
Weight of loaf, grams...........	432	430	416	431	430	443
Condition of crust, per cent......	95	95	95	95	94	91
Texture of crumb, per cent.......	95	95	95	94	93	92

flour from fresh wheat exposed to unfavorable weather conditions be so treated as to make it equal to the flour obtained from well-seasoned wheat?

The extract from shorts was made in the same way as the extract from bran. The effect of this extract was not pronounced like that of bran. The total time for rising was lessened, except with the loaf in which the largest amount was used where there was an abrupt increase. There was no notable effect on the maximum amount of rise. The spring in the oven and the loaf volume were increased. So far the effect of the shorts extract was not harmful with the exception of retarding the time of fermentation when the maximum amount was used. But the effect on the texture was of the same nature as the bran extract though very much less in degree. As the amount of the extract used was increased, the texture became poorer. This indicates that the active principles are present in larger proportion in the bran than in the. shorts. However, it should be noted that the larger part of the germs in this case were present in the bran. It would be an interesting study to note the effects of the germ and especially the germ which has slightly sprouted. These sprouts should also be separated.

It should be understood that germination in wheat used in these experiments was carried farther than it is in wheat ordinarily considered as sprouted. Furthermore, this wheat was milled without the customary scouring process. In these experiments it was desired to produce an extreme condition. Experiments reported in Bulletin No. 177 and experiments subsequently performed have shown that incipient germina-

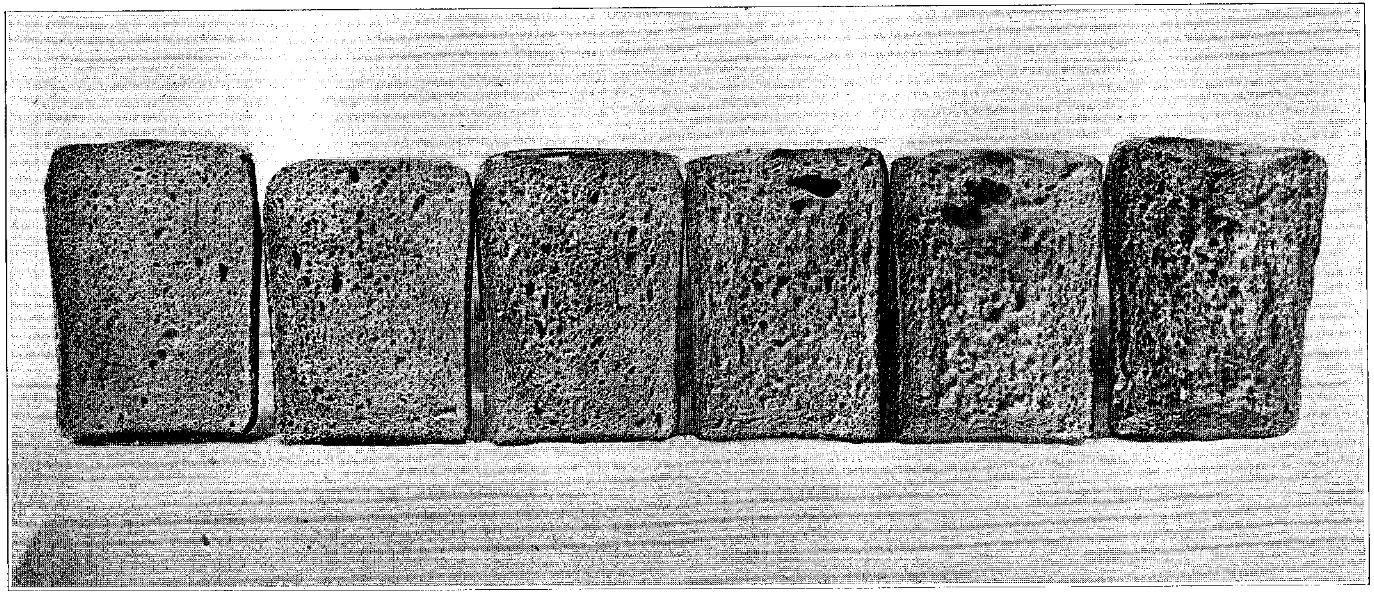

PLATE VII. Showing the effect of the use of extract of bran made from germinated wheat, cold extraction. Loaves arranged from left to right in order of quantities of bran extracted: 0 g., 2½ g., 5 g., 10 g., 21 g., 41 g.

