A STUDY OF

The Germ Constituents of Wheat

A Thesis submitted
to the Committee on
Post-Graduate Studies of
the University of Manitoba

By

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In partial fulfillment of the requirements for

the Degree of Master of Science

September 1930

ACKNOWLEDGMENTS

The writer wishes to express his grateful appreciation to Dr. W. F. Geddes, Department of Agricultural Chemistry of the University of Manitoba, for the suggestion of the problem, and for continued interest and help in its solution.

He also wishes to thank Mr. A. W. Alcock, Chief Chemist of the Western Canada Flour Mills, Ltd., Winnipeg, for the material used in the investigation, and for several valuable suggestions.

His thanks are also due to Messrs. S. T. Hadley and H. N. Bergsteinson for valuable technical assistance.

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A Study of the Germ Constituents of Wheat

Introduction

In recent years there has been an intensive and persistent investigation into those properties of wheat and wheat products which affect the volume and texture of bread. Many examinations have been made in an effort to determine the factors responsible for "strength" in flour, a strong flour being one which has the capacity to make large well-piled loaves. (Humphries - 1905)

While the nature and properties of the endosperm have been very thoroughly studied, less detailed attention has been paid to the influence of the germ constituents, which contain the bulk of the lipoid material. Salamon, (1908) stated that ether-extracted flour baked into a loaf better than that which could be baked from the original. Johnson (1928) confirmed this result with flours from wheat grown in four different regions. That this was not simply due to the removal of neutral fats was indicated by the work of Saunders, Nichols, and Cowan (1921) who reported that the addition of lard, butter, and certain vegetable oils had effected an improvement in the baking quality of both spring wheat patent and durum flours.

Working (1924) found that the addition of phosphatides from wheat and egg lecithin decreased the quality of the gluten in different grades of flour as measured by viscosimetric and baking tests. He ascribed this influence to an interfacial reduction of the surface tension of the gluten strands. The presence of wheat oil did not seriously affect the quality of the gluten. Sullivan and Near (1927a) found in the analysis of glutens from flour streams of varying strength that the lipoid content varied inversely as the gluten strength. They also found (1927b) that Durum wheat, which is of low gluten quality, has a higher ratio of lipoid/protein than hard wheats.

Geddes (1929) in an extensive investigation into the effect of heat on wheat and wheat products found an enhancement in baking quality by a moderate heat-treatment of a straight grade flour, though similar treatment of a flour of low extraction such as fifth middlings did not give as marked an improvement. Ether-extracted straight grade flour resembled fifth middlings in not giving a positive response to heat treatment, which suggested that the constituent influenced by the moderate heat treatment was ether soluble. This led Geddes (1930b) to try the effect on the baking quality of fifth middlings flour of the admixture of five percent of germ, both raw and after various heat treatments. The results were surprising and of marked interest. The presence of raw germ had a harmful effect on the quality of the bread baked by the standard procedure, but if the germ was first heat treated, or if the bread was baked adding 0.001 gram of potassium bromate per loaf in the dough mixture, the deleterious effects of the germ were largely removed. It was concluded that the cause of this degradation of baking quality was the phosphatides, the effect of which could be removed by heat treatment or the use of chemical improvers such as potassium bromate. While no direct evidence was presented, Geddes made the tentative suggestion that this was an oxidation of some germ constituent, the removal of which let the inherent qualities of the gluten come into play.

PROBLEM

The importance of the improvement in baking quality of higher extraction flours by heat treatment or chemical improvers was deemed sufficient warrant for the investigation reported in this thesis. The work was an extension into that field opened by Geddes (1930b). It includes a more comprehensive range of heat treatments of germ at different moisture levels, and a more detailed study of the treated material, both its effect on the baking quality of fifth middlings flour and the changes which take place in the germ during the treatments. An introductory study was made of the use of different baking procedures for flour-germ mixtures.

EXPERIMENTAL

Preparation of Material

The material used in this investigation was obtained from the St. Boniface mill of the Western Canada Flour Mills, Ltd., through the kindness of its Chief Chemist, Mr. A. W. Alcock. The fifth middlings flour, representing the purest endosperm stream, was dried to a moisture level of 10.40%, at which low point there should be only slight changes on keeping. Germ from the purest germ stream of the mill was ground in the laboratory Wiley mill, and passed through the 0.5 mm. screen which largely removed the less readily pulverized bran found in the germ. This finely ground germ was then mixed thoroughly and divided into five portions, which were treated as follows:

(1) One portion was spread out in a thin layer in a room where the temperature ranged from 25°C. to 30°C., and allowed to dry out for 36 hours, the material being turned frequently to ensure all of it being exposed to the dry air. This material was then mixed thoroughly and packed in tins. The moisture content as determined by the vacuum oven method was 7.48% .

(2) A second of these was set aside at the moisture level natural to it, which was found to be 13.34%

(3) A third portion was exposed in a thin layer in a room maintained at 90% humidity, and was turned

regularly, until it had reached a moisture content of 17.06% . This was then canned.

(4) The fourth portion, containing about 3500 grams was extracted successively with three five pound lots of ethyl ether, the liquid being removed after each extraction by a Buchner funnel. The remaining ether was evaporated by exposure to air, and the material dried to 8.02% moisture. This material had lost its yellowish color, and felt very much like fine sand mixed with small amounts of bran. It had little coherence, and was very dusty to handle.

(5) The final portion was simply wetted with ether in a large porcelain dish, mixed thoroughly and then the ether allowed to evaporate, without any of the material being extracted. When the ether had all evaporated, the remaining germ was thoroughly mixed and stored. The moisture content was 8.04% .

These samples were called respectively, low moisture, natural moisture, high moisture, ether extracted, and ether wetted, and are so designated throughout this thesis. The material was all stored at a temperature of approximately 0°C until required for use.

Heat Treatments

The method outlined by Geddes (1929) for the heat treatment of flour proved so satisfactory that it was considered advisable to follow it in this investigation, as it enabled the operator to maintain the moisture at a nearly constant point for most treatments. The detailed description is given by Geddes and need not be repeated, but it is advisable to give a brief outline of its method of use in these experiments. The basic part of the apparatus was atinned copper drum of about 510 cubic inches capacity, attached by a belt and chain drive to an electric motor capable of rotating the drum at 28 r. p. m. Material could be introduced into, or removed from the drum through a handhole which closed by a screw-threaded cover. As the drum was eccentrically mounted, material inside it was thrown from end to end, rapidly assuming the temperature of the constant-temperature oil bath in which the drum was rotated. The assembled apparatus is shown in Fig. 1

Material was always introduced into the hot drum, and at the end of the time of treatment, the drum and contents were rotated in cold water to prevent an additional period of heat treatment. Portions of 500 grams of germ were introduced for each treatment, except in the case of the ether extracted samples, where a scarcity of material limited the author to 400 grams. At the end of the treatment, the product was packed into 2 pound baking powder tins, which were almost filled. These were then placed in a refrigerator.

The changes in color and feel of the germ during the treatments showed a remarkable difference between the low and high moisture material. The former darkened only

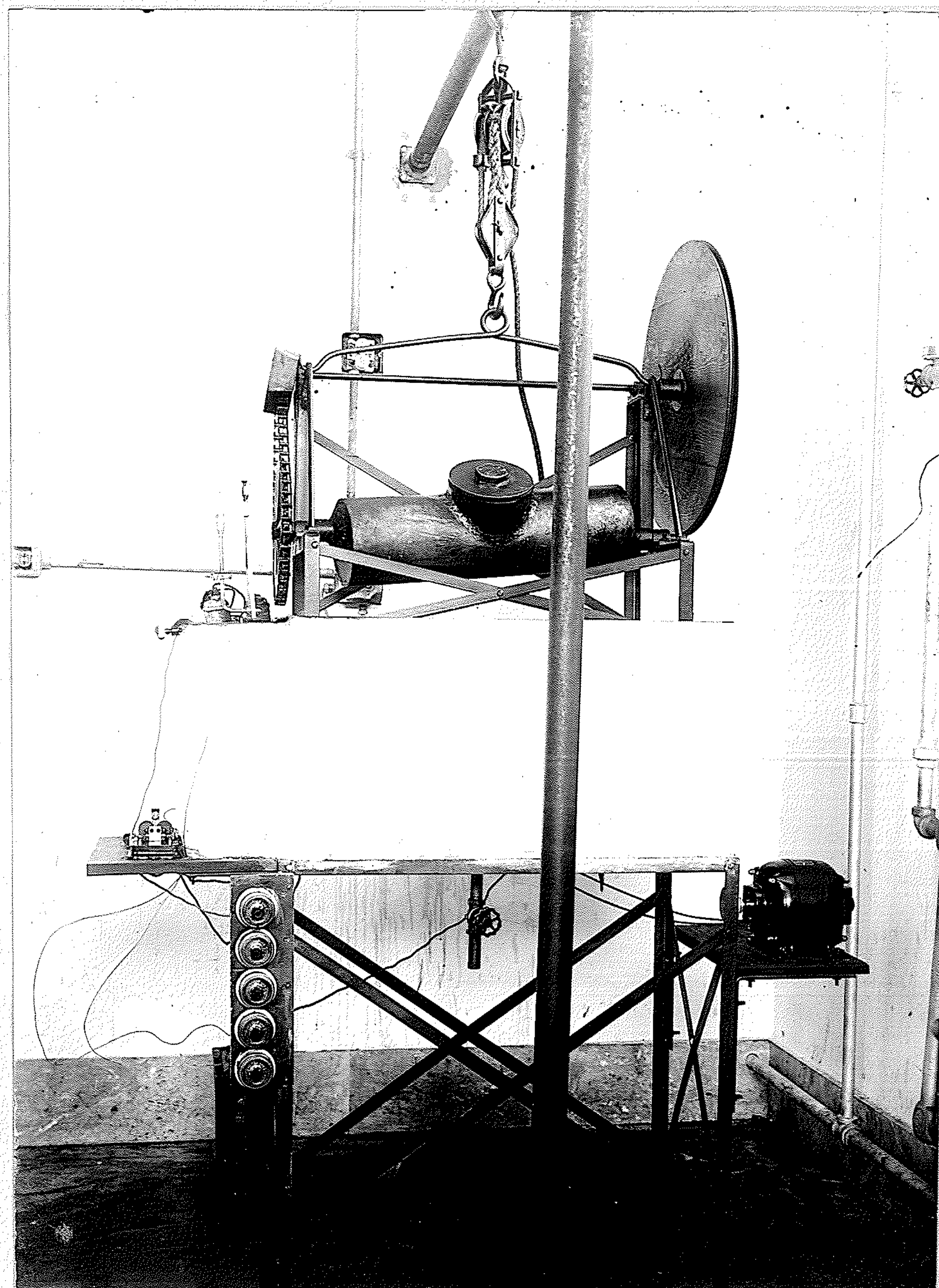

Fig. 1. Photograph of the Heat Treatment Apparatus Assembled ready for use.

slightly even at the highest heat treatment, and there was only a slight development of a gritty feeling. The latter showed the effect of even low heat treatments, and the high temperatures caused it to turn to a nut brown and to become very gritty to the feel. There was also a noticeable tendency on the part of the high moisture samples to form balls in the process of treatment. These varied in size, the largest being about half an inch in diameter; in the treatments at high temperatures, they became quite hard.

Baking Results

It is not the intention of the writer to deal with the very extensive literature concerning the different test baking procedures, as this has already been done satisfactorily by Brooke and Sherwood (1928), and by a committee of the American Association of Cereal Chemists under the chairmanship of Blish (1928). The baking method followed in this investigation is based on that suggested by this Committee, and adopted by the Associate Committee on Grain Research of the National Research Council of Canada. For the standard procedure, the dough was made with 100 grams of flour on a 13.5% moisture basis, 3 grams of baker's yeast, 2.5 grams of sucrose, 1 gram of salt and distilled water sufficient to give a dough of the desired consistency. This varied slightly, but it was usually about 63.5 cubic centimeters. The dough was mixed using a two hook laboratory Hobart mixer, running at No. 2 speed for three minutes. The temperature of the ingredients was maintained so that the dough came from the mixer at 30°C. The fermentation was carried out in a constant temperature cabinet, maintained at 30° and 75% relative humidity, the ratio of times for the first punch, second punch, and panning being as 9 : 4 : 2 . In all cases, the proofing time was 55 minutes at 30°, and the baking time 25 minutes at 221.1°C (430°F). The pans used measured 4¼" x 2¾" at the top, 3 11/16" x 2 1/6" at the bottom, and were of a depth of two inches. The volume of the loaves was measured 30 minutes after they came from the oven, in the apparatus devised by Geddes and Binnington (1928).

The loaves were kept overnight in a moist cabinet and judged the next morning, the basis of scoring being that adopted by the Associate Committee on Grain Research of the National Research Council of Canada. Each loaf was given a numerical score for the characteristics of crust color, symmetry, and texture, the maximum in each division being respectively 5, 5, and 10. If the fault for which a loaf was scored down was well marked, a letter was appended to the score. The letters used were,

Crust Color - p - paler than desired

d - darker than desired

Symmetry - g - green or underfermented

o - overfermented

Texture - c - coarse

o - open.

Allthe samples were baked in duplicate, and if the volumes did not agree within 20 cc. the baking was repeated.

A preliminary trial of baking indicated that a mixture of 10% germ in 90% of fifth middlings flour (both calculated on a 13.5% moisture basis) would give the most satisfactory results, and this proportion was followed in all the work reported in this thesis.

The mixtures were baked according to the standard procedure, and also using the bromate method - the standard procedure + 0.001 gram of potassium bromate for each loaf. The effect of the bromate in the dough has not been definitely decided, but the work of Blish and Sandstedt (1927) Larmour and MacLeod (1929) and Larmour (1930) indicates that the presence of potassium bromate allows a natural high gluten quality to manifest itself in better baking results.

The presence of raw (unheated) germ, especially in the low moisture samples decreased the handling qualities of the dough to a marked extent, the dough being less springy and more sticky especially during the earlier stages of fermentation. As fermentation proceeded, the handling qualities improved. These characteristics were less pronounced in the samples where the germ had been heat treated. In tables I and II are given the baking results of samples of germ of different moisture contents, which have been heat treated for different times and to different temperatures. The temperatures are in degrees Fahrenheit, and the times in hours.

Table No. I - Comparative Baking Results (Standard Procedure)
(3 hour Fermentation)

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Vth Midds.	-	-	629	5	5	6.7
Low Moist.	Control		571	3d	2g	3c
Nat Moist.	"		611	3d	2g	3c
High Moist	"		672	3.5d	3.5g	5c
Low Moist	110	3	600	3d	2g	3c
Nat. Moist	110	3	615	3d	2.5g	3.5c
High Moist	110	3	695	3.5d	4.4	6.5c
Low Moist.	130	3	601	3d	2g	3c
Nat. Moist	130	3	612	3.2d	3g	4c
High Moist	130	3	696	3.5d	4.2	6.5c
Low Moist	150	3	598	3d	2.2g	3c
Nat. Moist	150	3	640	3.5d	3.5g	5c
High Moist	150	3	671	3.5d	4.1o	6.7
Low Moist	170	1	572	3d	2.2g	3c
Nat. Moist	170	1	643	3.2d	3g	4c
High Moist	170	1	673	3.5d	4.5	6.7c
Low Moist	170	2	578	3d	2g	3c
Nat. Moist	170	2	635	4d	3.5g	5.5c
High Moist	170	2	672	3.7d	4.1o	6.7c
Low Moist	170	3	590	3d	2g	3c
Nat. Moist	170	3	661	3.7d	4.4	6c
High Moist	170	3	676	4d	3.7o	7c
Low Moist	170	4	591	3d	2.2g	3c
Nat. Moist	170	4	651	3.7d	4.4	6.7c
High Moist	170	4	674	3.5d	3.7o	7c
Low Moist	170	6	612	3d	2.2g	3.5c
Nat. Moist	170	6	685	4d	4.1o	6.7
High Moist	170	6	682	4d	3.5o	7c

Table I (cont.) Comparative Baking Results (Standard Procedure)

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	170	8	620	3d	2.5	3.5c
Nat. Moist	170	8	691	4d	3.7o	7o
High Moist	170	8	680	4d	3.7o	7o
Low Moist	170	10	614	3d	2.2g	3.6c
Nat. Moist	170	10	688	3.7d	4o	7o
High Moist	170	10	678	3.7d	3.5o	7
Low Moist	190	3	580	3d	2g	3c
Nat. Moist	190	3	684	3.7d	4.5	6.2c
High Moist	190	3	683	3.7d	4o	7o
Low Moist	210	3	600	3.2d	2.5g	4c
Nat. Moist	210	3	688	3.7d	4.4o	7o
High Moist	210	3	709	4d	4.2o	7o
Low Moist	230	3	646	3.7d	4.5	6.2c
Nat. Moist	230	3	678	3.7d	4.4	7
High Moist	230	3	701	4d	4.2o	7o

Table II

Comparative Baking Results
(Standard Procedure + 0.001g. of potassium bromate)
(3 hour Fermentation)

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Pure Vth Midds	-	-	696	5	5	8.2
Low Moist	Control		669	3.2d	3g	4c
Nat. Moist	"		660	3.2d	2.7g	5c
High Moist	"		702	3.5d	3.9	7c
Low Moist	110	3	637	3.6d	2.5g	4c
Nat. Moist	110	3	673	3.9d	3.2g	5.5c
High Moist	110	3	720	3.5d	4.3	7c
Low Moist	130	3	650	3.2d	2.7g	4c
Nat. Moist	130	3	692	3.5d	3.5g	5c
High Moist	130	3	731	3.6d	4c	6.7c
Low Moist	150	3	666	3.2d	2.7g	4c
Nat. Moist	150	3	720	3.2d	4.5	6c
High Moist	150	3	726	3.5d	4c	7c
Low Moist	170	1	667	3.2d	2.5g	4.5c
Nat. Moist	170	1	697	3.2d	3.7	5.5c
High Moist	170	1	725	3.2d	4.2	7c
Low Moist	170	2	662	3.5d	3g	4c
Nat. Moist	170	2	716	3.9d	4.5	7c
High Moist	170	2	685	3.9d	4c	7c
Low Moist	170	3	651	4d	2.5g	5c
Nat. Moist	170	3	704	3.7d	4.4	6.7c
High Moist	170	3	684	3.7d	3.5c	7c
Low Moist	170	4	633	3.7d	2.5g	4c
Nat. Moist	170	4	707	4d	3.9c	7c
High Moist	170	4	690	4d	3.5c	5c
Low Moist	170	6	661	4d	3g	4c
Nat. Moist	170	6	702	4.1d	4c	5.5c
High Moist	170	6	637	4.1d	3.2c	5c
Low Moist	170	8	661	3.5d	3g	4.5c
Nat. Moist	170	8	640	3.7d	3.2	5c
High Moist	170	8	635	4d	3.2c	5c
Low Moist	170	10	670	4d	3g	5.5c
Nat Moist	170	10	670	4.1d	3.5c	5c
High Moist	170	10	625	4.1d	3c	5c

Table II (cont.)

Comparative Baking Results

(Standard Procedure + 0.001g. of potassium bromate)

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	190	3	673	3.5d	3g	4.5e
Nat. Moist	190	3	722	3.5d	3.9o	6o
High Moist	190	3	664	4.1d	3.5o	6o
Low Moist	210	3	670	4.1d	4	5.5e
Nat. Moist	210	3	700	4.1d	4o	6o
High Moist	210	3	675	4.1d	4o	6o
Low Moist	230	3	685	3.7d	4.1o	6o
Nat. Moist	230	3	716	4d	3.7o	6o
High Moist	230	3	685	3.9d	3.5o	6o

The appearance of the loaves differed so much that it was decided to include photographs of the bread showing these changes. Fig. 2 shows the effect of raw germ at the three moisture levels on the baking quality of fifth middlings flour, using both the standard procedure and the bromate differential. It will be noticed that the response to bromate was most marked in the case of the low moisture sample, where the germ is having the most deleterious effect.

In order to compare the loaves quantitatively, it was necessary to incorporate the various measures of baking strength into one total, which would be called the single figure estimate. The method of calculation adopted is

Fig. 2 The Effect of Raw Germ at Different Moisture Levels on the Baking Quality of Fifth Middlings Flour.

based on that used by the Associated Committee on Grain Research of the National Research Council of Canada, but no allowance is made for absorption, which was practically the same in all samples. The calculation used was

(Loaf volume in cc. - 400) x .2 =
Crust Color x 2 =
Symmetry x 2 =
Texture x 2 = ________
Total (Single Figure Estimate) =

Table III gives the Single Figure Estimates for the loaves recorded in tables I and II, and it also includes the response to potassium bromate.

Table III

Single Figure Estimates and Response to Bromate for Loaves Recorded in Tables I and II

Material	Treatment Temp.	Treatment Time	Single Figure Estimate Standard P.	Single Figure Estimate Bromate Pro.	Response to Bromate
Pure Vth Midds.	-	-	91.9	103.8	11.9
Low Moist	Control		53.2	78.2	25.0
Nat. Moist	"		61.2	78.8	17.6
High Moist	"		83.4	95.6	12.2
Low Moist	110	3	59.0	71.6	12.6
Nat. Moist	110	3	64.5	85.3	20.8
High Moist	110	3	94.3	101.0	6.7
Low Moist	130	3	59.2	73.8	14.6
Nat. Moist	130	3	66.8	87.4	20.6
High Moist	130	3	94.1	101.5	7.4
Low Moist	150	3	59.0	77.0	18.0
Nat. Moist	150	3	77.0	97.4	20.4
High Moist	150	3	89.5	101.2	11.7
Low Moist	170	1	53.8	78.3	24.5
Nat. Moist	170	1	73.0	89.7	16.7
High Moist	170	1	90.7	100.8	10.1
Low Moist	170	2	54.6	77.4	22.8
Nat. Moist	170	2	78.5	101.0	22.5
High Moist	170	2	90.1	93.8	3.7
Low Moist	170	3	57.0	78.2	21.2
Nat. Moist	170	3	76.4	97.1	20.7
High Moist	170	3	91.6	92.2	0.6
Low Moist	170	4	57.6	71.0	13.4
Nat. Moist	170	4	86.5	98.3	11.8
High Moist	170	4	90.2	88.0	- 2.2
Low Moist	170	6	63.3	78.8	15.5
Nat. Moist	170	6	93.3	93.1	- 0.2
High Moist	170	6	92.4	77.0	-15.4

Table III (cont.)

Single Figure Estimates and Response to Bromate for Loaves Recorded in Tables I and II

Material	Treatment Temp.	Treatment Time	Single Figure Estimate Standard Fr.	Single Figure Estimate Bromate Fr.	Response to Bromate
Low Moist	170	8	65.5	78.7	13.2
Nat. Moist	170	8	94.6	76.8	-17.8
High Moist	170	8	92.4	80.1	-12.3
Low Moist	170	10	63.7	84.5	20.8
Nat. Moist	170	10	94.0	84.2	- 9.8
High Moist	170	10	91.0	74.2	-16.8
Low Moist	190	3	55.0	81.1	26.1
Nat. Moist	190	3	91.8	97.2	5.4
High Moist	190	3	93.0	86.0	- 7.0
Low Moist	210	3	63.4	86.7	23.3
Nat. Moist	210	3	94.8	94.2	- 0.6
High Moist	210	3	99.2	89.8	- 9.4
Low Moist	230	3	84.2	90.6	6.4
Nat. Moist	230	3	92.8	96.6	3.8
High Moist	230	3	98.0	89.8	- 8.2

The effect of several different temperatures of heat treatment on low, natural, and high moisture samples is shown pictorially in Figs. 3, 5, and 7, in which the time of treatment is constant at three hours. The graphs of Figs. 4, 6, and 8 show the variation of the Single Figure Estimate with temperature for all the temperature treatments, on the low, natural, and high moisture material respectively.