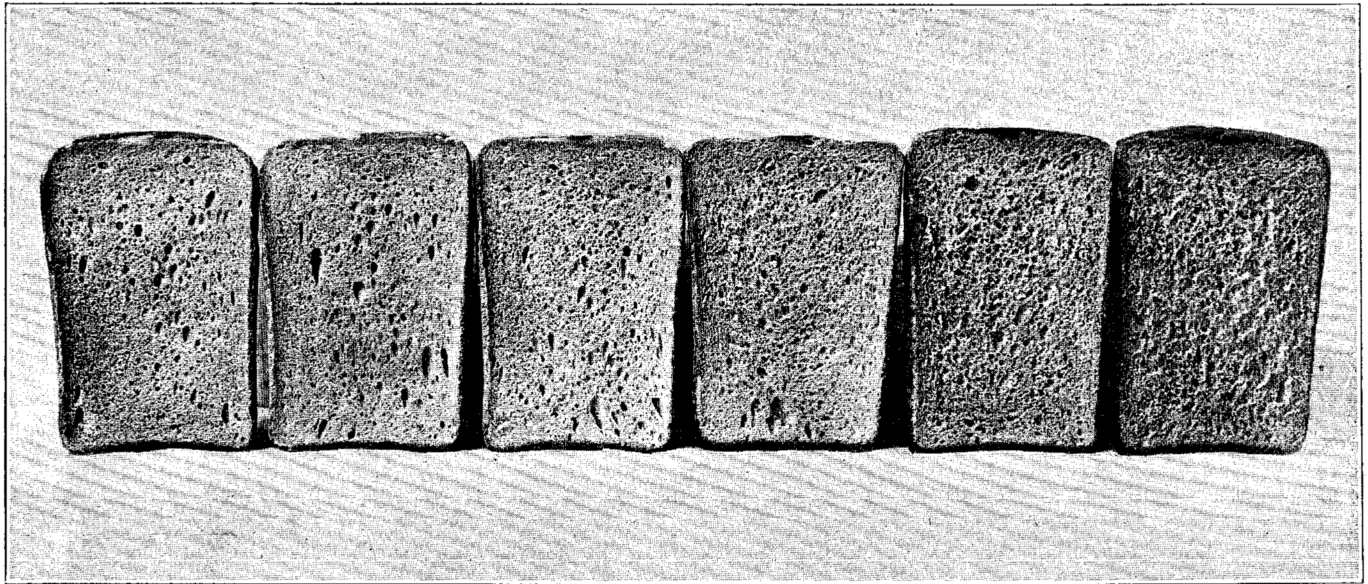

PLATE VIII. Showing the effect of the use of extract of shorts made from germinated wheat, cold extraction. Loaves arranged from left to right in order of quantities of shorts extracted: 0 g., 2½ g., 5 g., 10 g., 21 g., 41 g.

TABLE XXIII.—Baking results as affected by adding to sound flour cold extract from the shorts from germinated wheat.

		Extract from.	Extract from.	Extract from.	Extract from.	Extract from.
Extracted shorts used per loaf, grams	None	2½	5	10	21	41
Time for first rise, min.	60	53	49	45	47	67
Time for second rise, min.	69	60	57	57	49	73
Time for third rise, min.	24	20	19	19	19	23
Total time for proving, min.	153	133	125	121	115	163
Maximum amount of second rise, cm.,	23.5	25.0	24.5	21.5	22.0	23.0
Loss of materials before baking, grams	25	18	22	17	21	15
Loss of materials in baking and cooling, grams	52	56	52	60	51	45
Spring in oven, cm.	5.2	5.7	5.6	5.6	5.9	5.8
Volume of loaf, cc.	1460	1530	1520	1520	1530	1500
Weight of loaf, grams	418	421	421	418	423	435
Condition of crust, per cent	95	95	95	93	92	90
Texture of crumb, per cent	95	93	93	90	80	70

tion does not have such an effect on the baking qualities of flour as is ordinarily expected. Flour from slightly germinated wheat when mixed with flour from sound wheat will make good bread, but the following statements should be distinctly understood. Germination in the seed is a digestive process. This process is carried on by enzymes. As soon as germination starts, some of the substance in the seed is used up in the energy transformations which take place. The carbohydrates, principally starch, and the protein are gradually converted into soluble forms. This is a necessary transformation in order that these compounds may be transferred to the place where new tissues are formed in the stem and in the roots, The longer the germination proceeds the more of these compounds will be made soluble and transferred. When sprouted wheat is scoured the incipient stems and roots which have been constructed from the material in the kernel, are removed. For this reason the yield of flour is less from wheat that has germinated than from the same quality of wheat which has not germinated, and the decrease in the flour-producing capacity of the wheat is proportional to the amount of germination.

As was shown in Bulletin No. 177, and the same has been found true in subsequent experiments, flour from slightly germinated wheat will make a larger loaf than flour from the sound wheat. This is due to two causes: (1) Germination transforms a portion of the starch into sugar. This is an excellent yeast food; the yeast activity is stimulated and a larger loaf is the result. (2) The action of the enzymes on the proteins during germination is such that the gluten made from such flour is weaker in comparison with the gluten from normal flour. This weakening is proportional to the extent of germination. The quantity of gluten formed from germinated wheat flour is less than that formed from normal flour. The process is somewhat related to that which gluten undergoes when the dough ferments. The final result is that a larger loaf is possible if the wheat has undergone incipient germination.

If germination has not proceeded too far a larger loaf volume may be the result. However, the quantity of gluten formed from germinated wheat flour is less than that from normal flour. The changes which take place in the proteins of the wheat when it germinates are somewhat related to the changes which gluten undergoes when dough ferments under the action of yeast.