Fig. 3 The Effect of Different Temperature Treatments on Low Moisture Germ for 3 Hours, loaves baked by the Standard and Bromate Procedures.

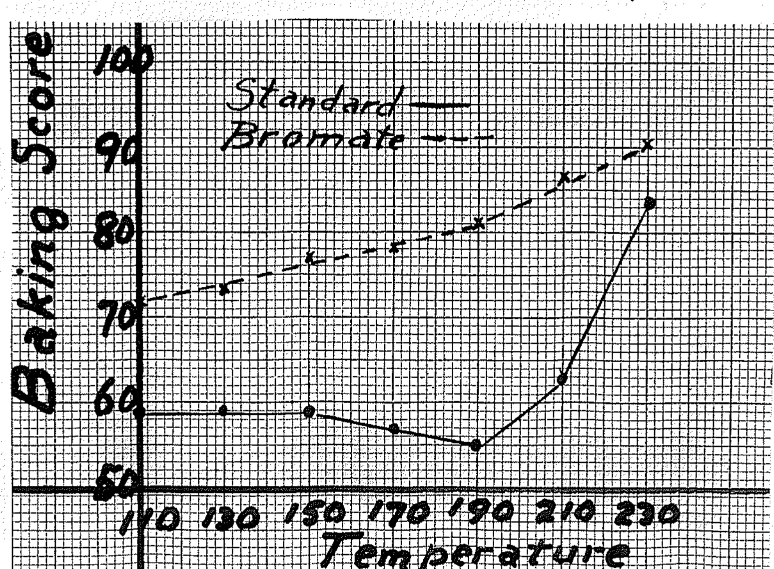

Fig. 4 Graph Showing the Relation between the Temperature of Heat Treatment of Low Moisture for 3 hours and the Single Figure Estimate of Loaves baked by the Standard andBromate Procedures.

Fig. 5 The Effect of Different Temperature Treatments on Natural Moisture Germ for 3 hours, loaves baked by the Standard and Bromate Procedures.

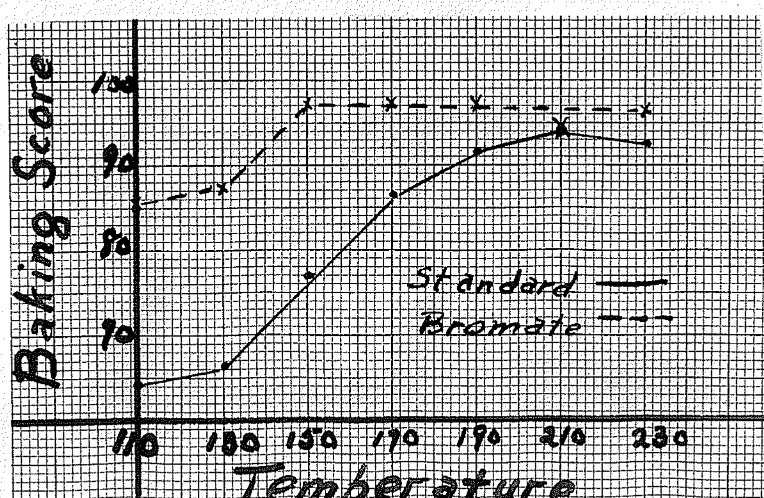

Fig. 6 Graph Showing the Relation between the Temperature of Heat Treatment of Natural Moisture Germ for 3 hours and the Single Figure Estimate of loaves baked by the Standard and Bromate Procedures.

Fig. 7 The Effect of Different Temperature Treatments on High Moisture Germ for 3 hours, loaves baked by the Standard and Bromate Procedures.

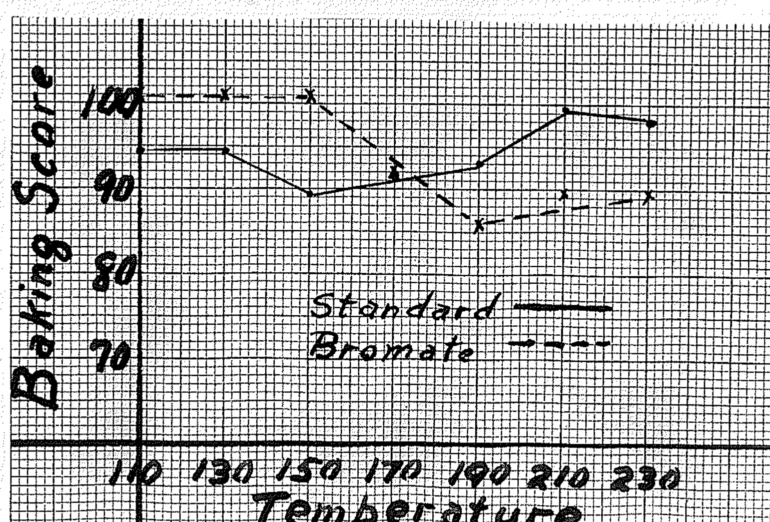

Fig. 8 Graph Showing the Relation between the Temperature of Heat Treatment of High Moisture Germ for 3 hours and the Single Figure Estimate of loaves baked by the Standard and Bromate Procedures.

In the low moisture material, the heat treatment improves the baking quality continuously for the standard procedure, although there are the characteristics of a green or under-fermented loaf in all cases. The presence of potassium bromate in the baking formula increases the volume and texture of the loaves. Where the germ had its natural moisture content, there was a more marked influence of heattreatment, and the single figure estimate for loaves baked by the standard procedure is very considerably above that for the low moisture germ. The high moisture germ, even at low heat heat treatments, gave a large well-formed loaf using the standard procedure, and the higher temperature treatments improved it only slightly. The use of the bromate differential showed a marked degradation in quality at temperatures as low as 170°F, the loaf having the characteristics of over-fermentation, a rough drawn side, rounded corners, a pale crust color, and anopen texture.

The effect of varying the time of treatment keeping the temperature constant at 170°F is shown pictorially in Figs. 9, 11, and 13 which are for germ of low, natural and high moisture respectively. The single figure estimates for a more extended series of loaves than that shown in the pictures, is given in the form of graphs in Figs. 10, 12, and 14.

Fig. 9 The Effect of Different Times of Treatment on Low Moisture Germ at 170°F, loaves baked by the Standard and Bromate Procedures.

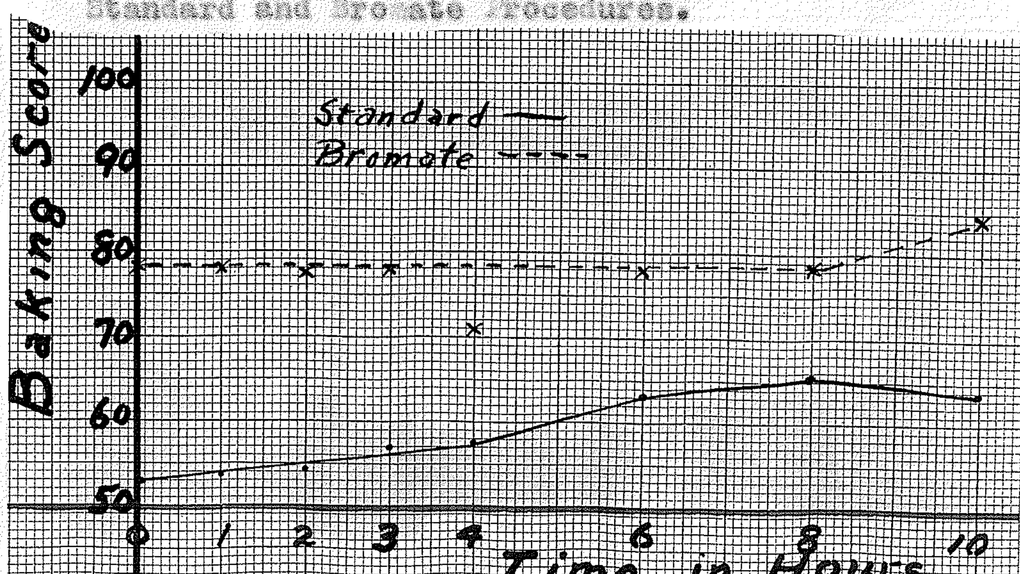

Fig. 10 Graph showing the Relation between the Time of Heat Treatment of Low Moisture Germ at 170°F and the Single Figure Estimate for loaves baked by the Standard and Bromate Procedures.

Fig. 11 The Effect of Different Times of Treatment on Natural Moisture Germ at 170°F, loaves baked by the Standard and Bromate Procedures.

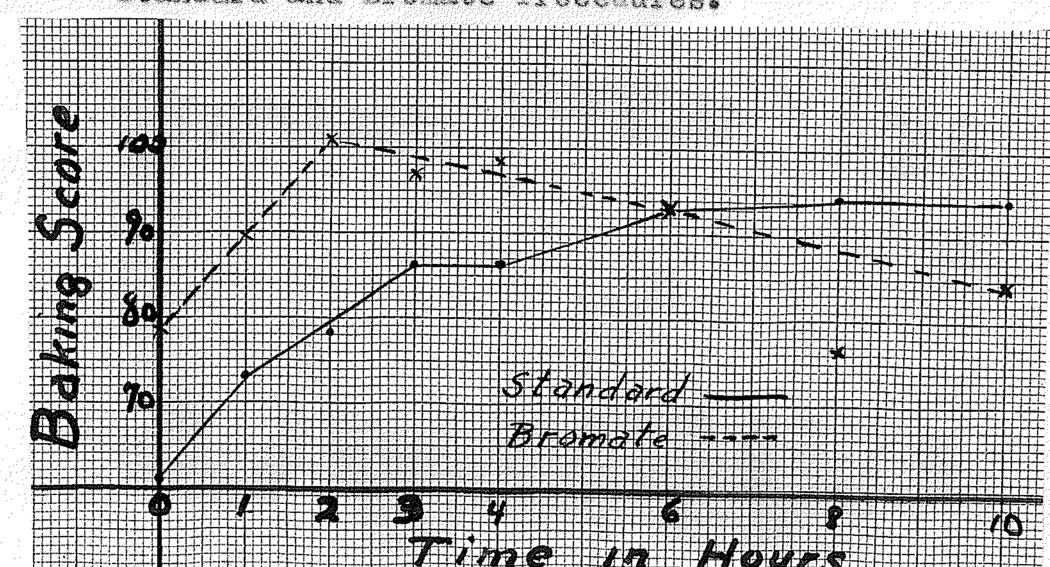

Fig. 12 Graph showing the Relation between the Time of Heat Treatment of Natural Moisture Germ at 170°F and the Single Figure Estimate for loaves baked by the Standard and Bromate Procedures.

Fig. 13 The Effect of Different Times of Treatment on High Moisture Germ at 170°F, loaves baked by the Standard and Bromate Procedures.

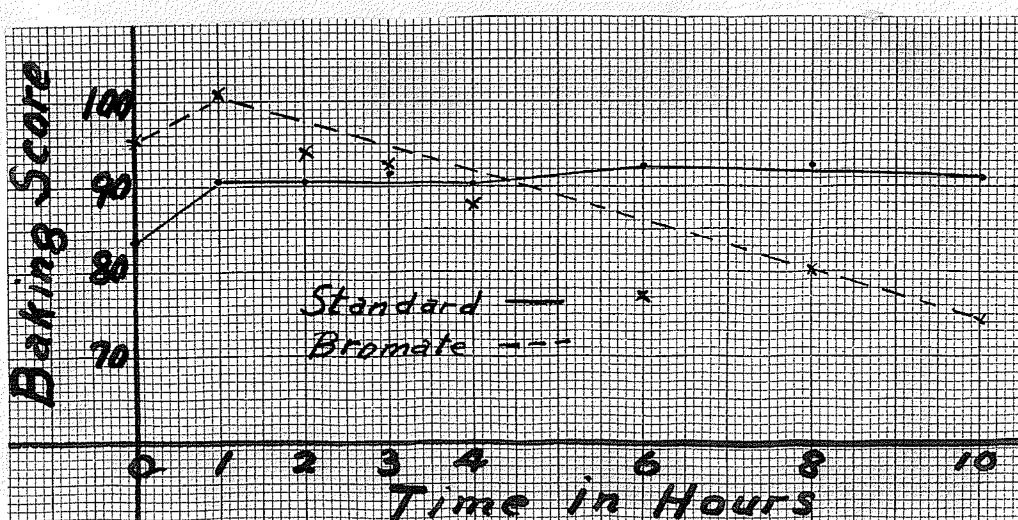

Fig. 14 Graph showing the Relation between the Time of Heat Treatment of High Moisture Germ at 170°F and the Single Figure Estimate for loaves baked by the Standard and Bromate Procedures.