To sum up: Germination, however slight, is undesirable for two reasons—less flour is possible, and the flour produced is weak. While this is true, flour from slightly germinated wheat should not be unconditionally condemned.

SUMMARY—Tables XXIV to XXXI.

These tables summarize and bring together into a comprehensive whole the more important factors from the preceding tables. Each table gives the results obtained for one important factor in all the trials with different chemicals or substances. The significant factors thus brought together in the tables are: time for first, second and third rise, as well as total time, maximum amount of rise of dough, spring or expansion in oven and texture of crumb. This serves to bring out in the fullest way possible the effect of the different chemicals or substances in regard to the significant factors so grouped.

TIME OF RISING AS AFFECTED BY THE DIFFERENT CHEMICALS OR SUBSTANCES.

TIME FOR FIRST RISE. TABLE XXIV.

In general there was no marked uniform increase or decrease in the time of first rise produced by these added materials. With some there was a decrease, with others there was an increase in time, but the changes did not show any such regularity that any general deductions or conclusions could be drawn. The two cases where the time was unduly long, and the instance where the maximum quantity was used, were due to the fact that the second rising was omitted,

TIME FOR SECOND RISE. TABLE XXV.

The results in the second rise were more pronounced. As a general rule this period was markedly shortened with most of the substances used. The sodium and potassium compounds did not aflect the result either may, but the heated bran extract and the cold extract from the shorts of germinated wheat showed a distinct lengthening of the period. The boiled bran extract from germinated wheat also showed the same tendency as far as the trial was comparable with the others.

TIME FOR THIRD RISE. TABLE XXVI.

In general the results were the same as in the second rise, with a few exceptions. Sodium formate showed a tendency to increase the time while potassium nitrate tended to decrease the time. The heated bran extract showed a distinct decrease, thus differing markedly in this respect from the second rise.

TOTAL TIME FOR RISING. TABLE XXVII.

This table gives the sum of the three periods given in the preceding tables, and smaller accidental differences would have a tendency to be equalized.

MAXIMUM AMOUNT OF RISE AS AFFECTED BY DIFFERENT SUBSTANCES. TABLE XXVIII.

As a class the amino-compounds showed a tendency to decrease the maximum volume of the dough, while the ammonium compounds showed no such tendency as a group. Also the bran extracts from sound bran showed no decrease, while the various products from germinated wheat showed a distinct decrease. As was pointed out above, the amino-compounds and ammonium compounds, as well as the various products obtained from sound and modified wheat, decreased the time of rising in-almost all cases. Here we evidently have, two classes of results. The time for rising may be shortened through two causes: either the presence of a food which stimulates the activity of the yeast, or a weakening of the gluten so that the same amount of yeast activity will accomplish the same result in a comparatively shorter time. In this latter case we are likely to have less maximum amount of rise in the dough than in the former case where the substance stimulates the yeast activity without affecting the quality of the gluten. An examination of the figures for the time of rising and comparing them with the maximum rise of dough would show that the amino-compounds as a class, whether used as pure chemicals or as found in germinated-wheat products, affect the gluten in an unfavorable way. On the other hand, substances which furnish food for the bacteria, such as the ammonium compounds and the extracts from sound bran, stimulate yeast activity without injuring the quality of the gluten. This opens up a very interesting and profitable line of investigation in regard to the different ways the gluten may be affected by the various methods of handling and storing wheat, as well as the chemical compounds which are the ultimate cause of the baking qualities of different flours.

SPRING IN THE OVEN AND LOAF VOLUME. TABLES XXIX AND XXX.

The figures in these tables do not show any concordance in results such that definite conclusions can be drawn from them. They do not, however, contradict the conclusions made above. In justice it should be said that the means at hand when these tests were made did not admit of as great accuracy in regard to the spring in the oven and loaf volume as the former measurements. The baking-pans as well as the apparatus for taking loaf volume have since been greatly improved, and in the future these measurements will be more accurate.

TEXTURE OF CRUMB AS AFFECTED BY THESE DIFFERENT SUBSTANCES. TABLE XXXI.

As a class the amino-compounds, with few exceptions, had an unfavorable effect on texture. The amino-compounds present in modified wheat products were the most pronounced in this respect. On the other hand, with a few exceptions, the ammonium compounds as well as the extracts from sound bran had no unfavorable effect on texture. Amino-compounds as a class are unfavorable to the baking qualities of the flour. As a group they are more pronounced in their effects than the proteins such as gliadin, glutenin, edestin or leucosin. It seems safe to conclude that a study of wheat flour along these lines would be more profitable than many of the methods hitherto used.

TABLE XXIV.—Time in Minutes for First Rise as Affected by Different Substances.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	75	70	75	73	75	80
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	70	70	70	80	73	75
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.025	70	70	67	75	75	82
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	53	52	50	52	55	59
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH+H_2O$	0.1	70	62	62	65	75	65
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	67	60	58	57	57	64
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	68	63	61	63	70	63
Ammonium chloride, HN_4Cl	0.025	60	60	62	60	63	62
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	65	70	65	70	75	75
Sodium phosphate, $Na_2HPO_4+12H_2O$	0.4	62	62	54	59	62	62
Sodium bicarbonate, $NaHCO_3$	0.1	63	68	68	68	70	66
Sodium formate, $H\cdot COONa+H_2O$	0.1	61	63	64	74	68	70
Potassium nitrate, KNO_3	0.1	60	65	60	60	61	65
Bran extract, cold extraction	2.5*	57	52	52	52	52	55
Bran extract, cold extraction, filtered	2.5*	57	59	52	52	50	50
Bran extract, hot extraction	2.5*	60	57	51	54	55	55
Wheat scourings, extract I	2.5*	55	52	51	50	52	53
Wheat scourings, extract II	2.5*	75	74	74	74	80	89
Flour from germinated wheat	25.0	71	63	55	56	70	113
Flour from germinated wheat	9.0	67	74	71	72	81	48
Cold bran extract from germinated wheat	2.5*	80	75	74	70	80	94
Boiled bran extract from germinated wheat	2.5*	50	55	60	55	104	165
Cold extract from the shorts of germinated wheat	2.5*	60	53	49	45	47	67

* These figures show the weights of material extracted.

TABLE XXV.—*Time in Minutes for Second Rise as Affected by Different Substances.*

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	75	75	65	62	55	50
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	75	70	65	60	62	62
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.025	73	70	68	67	63	54
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	80	73	65	53	55	54
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH+H_2O$	0.1	83	78	63	60	50	58
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	80	80	74	70	67	59
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	80	78	74	65	65	72
Ammonium chloride, HN_4Cl	0.025	75	75	73	71	63	62
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	80	70	71	62	63	63
Sodium phosphate, $Na_2HPO_4+12H_2O$	0.4	82	77	77	70	73	83
Sodium bicarbonate, $NaHCO_3$	0.1	88	83	77	89	85	81
Sodium formate, $H\cdot COONa+H_2O$	0.1	77	69	71	67	61	78
Potassium nitrate, KNO_3	0.1	75	65	70	70	80	75
Bran extract, cold extraction	2.5*	81	80	73	73	59	58
Bran extract, cold extraction, filtered	2.5*	78	70	71	70	65	68
Bran extract, hot extraction	2.5*	75	77	69	65	79	90
Wheat scourings, extract I	2.5*	56	54	49	52	47	43
Wheat scourings, extract II	2.5*	70	69	64	58	57	53
Flour from germinated wheat	25.0	68	57	45	39	43	0†
Flour from germinated wheat	9.0	73	61	59	52	39	42
Cold bran extract from germinated wheat	2.5*	67	65	61	53	56	58
Boiled bran extract from germinated wheat	2.5*	60	56	55	60	85	0†
Cold extract from the shorts of germinated wheat	2.5*	69	60	57	57	49	73

* These figures show the weights of material extracted.
† No second rise.

TABLE XXVI.—Time in Minutes for Third Rise as Affected by Different Substances.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	30	27	26	23	23	19
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	27	24	25	26	30	25
Leucin, $(CH_3)_2{\cdot}CH{\cdot}CH_2{\cdot}CH(NH_2)\cdot COOH$	0.025	27	26	22	25	24	24
Aspartic acid, $COOH{\cdot}CH_2{\cdot}CH(NH_2)\cdot COOH$	0.1	25	26	27	20	20	22
Asparagin, $CONH_2{\cdot}CH_2{\cdot}CH(NH_2)\cdot COOH+H_2O$	0.1	23	21	24	24	19	19
Ammonium acetate, $CH_3{\cdot}COONH_4$	0.1	27	21	18	17	12	15
Ammonium tartrate, $NH_4OOC{\cdot}CHOH{\cdot}CHOH{\cdot}COONH_4$	0.1	21	18	14	15	15	12
Ammonium chloride, HN_4Cl	0.025	22	20	20	17	16	14
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	17	19	16	18	18	18
Sodium phosphate, $Na_2HPO_4+12H_2O$	0.4	26	27	24	25	26	25
Sodium bicarbonate, $NaHCO_3$	0.1	25	24	25	29	29	33
Sodium formate, $H{\cdot}COONa+H_2O$	0.1	19	19	22	24	19	26
Potassium nitrate, KNO_3	0.1	26	24	26	22	21	19
Bran extract, cold extraction	2.5*	28	24	23	20	17	18
Bran extract, cold extraction, filtered	2.5*	26	23	22	21	20	19
Bran extract, hot extraction	2.5*	32	30	27	25	22	19
Wheat scourings, extract I	2.5*	24	21	18	17	19	17
Wheat scourings, extract II	2.5*	31	28	23	25	21	21
Flour from germinated wheat	25.0	23	20	18	18	20	30
Flour from germinated wheat	9.0	25	25	22	24	24	23
Cold bran extract from germinated wheat	2.5*	23	23	21	20	23	23
Boiled bran extract from germinated wheat	2.5*	17	17	20	16	19	17
Cold extract from the shorts of germinated wheat	2.5*	24	20	19	19	19	23

* These figures show the weights of material extracted.