In the low moisture samples, there is a continuous improvement for increasing time of treatment, as determined by the standard procedure, and the influence of bromate is to improve the loaves at all times of the range covered. The response to increasing time of treatment is more marked in the natural moisture material than in the drier germ, but the influence of bromate is not always toward a better loaf. The curve for bromate reaches its peak at 2 hours, and drops below the curve for the standard procedure at about six hours treatment. In the material of high moisture content, there is the same type of response to heat, although the control loaf, and those of short heat treatment are much better than the corresponding loaves with less moist germ. The bromate results show an almost continuous decline from the 1 hour treatment, and the loaves were badly over-fermented.

The effect of the potassium bromate is clearly in the same direction as the heat treatment, but it is evident that heat alone even in the higher moisture samples where it has its maximum effect is not as effective as chemical improvers with less heat. This had been observed in the case of wheat flour by Berliner and Ruter (1928) and by Geddes (1929). It could easily be accounted for by the suggestion of Geddes that there are two opposing effects of heat treatment, one a removal of certain deleterious agents found in the germ, the other a progressive degradation in the gluten quality. The former will take place at lower temperatures, accounting for the improvement noted with mild heat treatments. The higher heats will provide the maximum effect in reducing the amount of this harmful substance, but only at the expense of damaging the gluten quality. He suggests that the effect of bromate is to remove (presumably by oxidation) the harmful constituents leaving the gluten in its original state.

The effect of different fermentation times was next investigated. Fermentation tolerance, - the ability of a flour to withstand variation in the time of fermentation without greatly affecting the quality of the bread - is one of the most desirable qualities in a commercial flour, and frequently furnishes a measure of strength. In addition to the 3 hour fermentation period which had been used in baking the previously mentioned loaves, it was decided to use times of 1½ hours and 4½ hours, the ratio of the times to the first punch, second punch, and panning being maintained at 9 : 4 : 2 . These fermentation times were selected as they gave a slightly under-fermented, a correctly fermented, and a slightly over-fermented appearance to loaves from fifth middlings flour baked according to the standard procedure. A selection was made of the germ samples, and this was baked at the two new fermentation times, by both standard and bromate procedure. The results are given in Tables IV to VII.

Table IV

Comparative Baking Results -(1 3/4 hour fermentation)

Standard Procedure

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	Control		566	3d	2g	2.5c
Nat. Moist	"		624	3d	2.2g	2.5c
High Moist	"		699	3.5d	3.9	5c
Low Moist	170	2	588	3d	2g	2.5c
Nat. Moist	170	2	655	3.5d	3.2g	3.5c
High Moist	170	2	711	3.5d	4.5c	5c
Low Moist	170	4	592	3d	2g	2.5c
Nat. Moist	170	4	684	3.5d	4.4	5c
High Moist	170	4	705	3.5d	4.5c	5c
Low Moist	170	6	582	3d	2g	2.7c
Nat. Moist	170	6	686	3.5d	4.4	5c
High Moist	170	6	720	3.5d	4.5	6c
Low Moist	170	8	597	3d	2g	2.7c
Nat. Moist	170	8	684	3.5d	4c	5c
High Moist	170	8	756	3.5d	4c	6.2c&c
Low Moist	170	10	602	3d	2.2g	2.7
Nat. Moist	170	10	710	3.5d	4c	5.7c
High Moist	170	10	759	3.5d	4.4c	6.2c&c

Table V

Comparative Baking Results (4 1/4 hour fermentation)

Standard Procedure

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	Control		595	4p	2.5g	3c
Nat. Moist	"		611	4p	3.5g	4c
High Moist	"		585	4.5p	4.1	6.7c
Low Moist	170	2	570	4p	2.5g	3c
Nat. Moist	170	2	629	4.5p	3.9g	6.5c
High Moist	170	2	665	4.5p	4c	7c

Table V (cont.)

Comparative Baking Results (4 1/4 hour fermentation)

Standard Procedure

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	170	4	557	4p	2.5g	3c
Nat. Moist	170	4	659	4.5p	4.4	7.8
High Moist	170	4	664	4.5p	4o	6.7o
Low Moist	170	6	570	4p	2.5g	3c
Nat. Moist	170	6	655	4.5p	4.5o	7
High Moist	170	6	672	4.5p	4o	7o
Low Moist	170	8	580	4p	2.5g	3c
Nat. Moist	170	8	629	4.5p	4.5o	7.5
High Moist	170	8	655	4.5p	4o	7o
Low Moist	170	10	580	4p	3.2g	4c
Nat. Moist	170	10	634	4.5p	4.2o	7o
High Moist	170	10	621	4.5p	3.9o	6.5o

Table VI

Comparative Baking Results (1 3/4 hour fermentation)

Standard Procedure + 0.001g of potassium bromate

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	Control		618	3d	2.5g	3.5c
Nat. Moist	"		639	3.2d	3.5g	3.5c
High Moist	"		736	3.5d	4o	6.5c
Low Moist	170	2	608	3d	2.5g	3c
Nat. Moist	170	2	675	3.5d	4.2	5.5c
High Moist	170	2	714	3.5d	4.2o	6.2c&o
Low MMoist	170	4	618	3d	2.5g	3c
Nat. Moist	170	4	716	3.5d	4.2o	5.5c
High Moist	170	4	709	3.5d	4.5o	6.2o
Low Moist	170	6	621	3d	2.5g	3c
Nat. Moist	170	6	720	.3.5d	4.2o	6.2c&o
High Moist	170	6	715	3.5d	4.2o	6c&o

Table VI (cont.)

Comparative Baking Results (1 3/4 hour fermentation)

Standard Procedure + 0.001g. of potassium bromate

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	170	8	622	3d	2.5g	3.8c
Nat. Moist	170	8	712	3.5d	4.2o	6.2c&o
High Moist	170	8	737	3.5d	4.2o	6.2c&o
Low Moist	170	10	633	3.5d	3.1g	3.8c
Nat. Moist	170	10	733	3.5d	4.2o	6.2c&o
High Moist	170	10	706	3.5d	4.1o	6.5o

Table VII

Comparative Baking Results (4 1/4 hour fermentation)

Standard Procedure + 0.001g. of potassium bromate

Material	Treatment Temp.	Treatment Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moist	Control		625	4.2p	3.5g	5.8c
Nat. Moist	"		647	4.5p	4.2g	7.5
High Moist	"		620	4.5p	4o	7.5
Low Moist	170	2	629	4.2p	3.5g	6.5c
Nat. Moist	170	2	629	4.5p	4o	7o
High Moist	170	2	619	4.5p	3.5o	6o
Low Moist	170	4	634	4.2p	3.5g	7c
Nat. Moist	170	4	628	4.5p	4o	6o
High Moist	170	4	596	4.5p	3.5o	6o
Low Moist	170	6	632	4.5p	3.5g	6.5c
Nat. Moist	170	6	663	4.5p	3.5o	6o
High Moist	170	6	593	4.5p	3.5o	6o
Low Moist	170	8	630	4.5p	3.9g	6.5c
Nat. Moist	170	8	627	4.5p	3.8o	6o
High Moist	170	8	553	4.5p	3.5o	6o
Low Moist	170	10	593	4.5p	4g	6.5c
Nat. Moist	170	10	597	4.5p	3.5o	6o
High Moist	170	10	539	4.5p	3.5o	6o

A summary of the single figure estimates of baking quality of the loaves baked in the two procedures for the three fermentation times, is given in Table VIII .

Table VIII

Summary of Single Figure Estimates

for Different Fermentation Times

Material	Treatment Temp.	Time	Standard Procedure 1½hrs.	3hrs.	4½hrs.	Bromate Procedure 1½hrs.	3hrs.	4½hrs.
Low Moist	Control		52.7	53.2	61.0	65.1	76.2	77.9
Nat. Moist	"		62.6	61.2	70.0	71.8	76.8	89.4
High Moist	"		87.6	83.4	74.7	101.7	95.6	85.5
Low Moist	170	2	55.1	54.6	56.0	61.6	77.4	80.8
Nat. Moist	170	2	75.0	78.5	82.1	87.6	101.0	83.8
High Moist	170	2	93.2	90.1	91.0	97.1	93.8	77.8
Low Moist	170	4	55.9	57.6	53.4	63.6	71.0	87.4
Nat. Moist	170	4	87.6	86.5	92.1	95.2	98.3	77.4
High Moist.	170	4	92.0	90.2	90.4	96.6	89.0	73.3
Low Moist	170	6	54.6	63.3	56.0	64.2	78.2	81.9
Nat. Moist	170	6	86.0	93.3	90.0	98.3	93.1	86.6
High Moist	170	6	98.0	92.4	92.6	96.5	77.0	72.6
Low Moist	170	8	57.7	65.5	58.0	65.9	78.7	82.3
Nat. Moist	170	8	85.8	94.6	86.3	96.7	76.8	80.1
High Moist	170	8	105.4	92.4	89.0	101.7	80.1	64.6
Low Moist	170	10	59.2	63.7	63.5	70.3	84.5	76.7
Nat. Moist	170	10	94.3	94.0	85.3	100.9	84.2	73.4
High Moist	170	10	106.4	91.0	80.5	95.9	74.2	61.8

In the low moisture samples, there was a slight improvement in the baking results by a longer fermentation time, either by the standard or bromate method until the time of heat treatment was six hours, by which time the degradation of the gluten quality was becoming evident. Loaves baked from natural and high moisture germ by the standard procedure were improved by longer fermentation if the period of heat treatment was short, but for the longer treatments, the loaves were easily overfermented. The use of the bromate procedure shortened the optimum fermentation time, especially in the longer heat treated germ samples. The use of increased periods of fermentation with its changes is thus apparently similar in its effect as an improving agent on germ-flour loaves, to heat treatment and the use of chemical improvers such as potassium bromate.

The effect of time of fermentation on various germ samples is shown in Figs. 15 - 19, in which the three moisture levels of raw germ are shown and also a natural moisture sample receiving a moderate heat treatment and finally a high moisture sample which had been kept at 170°F for 10 hours. In the case of the last, there is a pronounced negative response to longer fermentation, and this is accentuated by the use of bromate in the baking formula.

The effect of fermentation is indicated by the change in handling qualities of the dough. Longer fermentation times improved the ease of handling the raw germ, but where the germ had been heat treated at high moisture, the longer fermentation seemed to exhaust the dough, and it lost its resiliency and spring.

Fig. 15 The Effect of Varying the Fermentation Time on Low Moisture Raw Germ, using the Standard and Bromate Procedures.