TABLE XXVII.—Total Time in Minutes for Rising as Affected by Different Substances.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	180	172	166	158	153	149
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	172	164	160	166	165	162
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.025	170	166	157	167	162	160
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	160	151	142	125	130	135
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH+H_2O$	0.1	176	161	149	149	144	142
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	174	161	150	144	136	138
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	169	159	149	143	150	147
Ammonium chloride, HN_4Cl	0.025	157	155	155	148	142	138
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	162	159	152	150	156	156
Sodium phosphate, $Na_2HPO_4+12H_2O$	0.4	170	166	155	154	161	170
Sodium bicarbonate, $NaHCO_3$	0.1	176	175	170	186	184	180
Sodium formate, $H\cdot COONa+H_2O$	0.1	157	151	157	165	148	174
Potassium nitrate, KNO_3	0.1	161	154	156	152	162	159
Bran extract, cold extraction	2.5*	166	156	148	145	128	131
Bran extract, cold extraction, filtered	2.5*	161	152	145	143	135	137
Bran extract, hot extraction	2.5*	167	164	147	144	156	164
Wheat scourings, extract I	2.5*	135	127	118	119	118	113
Wheat scourings, extract II	2.5*	176	171	161	157	158	163
Flour from germinated wheat	25.0	162	140	118	113	133	143
Flour from germinated wheat	9.0	165	160	152	148	144	113
Cold bran extract from germinated wheat	2.5*	170	163	156	148	159	173
Boiled bran extract from germinated wheat	2.5*	127	128	135	131	208	192
Cold extract from the shorts of germinated wheat	2.5*	153	133	125	121	115	163

* These figures show the weights of material extracted.

TABLE XXVIII.—Maximum Amount of Second Rise as Affected by Different Substances, Cubic Centimeters.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	2100	2100	2000	1950	1850	1850
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	2100	2000	2000	1800	1800	1800
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH\cdot(NH_2)\cdot COOH$	0.025	2100	2100	2000	2000	1900	1900
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	2200	2150	2100	2100	2250	2300
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH + H_2O$	0.1	2250	2300	2100	2000	2050	2100
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	2350	2350	2350	2350	2350	2250
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	2400	2400	2400	2400	2500	2500
Ammonium chloride, NH_4Cl	0.025	2400	2450	2200	2300	2300	2250
Ammonium phosphate. $(NH_4)_2HPO_4$	0.1	2450	2350	2250	2350	2300	2000
Sodium phosphate, $Na_2HPO_4 + 12H_2O$	0.4	2200	2150	2150	2200	2150	2100
Sodium bicarbonate, $NaHCO_3$	0.1	2200	2150	2150	1900	1950	1850
Sodium formate, $H\cdot COONa + H_2O$	0.1	2250	2250	2150	2150	2200	2150
Potassium nitrate, KNO_3	0.1	2450	2400	2300	2350	2550	2550
Bran extract, cold extraction	2.5*	2350	2350	2400	2350	2350	2350
Bran extract, cold extraction, filtered	2.5*	2200	2200	2250	2400	2400	2250
Bran extract, hot extraction	2.5*	2250	2300	2350	2300	2450	2320
Wheat scourings, extract I	2.5*	2400	2400	2450	2480	2300	2200
Wheat scourings, extract II	2.5*	2000	2000	1900	1900	1750	1700
Flour from germinated wheat	25.0	2400	2200	1800	1650	1650	1500
Flour from germinated wheat	9.0	2000	2050	1800	1750	1500	1350
Cold bran extract from germinated wheat	2.5*	2100	1950	1950	1850	1850	1850
Boiled bran extract from germinated wheat	2.5*	2350	2450	2200	2300	2300	1200
Cold extract from the shorts of germinated wheat	2.5*	2350	2500	2450	2150	2200	2300

* These figures show the weights of material extracted.

TABLE XXIX.—Spring in Oven as Affected by Different Substances, Centimeters.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	4.4	4.8	4.6	3.9	3.9	4.2
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	4.3	3.9	2.5	3.1	3.5	1.8
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH\cdot(NH_2)\cdot COOH$	0.025	4.5	4.5	4.0	3.5	5.1	4.5
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	5.5	5.3	4.9	4.9	5.5	5.5
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH + H_2O$	0.1	5.1	5.2	5.1	4.8	3.8	4.6
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	4.4	5.2	5.4	5.5	5.5	5.3
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	4.7	5.0	4.8	5.2	5.6	4.4
Ammonium chloride, NH_4Cl	0.025	3.3	4.2	3.8	5.3	6.1	6.1
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	5.0	5.4	5.5	5.4	5.4	5.4
Sodium phosphate, $Na_2HPO_4 + 12H_2O$	0.4	4.4	4.5	4.7	4.2	4.5	4.6
Sodium bicarbonate, $NaHCO_3$	0.1	4.0	4.5	4.0	2.6	2.5	2.0
Sodium formate, $H\cdot COONa + H_2O$	0.1	5.5	5.5	5.3	5.1	5.5	5.5
Potassium nitrate, KNO_3	0.1	5.0	4.8	4.1	4.5	5.1	5.1
Bran extract, cold extraction	2.5*	4.9	4.9	4.7	5.3	5.4	5.6
Bran extract, cold extraction, filtered	2.5*	5.0	5.2	5.4	5.4	5.6	5.7
Bran extract, hot extraction	2.5*	4.2	4.5	4.8	5.4	5.6	5.9
Wheat scourings, extract I	2.5*	5.4	5.7	5.4	5.1	5.1	5.1
Wheat scourings, extract II	2.5*	3.8	4.0	3.1	3.9	3.5	2.9
Flour from germinated wheat	25.0	4.9	5.4	5.6	4.0	4.2	1.1
Flour from germinated wheat	9.0	4.3	4.5	4.7	4.5	3.7	2.7
Cold bran extract from germinated wheat	2.5*	4.3	3.4	4.0	4.0	4.3	4.5
Boiled bran extract from germinated wheat	2.5*	3.6	5.6	5.1	5.5	5.4	4.8
Cold extract from the shorts of germinated wheat	2.5*	5.2	5.7	5.6	5.6	5.9	5.8

* These figures show the weights of material extracted.

TABLE XXX.—Loaf Volume as Affected by Different Substances, Cubic Centimeters.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	1380	1390	1370	1280	1300	1320
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	1380	1330	1270	1240	1180	1180
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH\cdot(NH_2)\cdot COOH$	0.025	1380	1340	1380	1270	1360	1330
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	1460	1470	1460	1420	1500	1530
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH + H_2O$	0.1	1440	1410	1380	1380	1300	1370
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	1440	1490	1490	1500	1520	1500
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	1460	1470	1450	1520	1550	1400
Ammonium chloride, NH_4Cl	0.025	1300	1420	1260	1520	1600	1610
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	1470	1470	1470	1470	1440	1430
Sodium phosphate, $Na_2HPO_4 + 12H_2O$	0.4	1430	1450	1460	1400	1410	1420
Sodium bicarbonate, $NaHCO_3$	0.1	1330	1370	1350	1210	1170	1170
Sodium formate, $H\cdot COONa + H_2O$	0.1	1550	1580	1500	1470	1550	1500
Potassium nitrate, KNO_3	0.1	1500	1480	1440	1500	1520	1520
Bran extract, cold extraction	2.5*	1480	1490	1410	1510	1520	1520
Bran extract, cold extraction, filtered	2.5*	1470	1500	1520	1550	1550	1550
Bran extract, hot extraction	2.5*	1400	1420	1440	1520	1550	1560
Wheat scourings, extract I	2.5*	1450	1480	1500	1520	1540	1490
Wheat scourings, extract II	2.5*	1360	1460	1280	1350	1260	1190
Flour from germinated wheat	25.0						
Flour from germinated wheat	9.0	1400					
Cold bran extract from germinated wheat	2.5*	1350	1290	1310	1360	1320	1350
Boiled bran extract from germinated wheat	2.5*	1360	1460	1400	1500	1460	1420
Cold extract from the shorts of germinated wheat	2.5*	1460	1530	1520	1520	1530	1500

* These figures show the weights of material extracted.

TABLE XXXI.—Texture of Crumb as Affected by Different Substances; 100 Considered Perfection.

Substance added.	Minimum quantity, grams.	Times minimum quantity. 0	1	2	4	8	16
Peptones	0.4	95	95	95	85	85	90
Glycocoll, $CH_2(NH_2)\cdot COOH$	0.1	95	85	80	80	75	80
Leucin, $(CH_3)_2\cdot CH\cdot CH_2\cdot CH\cdot(NH_2)\cdot COOH$	0.025	92	92	90	90	88	88
Aspartic acid, $COOH\cdot CH_2\cdot CH(NH_2)\cdot COOH$	0.1	98	98	98	98	99	99
Asparagin, $CONH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH + H_2O$	0.1	97	97	95	93	88	88
Ammonium acetate, $CH_3\cdot COONH_4$	0.1	90	88	88	85	85	85
Ammonium tartrate, $NH_4OOC\cdot CHOH\cdot CHOH\cdot COONH_4$	0.1	90	90	90	90	90	90
Ammonium chloride, NH_4Cl	0.025	96	97	96	95	98	99
Ammonium phosphate, $(NH_4)_2HPO_4$	0.1	94	94	94	94	94	94
Sodium phosphate, $Na_2HPO_4 + 12H_2O$	0.4	95	92	93	95	96	96
Sodium bicarbonate, $NaHCO_3$	0.1	95	95	92	90	90	85
Sodium formate, $H\cdot COONa + H_2O$	0.1	95	96	98	97	94	94
Potassium nitrate, KNO_3	0.1	95	90	90	95	93	96
Bran extract, cold extraction	2.5*	97	96	94	91	88	85
Bran extract, cold extraction, filtered	2.5*	100	100	100	100	95	95
Bran extract, hot extraction	2.5*	97	98	99	99	100	95
Wheat scourings, extract I	2.5*	95	95	95	94	92	85
Wheat scourings, extract II	2.5*	95	96	92	91	80	50
Flour from germinated wheat	25.0	95	60	60	40	20	0
Flour from germinated wheat	9.0	95	85	80	50	25	0
Cold bran extract from germinated wheat	2.5*	95	90	88	65	50	40
Boiled bran extract from germinated wheat	2.5*	95	95	95	94	93	92
Cold extract from the shorts of germinated wheat	2.5*	95	93	93	90	80	70

* These figures show the weights of material extracted.