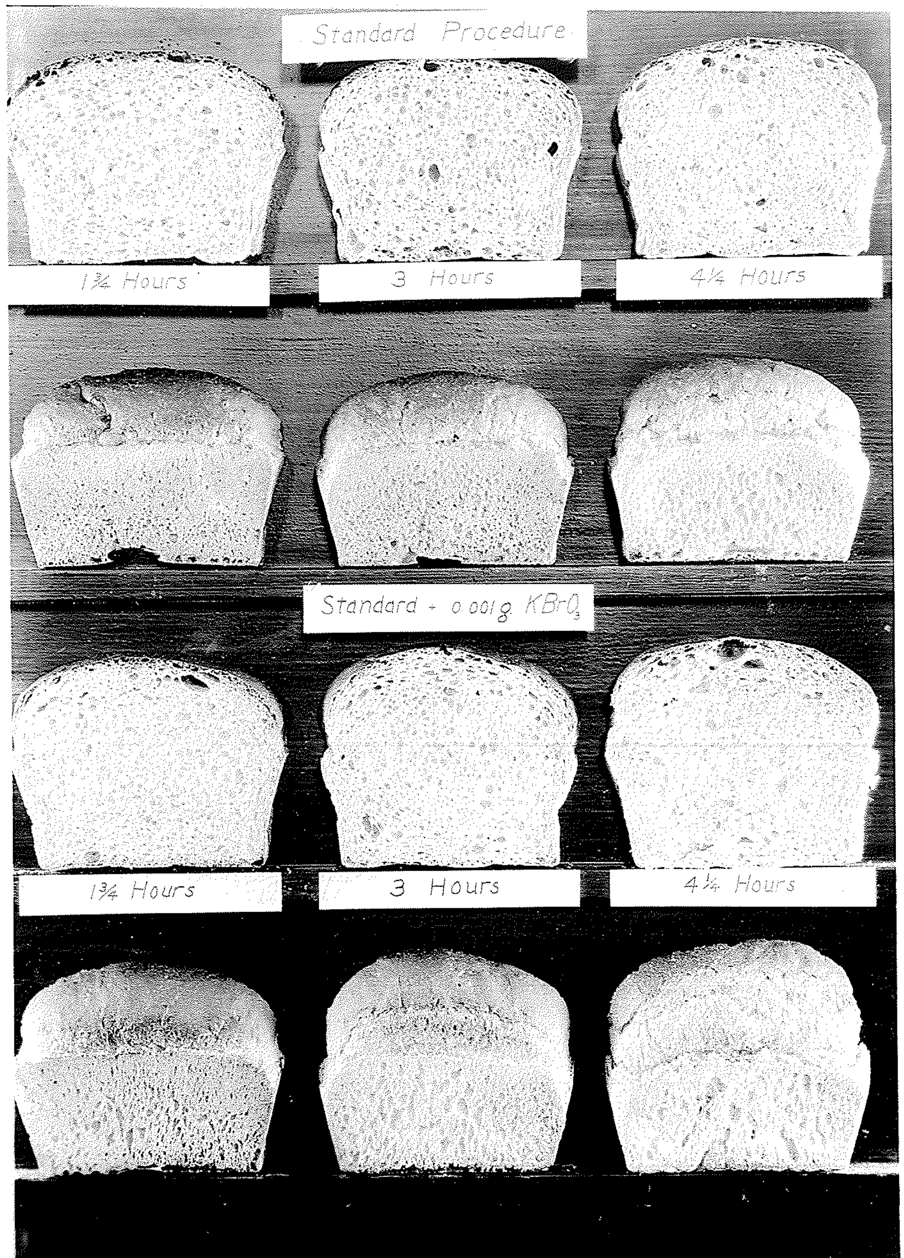

Fig. 16 The Effect of Varying the Fermentation Time on Natural Moisture Raw Germ, using the Standard and Bromate Procedures.

Fig. 17 The Effect of Varying the Fermentation Time on High Moisture Raw Germ, using the Standard and Bromate Procedures.

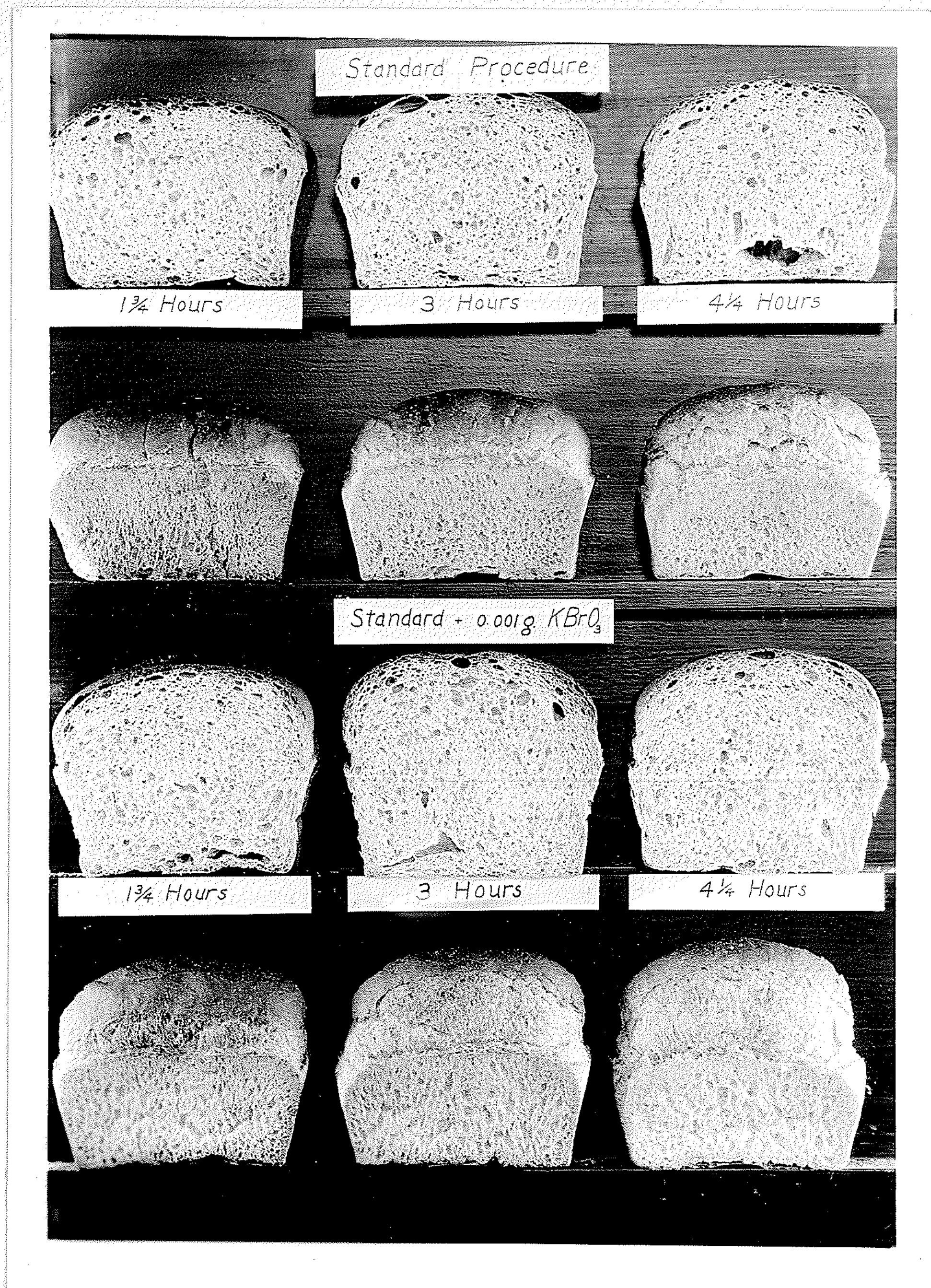

Fig. 18 The Effect of Varying the Fermentation Timeon Natural Moisture Germ heated at 170°F for 2 hours, using the Standard and Bromate Procedures.

Fig. 19 The Effect of Varying the Fermentation Time on High Moisture Germ heated at 170°F for 10 hours, using the Standard and Bromate Procedures.

Results with Ether Extracted and Ether Wetted Germ

The effect of ether extraction of a straight grade flour was found by Geddes (1930b) to be an improvement in baking quality, but the response to bromate in the case of the ether extracted material was decreased; in the case of the samples where the extracted germ was subsequently heat treated, the response to bromate became negative. In view of the observed relation of ether extraction to baking quality in straight flours, but not in Fifth middlings which is always less contaminated with germ, it was decided to subject the ether extracted and ether wetted material to various heat treatments, and then to bake them in the usual manner according to the standard and bromate procedures, having a 3 hour fermentation. The baking results are given in Tables IX and X

Table IX

Comparative Baking Results for Ether Extracted and Ether Wetted Germ (Standard Procedure, 3 hour Fermentation)

Material	Treatment Temp.	Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moisture	Control		571	3d	2g	3c
Extracted	Control		564	3d	2g	3c
"	170	1	588	3d	2g	3.5c
"	170	2	566	3d	2.2g	3c
"	170	3	581	3d	2g	3c
"	170	4	577	3d	2.2g	3c
"	170	6	601	3d	2.2g	3c
"	170	8	585	3d	2g	3.5c
"	170	10	580	3d	2.5g	3c

Table IX (cont.)

Comparative Baking Results for Ether Extracted and Ether Wetted Germ (Standard Procedure, 3 hour Fermentation)

Material	Treatment Temp.	Time	Volume in cc.	Crust Color	Symmetry	Texture
Wetted	Control		590	3d	2g	3c
Wetted	170	1	592	3d	2.2g	3c
"	170	2	580	3d	2g	3.5c
"	170	3	593	3d	2.2g	3c
"	170	4	610	3d	2.5g	3.5c
"	170	6	632	3d	2.5g	3c
"	170	8	614	3d	2.5	4
"	170	10	632	3d	2.5	3.5c

Table X

Comparative Baking Results for Ether Extracted and Ether Wetted Germ (Bromate Procedure, 3 hour Fermentation)

Material	Treatment Temp.	Time	Volume in cc.	Crust Color	Symmetry	Texture
Low Moisture	Control		669	3.2d	3g	4c
Extracted	Control		610	3.5d	2.5g	4c
"	170	1	624	3.2d	2.5g	4.5c
"	170	2	643	3.2d	2.7g	4c
"	170	3	636	3.2d	2.5	5
"	170	4	640	3.5d	3g	4.5c
"	170	6	644	3.5d	3.2g	4.5c
"	170	8	647	3.5d	2.7g	4.5c
"	170	10	619	3.2d	3g	4.5c
Wetted	Control		659	3.7d	2.7g	4.5c
"	170	1	647	3.2d	2.7g	5c
"	170	2	650	3.5d	2.7g	4.5c
"	170	3	657	3.2d	2.7g	4.5c
"	170	4	661	4d	2.5g	5c
"	170	6	663	3.5d	3.2g	4.5c
"	170	8	658	3.7d	3.2g	4.5c
"	170	10	657	3.6d	3g	4.5c

In order to compare these results with non-extracted or wetted germ of about the same moisture content, these results are summarized into single figure estimates and compared with the single figure estimates of low moisture germ samples treated similarly. This will be found in Table XI

Table XI

Single Figure Estimates of Ether Extracted, Ether Wetted, and Low Moisture Germ Loaves

Treatment		Single Figure Estimate					
		Standard Procedure			Bromate Procedure		
Temp.	Time	Low Moist.	Extrac.	Wetted	Low Moist.	Extrac.	Wetted
Control		53.2	51.8	57.0	76.2	66.0	78.1
170	1	53.8	58.1	57.8	78.3	69.7	76.2
170	2	54.6	52.6	56.5	77.4	72.4	75.9
170	3	57.0	55.2	58.0	76.2	76.6	76.7
170	4	57.6	54.8	63.5	71.0	74.5	80.2
170	6	63.3	59.6	66.4	76.2	75.3	79.8
170	8	65.5	57.8	65.8	76.7	78.3	78.9
170	10	63.7	56.0	67.9	84.5	69.7	78.1

It is to be observed that in the case of the extracted material, the loaves are smaller than the others of corresponding heat treatment. A possible explanation for this rather unexpected result will be given later in this thesis. The slightly higher estimates found for the ether wetted samples as compared to the low moisture non-wetted germ is possibly due to the moisture difference of about 0.5%, as the moisture effect is very noticeable in all this work. There is also the possibility that it is due to some change in the manner

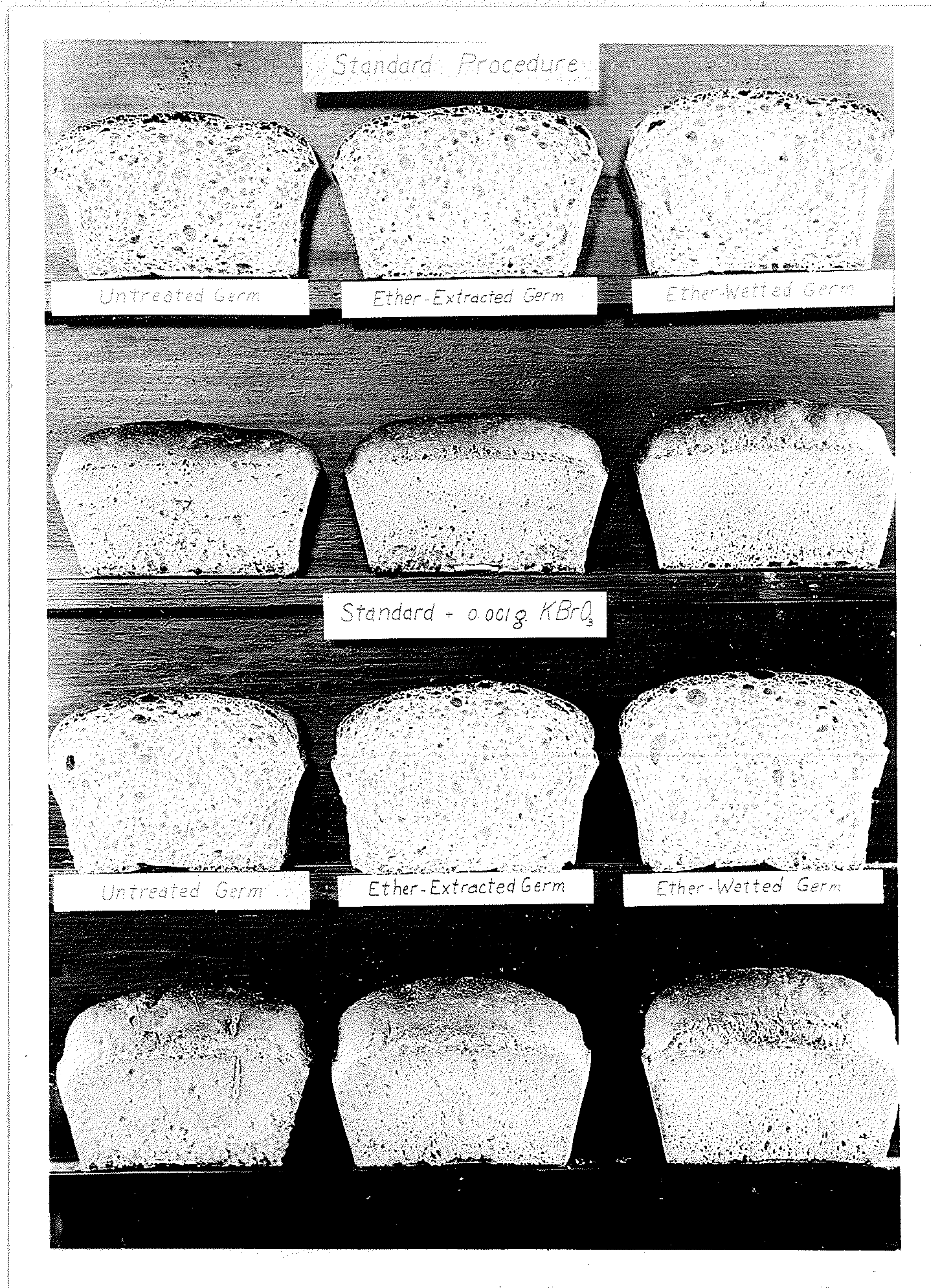

Fig. 20 The Effect of Ether Extraction and Ether Wetting on Germ of Low Moisture Content.

of association of the other soluble material with the gluten strands. No investigation was made of this point.

The Effect of Different Improvers

A comparative study was made of the effect of different improvers on a pure fifth middlings flour, on a low moisture raw germ mixture, and on a high moisture germ sample which had been heated at 170°F for 6 hours. The middlings flour used in this part of the work was not the same as that used in the baking previously reported, accounting for the slight variations in the score for the standard and bromate procedures. The results for the fifth middlings flour are for single determinations except by the standard and bromate procedures. The germ samples were baked in duplicate, and the results are the average. These are reported in Table XII, and Table XIII gives the single figure estimates along with the response to the improver.

The effect of the chlorates, bromates, and iodates is particularly interesting, in view of the opinion that these compounds function as oxidizing agents. Potassium chlorate is the most readily decomposed, potassium iodate least readily, while potassium bromate is intermediate. As these improvers were added at the rate of 0.001g. per loaf for potassium bromate, and an oxygen equivalent amount for the other oxidizing agents, they should give an effect proportional to their ease of decomposition if their effect is purely due to oxidation. As they do not follow this

Table XII

Comparative Baking Results with Different Improvers (3 hour fermentation)

Material #	Improver	Volume in cc.	Crust Color	Symmetry	Texture
Vth Middlings	Stand. Pro.	668	5	5	9
170-6 High M.	" "	647	4.5d	4o	7o
Raw Low M.	" "	588	3d	3g	3c&o
Vth Middlings	$KBrO_3$	683	5	4.5o	9
170-6 High M.	"	563	4.5d	3.5o	5c&o
Raw Low M.	"	638	3.5d	3.5g	5.5o
Vth Middlings	$KClO_3$	670	5	5	9
170-6 High M.	"	690	4d	4.5o	7o
Raw Low M.	"	583	3d	3g	3c&o
Vth Middlings	KIO_3	585	5	4o	9
170-6 High M.	"	513	4.5d	3.5o	5c&o
Raw Low M.	"	635	3.5d	3.5g	4o
Vth Middlings	$NaBrO_3$	670	5	4.5o	9
170-6 High M.	"	578	4.5d	3.5o	6o
Raw Low M.	"	648	3.5d	3.5g	4o
Vth Middlings	CaO_2	640	5	5	9
170-6 High M.	"	665	4.5d	4o	6o
Raw Low M.	"	583	3d	3g	3c&o
Vth Middlings	$K_2S_2O_8$	660	5	5	9
170-6 High M.	"	640	4.5d	4o	6o
Raw Low M.	"	605	3d	3g	3c&o
Vth Middlings	$(NH_4)_2HPO_4$	690	5	5	9
170-6 High M.	" "	700	4d	4.5o	7o
Raw Low M.	" "	643	3d	2.5g	3c&o
Vth Middlings	Malt-Phos*	718	4.5p	4.5g	7.5o
170-6 High M.	" "	715	2.5d	4.5o	7o
Raw Low M.	" "	643	3d	2g	3c&o

\# - The material represented by 170-6 High M. is a mixture containing germ of high moisture which had been heated at 170°F for 6 hours. The other germ mixture is unheated low moisture material.

* - Malt-Phos. is a mixture of diastatic malt (about 200° Lintner) and dibasic ammonium phosphate added at the rate of 0.125g. of malt and 0.05 g. of phosphate per loaf.

Table XIII

Single Figure Estimates and Response to Improvers for Different Improvers

Material	Improver	Single Figure Estimate	Response to Improver
Vth Middlings	Stand. Proc.	100.6	---
170-6 High M.	" "	87.4	---
Raw Low M.	" "	58.6	---
Vth Middlings	$KBrO_3$	102.6	2.0
170-6 High M.	"	63.6	-23.8
Raw Low M.	"	78.1	19.5
Vth Middlings	$KClO_3$	103.0	2.4
170-6 High M.	"	96.0	8.6
Raw Low M.	"	57.6	-1.0
Vth Middlings	KIO_3	82.0	-18.6
170-6 High M.	"	53.6	-33.8
Raw Low M.	"	73.0	14.4
Vth Middlings	$NaBrO_3$	100.0	-0.6
170-6 High M.	"	69.0	-18.4
Raw Low M.	"	75.6	17.0
Vth Middlings	CaO_2	95.0	-5.6
170-6 High M.	"	88.0	0.6
Raw Low M.	"	57.6	-1.0
Vth Middlings	$K_2S_2O_8$	99.0	-1.6
170-6 High M.	"	83.0	-4.4
Raw Low M.	"	62.0	3.4
Vth Middlings	$(NH_4)_2HPO_4$	105.0	4.4
170-6 High M.	"	98.0	10.6
Raw Low M.	"	48.6	-10.0
Vth Middlings	Malt-Phos.	103.5	2.9
170-6 High M.	" "	98.0	10.6
Raw Low M.	" "	47.6	-11.0

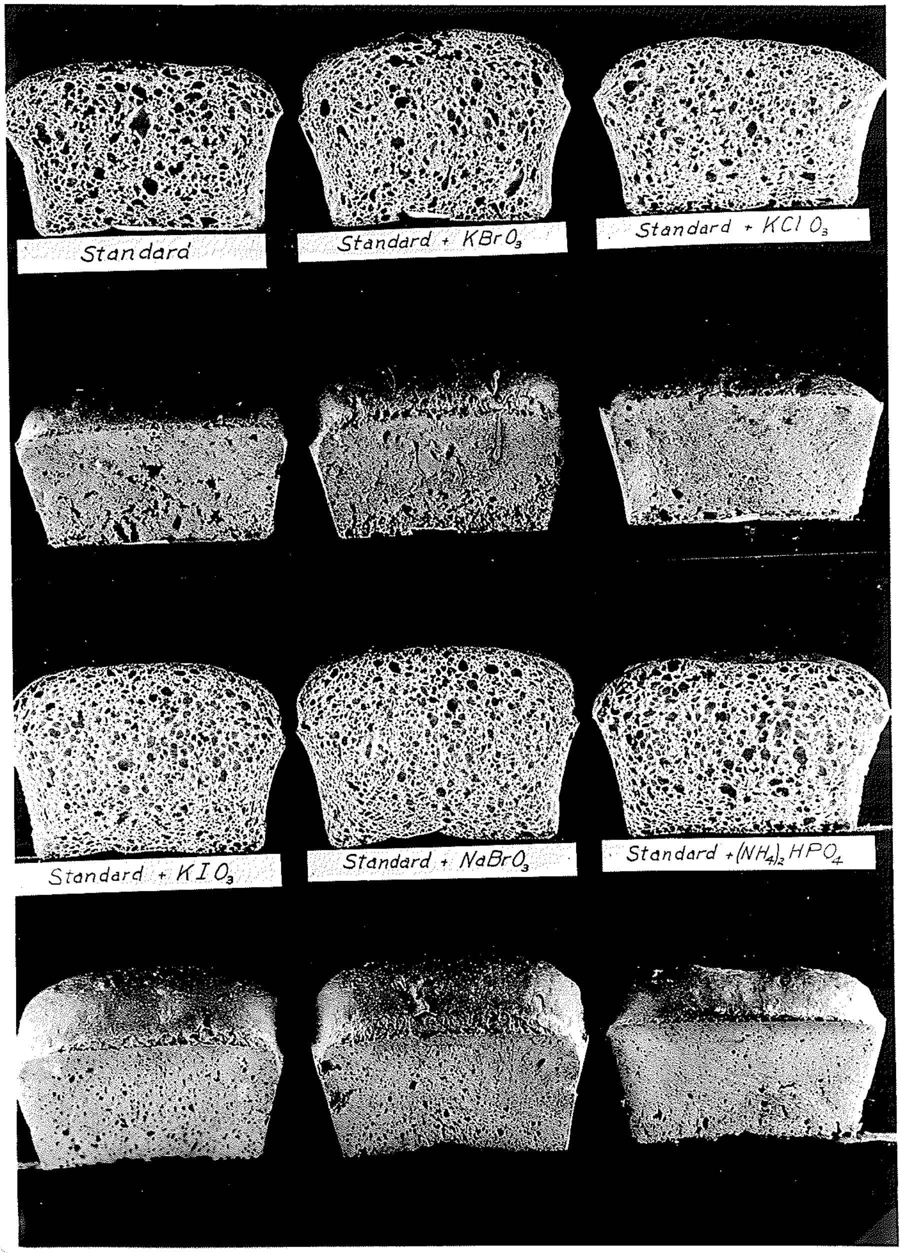

Fig. 21 The Effect of Different Improvers on Low Moisture Raw Germ Leaves.