Effect of Adding Starch, Bran or Bran Extract to Flour.

In the test with starch, bran and bran extract the check loaf was baked in the usual way. In the second loaf were used 260 grams of flour and 40 grams of cornstarch. Starch was used in order to have one loaf in which there was the same amount of flour as the loaves to which bran was added. In this way starch would act more as a diluent, neither increasing nor decreasing the amount of gluten. Furthermore, it would not have any harmful influence on the yeast. The addition of starch has the same effect as a decrease of the percentage of protein without any change in its quality. Starch fulfils these requirements better than any substance readily obtained. In the third loaf were used 40 grams of bran and 260 grams of flour. It was found necessary to use 15 cc. more of water in this loaf in order to get the dough of the same stiffness as the check loaf. In the fourth loaf were used 40 grams of bran extracted with cold water over night. The dry bran was weighed before extracting and then the weight of the wet bran gave data to correct for the amount of water held by the bran. The bran was washed several times with water through linen, then the surplus water was squeezed out. It was found necessary to use 5 cc. more of water for this loaf than the check loaf. Loaf number five was prepared the same way as number four except that the bran was extracted with hot water. It was boiled for about ten minutes in water, washed several times on linen with hot water, and then the surplus water was squeezed out. For number six the cold extract of 40 grams of bran was used. This corresponds to the test where cold bran extract was used in the baking. This test with these various conditions was repeated and the same results were obtained, so it is safe to conclude that they were not accidental but due to the conditions of the test.

There was a regular shortening of the total time for rising, being longest for the check loaf and shortest for the loaf where bran extract was used. The total difference was 37 minutes. In the second test the difference was 35 minutes. The presence of starch diminished the total expansion, oven spring and loaf volume as compared with the check loaf. The texture was not impaired by the presence of starch but was equal to the check loaf. The use of bran diminished in a larger measure the total expansion, oven spring and loaf volume. This loaf had the least total expansion and loaf volume. The texture was also poorest in this loaf. It is remarkable that the cold extracted bran should differ in so marked a degree from the nonextracted bran. The oven spring, total expansion and loaf volume were so much larger in every case that the result can not be due to accident, and the same results were obtained in the second trial. The total expansion, oven spring and loaf volume were somewhat less with the hot extracted bran than with the cold extracted bran. The effect of the cold bran extract was, in the main, the same as when this substance was tried before. It had the shortest total time for rising, the largest total expansion, oven spring and loaf volume in this test. The texture of this loaf was also a shade better than the cheek loaf.

This test suggests an interesting question. Why should the unextracted bran give poorer results than when the extracted bran and the bran extract were used separately? The difference between the cold extracted bran and the hot extracted bran can possibly be explained as due to the difference in the enzymes present. Why should the extracted bran give a larger loaf volume with a better texture than the unextracted bran when the extract by itself proves to be very beneficial and, in fact, gives a loaf superior to all? Does the bran when it is mixed with the dough without previous wetting act merely as so much inert matter, like the starch? Is it only when these matters have been dissolved that they are enabled to act in influencing the baking of the bread. Could a better "Graham" bread be baked if the bran was used separately from the flour,

TABLE XXXII.—Baking results showing comparative effect of the use of starch, bran and bran extract. Trial I.

		Starch.	Bran.	Cold extracted bran.	Hot extracted bran.	Cold water extract from 40 gr. bran.
Grams used per loaf	None	40	40	40	40	....
Time for first rise, min.	57	65	65	57	65	58
Time for second rise, min.	88	74	68	70	56	62
Time for third rise, min.	28	29	21	21	21	21
Total minutes for rising	173	168	154	148	142	136
Maximum amount of second rise, cm.	22.5	20.0	16.0	19.5	18.0	22.5
Loss of materials before baking, grams	18	19	21	15	13	10
Loss of materials in baking and cooling, grams	45	42	43	54	47	45
Spring in oven, cm.	4.3	2.7	2.7	4.0	3.2	5.5
Volume of loaf, cc.	1430	1290	1260	1380	1300	1520
Weight of loaf, grams	432	434	446	431	440	440
Condition of crust, per cent	95	95	90	90	90	94
Texture of crumb, per cent	95	95	91	92	92	96