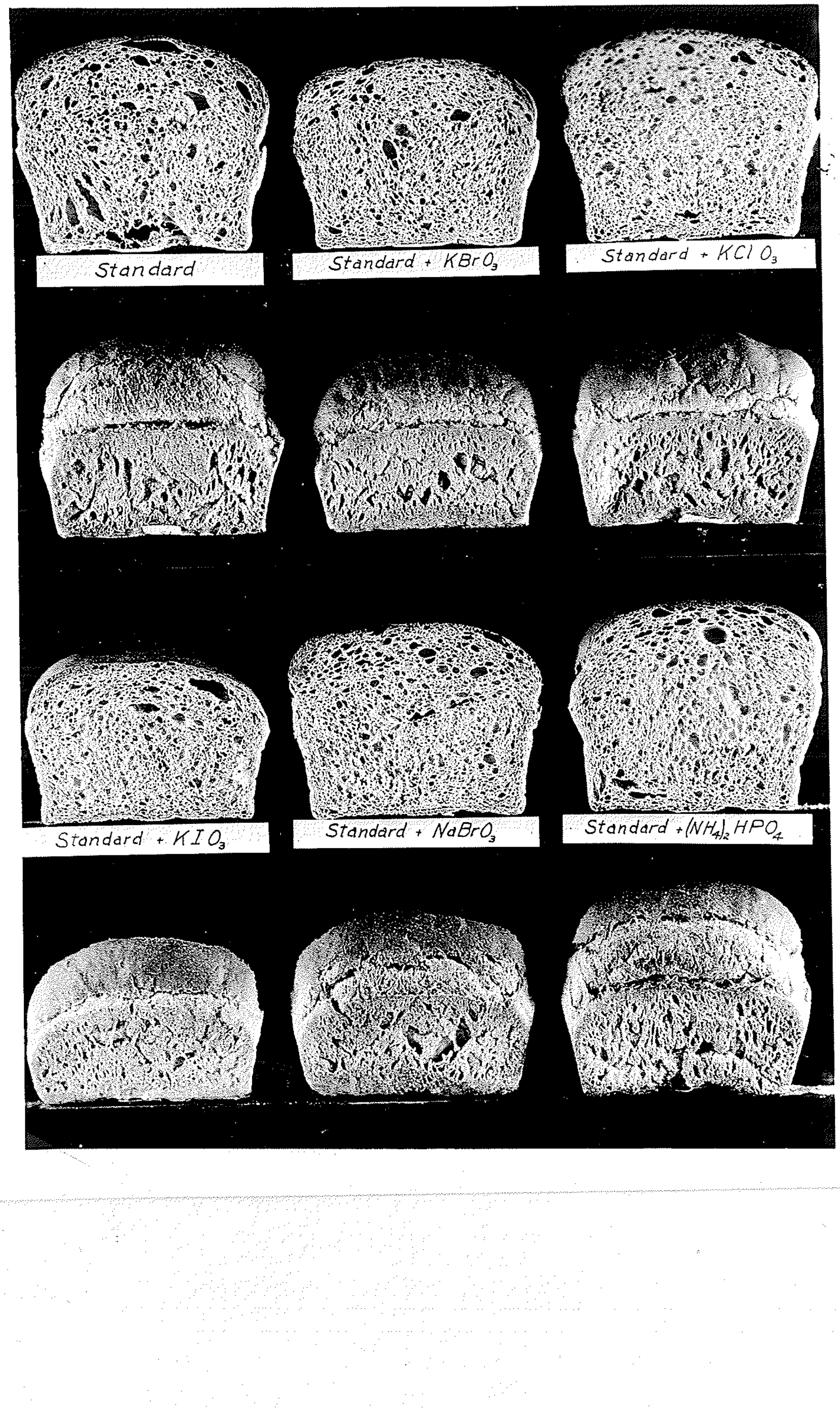

Fig. 22. The Effect of Different Improvers in Baking loaves made with Germ of High Moisture Heated at 170°F for 6 hours.

order, there is some ground for the belief that oxidation is not the only, or indeed the principal effect.

Potassium iodate seems to have a more marked deleterious effect on the heat treated germ than potassium bromate, without any correspondingly greater improvement in the raw germ sample. The effect of the ammonium phosphate, added at the rate of 0.05g. per loaf, was to increase the volume of the fifth middlings loaf and of the heat treated loaf markedly, while the loaf made with the raw germ was definitely under-fermented. The malt-phosphate dough had 0.05g of dibasic ammonium phosphate and 0.125g. of malt (200°Lintner) per loaf. Its effect was similar to that of the phosphate itself, and indicated that there was no scarcity of diastatic power in the germ samples. The effect of improvers should be more thoroughly investigated.

Analytical Examination of the Pure Heat Treated Samples of Germ

In an attempt to find from analytical data some explanation of the interesting results found in baking, an analysis was made of a series of selected samples of pure germ. The selection was made to include

(1) Controls

(2) Samples where the heat treatment had caused improvement in baking quality

(3) Samples where the heat treatment had caused degradation of baking quality.

The following samples were selected as showing these characteristics: untreated, treated at 170°F for 2 hours, treated at 170°F for 6 hours, and treated at 170°F for 10 hours, for the three moisture levels in each case. In Table XIV is given the single figure estimate for each of these samples baked by the standard and bromate methods.

Table XIV

Single Figure Estimate (Standard Procedure) of Samples Selected for Analysis

Treatment Temp.	Time	Low Moist.	Nat. Moist.	High Moist.
Control		53.2	61.2	88.4
170	2	54.6	78.5	90.1
170	6	63.3	93.3	92.4
170	10	63.7	94.0	91.0

Single Figure Estimate (Bromate Procedure) of Samples Selected for Analysis

Treatment Temp.	Time	Low Moist.	Nat. Moist.	High Moist.
Control		78.2	78.8	95.6
170	2	77.4	101.0	93.8
170	6	78.2	95.1	77.0
170	10	84.5	84.2	74.2

Most of the analyses reported were made on these samples. In some instances, others were added in order to investigate special parts of the work beyond the range covered, and in other cases, lack of time compelled a smaller selection.

(a) <u>Moisture</u>

Although the apparatus for heat treatment prevents any great moisture changes due to the treatment, water vapor would be lost from the germ during its treatment until the air and material in the drum were in moisture equilibrium.

Moisture determinations were made by the standard A. A. C. C. vacuum oven method. The oven was maintained at 105°c. The average of duplicate results, agreeing within the usual limits of error, are given in Table XV

<u>Table XV</u>

<u>Moisture Content of the Germ Samples</u>

Treatment Temp.	Time	Low Moist.	Nat. Moist.	High Moist.	Extrac.	Wetted
Control		7.48%	13.34%	17.06%	8.02%	8.04%
110	3	7.30%	12.93%	16.33%		
130	3	7.23%	12.70%	16.01%		
150	3	7.44%	12.90%	16.81%		
170	1	7.04%	12.17%	15.99%	7.91%	7.84%
170	2	7.38%	12.78%	16.11%	7.64%	7.96%
170	3	7.38%	12.98%	15.99%	7.90%	7.72%
170	4	7.20%	12.99%	16.21%	7.88%	7.87%
170	6	7.35%	12.83%	15.80%	7.92%	7.91%
170	8	7.15%	12.77%	16.27%	7.65%	7.74%
170	10	7.11%	12.71%	16.09%	7.77%	7.82%
190	3	6.84%	11.07%	14.63%		
210	3	7.00%	12.27%	14.56%		
230	3	7.29%	11.09%	13.07%		

(b) Titratable Acidity

The amount of titratable acid in low grade flours has been found by Bell (1909) and Marion (1909) to increase with storage, the cause of the change being due to bacterial growth, enzymatic activity, and oxidation. Geddes (1930a) on the other hand found that while heat treatment in many respects resembled long storage, in its effect on titrable acidity, heat treatment caused a decrease. In order to find whether this result was due only to the endosperm constituents, or to the germ constituents as well, it was decided to measure the titratable acidity of the germ samples. The method followed was the official A.A.C.C. procedure, using 18g. of material on a 13.5% moisture basis. The duplicate determinations were required to check to .02% , the results being expressed as lactic acid.

Table XVI

Titratable Acidity Values

Treatment Temp.	Time	Low Moisture	Natural Moisture	High Moisture
Control		.765%	.755%	.825%
170	2	.660%	.607%	.507%
170	6	.665%	.610%	.585%
170	10	.685%	.632%	.670%
190	3	.575%	.455%	.415%
210	3	.445%	.365%	.395%

The use of germ samples, which have a high buffer value, makes it very difficult to determine the end-point of the titration, which probably accounts for the irregularity of the results at 170°F. The tendency of the heat treatments is quite well marked toward a reduction of acidity with higher treatment.

(c) Hydrogen-ion Concentration and Buffer Value

The importance of the hydrogen-ion concentration of flour, and of the dough in baking has been the subject of much attention since the pioneer work of Jessen-Hansen (1911) who emphasized the necessity of the correct pH if the loaf volume is to be the maximum for that type of flour. His conclusion was that the optimum for most flour was at a pH = 5, though it was a little higher in the work with low grade flours, and a little lower for patent flours. Jessen-Hansen's conclusions were supported by Cohnand Henderson (1918) who pointed out that the degree of acidity determined the physical state of the gluten as well as the enzymic activity of the dough. They recommended an acidity such that methyl red is just turned from red to orange (approximately pH = 5). Dunlap was also in support of this position (1926). He concluded from his work that flours with a lower initial pH produce with a shorter fermentation, a bread quality unobtainable with a fresh flour.

Other investigators have been more critical toward these conclusions. Bailey (1925) suggested that if the best bread resulted at a pH about 5.0 , it was due possibly to accelerated enzymic activity, and he further stated that there was as yet no tangible evidence to prove that acidulation of the dough improved its physical properties in a direction that made for better bread. Rumsey (1922) had already noted that the activity of diastatic enzyme depended largely on the hydrogen-ion concentration. Johnson (1925) in a study of the acids formed in dough fermentation showed that carbonic acid was chiefly responsibbe for acidity, and Kent-Jones (1927) from this suggested that the greater acidity in bigger loaves might be an effect rather than a cause. This suggestion would not explain the enhanced values found by direct acidification reported by several workers. Fisher and Halton (1929a&b) concluded as the result of a series of investigations of different types of wheat flour, that the hydrogen-ion concentration was a factor of little importance in bread making, and contributed little or nothing to bread quality.

The buffer value of flour is also of importance in considering any changes in hydrogen-ion concentration in baking as it prevents wide variation during fermentation, and consequently allows more variation in fermentation procedure with less effect on the bread.

The hydrogen-ion concentration and the buffer value of extracts from the germ were determined by the standard A.A.C.C. method. Toluol was added to the distilled water to prevent bacterial action. The electrometric determination of pH was made by Fisher and Halton's method (1928) using a gold wire electrode and quinhydrone, against a saturated KCl calomel half cell. The accuracy of the assembled apparatus was checked against a buffer solution of known acidity, and at frequent intervals during the readings the a accuracy was checked similarly. In order to prevent the gold electrode carrying impurities into the liquid whose hydrogen-ion concentration was to be measured, duplicate samples were made of each solution, and one was used for a rinsing liquid, the reading being made on the other.