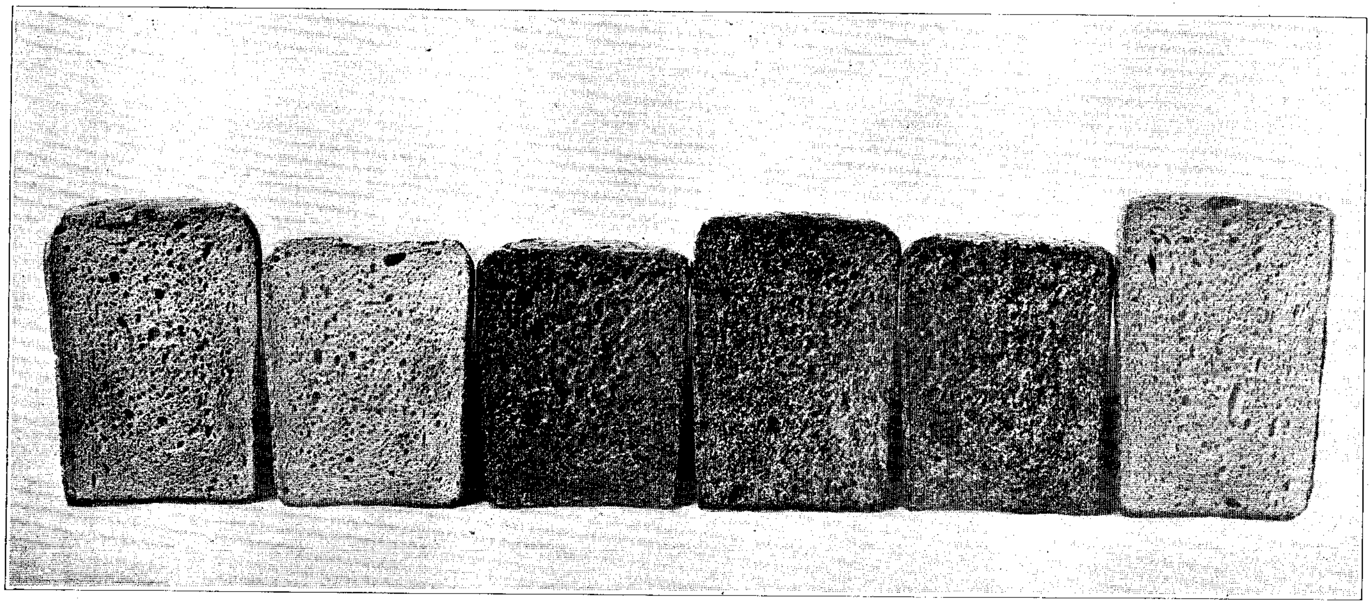

PLATE IX. Showing the effect of the addition of starch, bran and bran extract. Loaves arranged from left to right in order of the following amounts used: Check, 40 g. starch, 40 g. bran, 40 g. cold extracted bran, 40 g. hot extracted bran, cold water extract from 40 g. bran.

mixed with water beforehand and allowed to soak for some time?

Table XXXIII gives the result of a second trial with starch, bran and bran extract. The results are, in the main, similar to those given in table XXXII and serve to corroborate the conclusions.

TABLE XXXIII.—Baking results showing the comparative effect of the use of starch, bran and bran extract. Trial II.

		Starch.	Bran.	Cold extracted bran.	Hot extracted bran.	Cold water extract from 41 gr. bran.
Grams used per loaf	None	40	40	40	40	....
Time for first rise, min	60	56	65	57	63	54
Time for second rise, min	79	74	59	59	52	53
Time for third rise, min	23	29	19	21	22	20
Total minutes for rising	162	159	143	137	137	127
Maximum amount of second rise, cm.	22.5	20.5	16.5	19.0	13.5	23.5
Loss of materials before baking, grams	20	13	13	5	5	5
Loss of materials in baking and cooling, grams	44	49	47	53	40	47
Spring in oven, cm	3.9	2.8	2.5	3.6	3.5	5.6
Volume of loaf, cc	1410	1290	1250	1370	1310	1540
Weight of loaf, grams	431	433	435	437	447	443
Condition of crust, per cent	95	95	90	90	90	94
Texture of crumb, per cent	95	95	91	92	92	96

SUMMARY TABLE XXXIV.—Effect of Starch, Bran, and Bran Extract.

	Time for total rise, minutes.		Loaf volume, cc.		Loaf texture, 100 = perfection.	
	I	II	I	II	I	II
Check	173	162	1430	1410	95	95
Starch, 40 g.	168	159	1290	1290	95	95
Bran, 40 g.	154	143	1260	1250	91	91
Bran, extracted by cold water, 40 g.,	148	137	1380	1370	92	92
Bran, extracted by hot water, 40 g.,	142	137	1300	1310	92	92
Extract from 40 g. bran, cold water,	136	127	1520	1540	96	96

SUMMARY.

The results presented in this bulletin show that a line of investigation has been entered upon which should lead to very fruitful results, even though no very definite conclusions may be based upon those thus far attained. This investigation shows that the baking qualities of flour depend upon much more than a definite relation between gliadin and glutenin. That the baking qualities of flour bear an intimate relation to chemical substances that may naturally be present, or that may be produced from normal constituents of the flour or introduced through imperfect milling, is beyond question. The most active substances seem to be derivatives of the proteins which even in very small amount exert a pronounced influence. These substances may be produced by changes incident to germination or by hydrolytic processes accompanying bread making.