Due to the high buffer value of the germ, it was necessary to use $\frac{N}{2}$ lactic acid in order to prevent too great dilution. The buffer value is calculated on the basis of Van Slyke (1922) as the ratio $\frac{dB}{dpH}$. A solution has a buffer value of 1 when 1 litre will take up 1 gram-equivalent of strong acid or base per unit change in pH. Table XVII gives the pH readings for some of the samples, and also the buffer value for selected samples of natural moisture. All readings are of duplicates within 0.04 in pH.

Table XVII

The Influence of Heat Treatment on the Hydrogen-ion Concentration and Buffer Value of Wheat Germ

Treatment Temp.	Time	Hydrogen-ion Concentration (in pH) Low Moist.	Nat. Moist.	High Moist.	Buffer Value (Nat. Moisture)
Control		6.47	6.32	6.43	10.00×10^{-3}
170°F	2	6.42	6.23	6.10	10.50×10^{-3}
170	6	6.39	6.16	6.25	10.71×10^{-3}
170	10	6.34	6.12	6.04	10.15×10^{-3}
230	3	6.16	6.13	6.04	11.19×10^{-3}

In view of the conflicting nature of the conclusions about the effect of changes in hydrogen-ion concentration in dough, it was decided to run a very brief series of baking tests on two types of germ mixture, using direct acidification with lactic acid. The loaves were mixed on the basis of a 200 gram loaf, and after mixing, the dough was divided into two halves, one of which was fermented and baked, the other used used to make pH readings at the end of the fermentation period. Three fermentation times were used, 1 3/4 hours, 3 hours, and 4 1/4 hours, on two germ mixtures, one being low moisture raw germ, the other a high moisture sample which had been heated at 170°F for 10 hours. They were in the usual 10% mixture with fifth middlings, and the lactic acid was added at the rate of 0, 5, 10, and 15 cc. of $\frac{N}{2}$ lactic acid for each 200 grams of flour. This would correspond to half that amount of acid for each 100 gram loaf that was baked. The hydrogen-ion concentration readings were made electrometrically on the decantate from an intimate mixture of 16 grams of dough with 50 cc. of distilled water.

In Table XVIII are given the results of the baking tests, and the pH readings of the different samples and treatments. They are the figures for single determinations.

It is quite evident from these results that the presence of lactic acid in the concentration used had a distinct effect on the quality of the bread. That this effect is not due solely to the development of a definite pH value may be seen from the low moisture raw germ sample, where there is a pronounced improvement with increased acid in the shorter fermentation, but an equally pronounced degradation with increased acid in the longer fermentation, although the acidity of the two doughs with maximum acid added is not greatly different when measured by electrometric means. It is however evident that increased fermentation and increased acidity work in the same direction in their effect on germ, and that heat treatment also works inthis direction

Table XVIII

The Effect of the Addition of Lactic Acid on the Baking Quality and Hydrogen-ion Concentration of Germ Mixtures

4 1/4 hour Fermentation

Material	Acid Added	Volume in cc.	Crust Color	Symmetry	Texture	Single Figure Estimate	pH at end of Fermentation time
Raw Low	0cc.	586	3.5d	3g	3c	59	5.20
Tr. High	0cc.	672	4.5d	4o	8	95	5.18
Raw Low	5cc.	567	4.5d	2.5g	3c	56	4.99
Tr. High	5cc.	617	4.5d	4o	8	84	4.95
Raw Low	10cc.	482	4.5d	2g	2c	35	4.68
Tr. High	10cc.	523	4.5d	2.5o	5c	54	4.64
Raw Low	15cc.	452	4.5d	1.5g	1.5c	27	4.45
Tr. High	15cc.	462	4.5d	2.5o	5c	41	4.41

3 hour Fermentation

Material	Acid Added	Volume in cc.	Crust Color	Symmetry	Texture	Single Figure Estimate	pH at end of Fermentation time.
Raw Low	0cc.	582	3.5d	3g	3c	58	5.24
Tr. High	0cc.	701	4d	4o	7o	97	5.21
Raw Low	5cc.	562	3.5d	3g	3c	58	5.01
Tr. High	5cc.	647	4.5d	4o	8	90	4.98
Raw Low	10cc.	598	3.5d	3g	3c	62	4.72
Tr. High	10cc.	572	4.5d	3.5o	7o	71	4.70
Raw Low	15cc.	499	3.5d	2g	2c	37	4.51
Tr. High	15cc.	502	4.5d	2.5o	5c	49	4.47

Table XVIII (cont.)

Hour

1 3/4 Fermentation

Material	Acid Added	Volume in cc.	Crust Color	Symmetry	Texture	Single Figure Estimate	pH at end of Fermentation time
Raw Low	0cc.	580	3.5d	2.5g	3c	57	5.20
Tr. High	0cc.	712	4d	4o	7o	99	5.17
Raw Low	5cc.	600	3d	2.5g	3c	60	5.04
Tr. High	5cc.	670	4d	3.5o	7o	90	4.94
Raw Low	10cc.	602	3d	3g	3c	61	4.81
Tr. High	10cc.	546	4d	3o	5c	58	4.79
Raw Low	15cc.	609	3d	3.5g	4c	67	4.56
Tr. High	15cc.	492	4d	3o	5c	47	4.56

3 hour Fermentation

Material	Acid Added	Volume in cc.	Crust Color	Symmetry	Texture	Single Figure Estimate	pH at end of Fermentation time
Vth Midds	0cc.	651	5	5	9	97	4.96
Vth Midds	5cc.	727	5	5	9	113	4.72
Vth Midds	10cc.	630	4p	4o	8	86	4.42
Vth Midds	15cc.	506	3.5p	3o	5c	49	4.18

\# The material used was raw or unheated germ of low moisture and a high moisture germ heated at 170°F. for 10 hours.

(d) Iodine Numbers

The introduction of 10% germ into the middlings flour increased materially the amount of fat in the dough, which might have an important effect on the bread. It is well known that the germ contains a large percentage of a yellow oil, about half of which can be expressed (Ball 1926). The analysis of this wheat oil by Ball (1926) disclosed the fact that it was to a large extent composed of unsaturated glycerides, the iodine number given by Ball being about 123. This compares with DeNegri's (1898) result at 115; Frankfurter and Harding (1899) reported 115; and Alpers (1918) found 122.6 . The effect of this unsaturated oil in the dough is hard to estimate, as little work has been published on the relation of shortening agents to baking. Davis (1921) reported that in a comparative series of tests on sugar cookies, unsaturated fats had not as great shortening power as hydrogenated. A. H. Johnson, in unpublished work, discussed the shortening power of various fats and oils, and concluded that the degree of unsaturation could be taken as a measure of shortening power. Similarly, Saunders, Nichols, and Cowan (1921) found that unsaturated fats gave marked improvement in loaf volume when they were added at the rate of 3% to the usual baking mixture. In view of the marked possibility of oxidation of the wheat oil in the process of heat treatment the iodine numbers were determined for a number of samples of germ, by the method advocated by Wij. Ether extracted fats were used in the determinations, which were made in duplicate. The average results are given in Table XIX

The results are inconclusive. Rechecks on those samples where the value seems out of line, as in the 2 hour high moisture treatment, gave consistent results. There seems to be nothing in the degree of unsaturation of the fats to explain the baking results.

Table XIX

The Effect of Heat Treatment on the Iodine Number of Germ

Treatment Temp.	Time	Material	Iodine Number of Germ Fat
Control		Low Moisture	119.5
"		Nat. Moisture	120.8
"		High Moisture	116.3
170°F	2hr.	Low Moisture	127.5
170	2	Nat. Moisture	116.6
170	2	High Moisture	104.1
170	6	Low Moisture	128.0
170	6	Nat. Moisture	118.2
170	6	High Moisture	119.4
170	10	Low Moisture	130.4
170	10	Nat. Moisture	123.9
170	10	High Moisture	124.1

(e) Lipoids and Lipoid Phosphorus

The studies of Working (1924) and of Sullivan and Near (1927a) on the effect of lipoids in wheat flour indicated that they had an important influence on the quality of the gluten. The term lipoid has been used here in its wider meaning and includes the neutral fats, the fatty acids, the nitrogen and phorphorus containing substituted fats, phytin, the sterols, and coloring matter. From the behaviour of straight grade flours on heat treatment, and with ether extraction, Geddes (1930b) surmised that lipoids such as the phosphatides had been one of the causal factors in the degradation of baking quality due to germ constituents. The similar effect of heat treatment and improvers on the flour-germ mixtures suggested that changes in the phosphatides might be responsible for the variation in baking results which the writer found. The total lipoids were estimated by the method of Sullivan and Near (1927a and 1928) using a hot ammoniacalalcohol extraction, followed by an ether extraction. Care was taken to make sure that the alcohol washed through the material at least six times per hour. The amounts of lipoid material obtained in this way did not show any significant variation, the average of 9 determinations being 12.43% . In the case of the ether extracted material, the determination showed that approximately 4.4% of the dry matter was lipoids, even after the extraction. This corresponded to the work of Sullivan and Near (1928) who found that complete ether extraction left from 10 - 35% of the lipoid material. Similarly, Rask and Phelps (1925) had found with flour that ether extraction left a large proportion of the lipoid material. The high results in the case of our extracted germ were probably due to an incomplete extraction in the method as already described.

The analysis of the lipoids for their phosphorus content provided results which throw light on the cause of the baking scores obtained.. This lipoid phosphoric acid determination was made by the official A.A.C.C. method, using a volumetric procedure for the estimation of the phosphate. The figures for the percentage of lipoid phosphoric acid in the selected germ samples are given in Table XX.

Table XX

The Concentration of Lipoid Phosphoric Acid in Germ of Different Moisture and Heat Treatments

Material	Treatment		% of Lipoid P_2O_5 (dry matter)
Low Moisture	Control		.204%
Nat. Moisture	"		.157%
High Moisture	"		.107%
Low Moist.	170°F	2 hours	.196%
Nat. Moist.	170	2	.121%
High Moist.	170	2	.120%
Low Moist.	170	6	.196%
Nat. Moist.	170	6	.105%
High Moist.	170	6	.109%
Low Moist.	170	10	.188%
Nat. Moist.	170	10	.116%
High Moist.	170	10	.095%
Ether Extrac.	170	2	.188%
Ether Wetted	170	2	.202%
Ether Extrac.	170	6	.194%

The figures show a marked decrease in the amount of lipoid phosphoric acid with either increased moisture, or increased heat treatment, parallel to the deleterious effect of the germ when it is added to middlings flour. Eviently the organic phosphorus compounds are being changed by some chemical action, possibly hydrolysis, into inorganic phosphoric acid derivatives which would not be collected by the lipoid extraction. The formation of these phosphates may be partially responsible for the increased buffer value in the samples of higher heat treatment. The total amount of phosphorus in several representative samples covering both moisture and heat temperature variation was determined by the official A.O.A.C. method for plant products, using the magnesium nitrate oxidation. The value found as the average of six determinations was 2.07% of P_2O_5 , the individual determinations agreeing closely.

On the assumption that the deleterious effect of the germ is due to lipoid phosphorus compounds, the similarity of baking results between the ether extracted and the non-extracted germ may be explained by these figures. The lipoid phosphoric acid is practically the same in correspondingly treated germ, which indicates that the extraction had not removed the phosphorus compounds which presumably are the cause of baking degradation.

(f) Protein Analysis

The proteins of wheat germ are reported by Osborne (1924) to be largely albumins, globulins and proteoses. Osborne and Campbell (1900) obtained no gliadin or glutenin, but a large amount of nucleoproteins. The absence of any gluten prevents any satisfactory test of imbibition or similar phenomena, but the effect of heat treatment on the selected series of germ samples was measured to some extent by the solubility of the proteins in different solutions. The proteins were dissolved in 5% potassium sulphate solution and then the residue extracted with 70% alcohol according to the standard A.A.C.C. method, except that 3 gram samples were used. Fresh 3 gram samples were peptized with 200 cc. of $\frac{N}{2}$ potassium iodide solution by shaking mechanically for 2 hours, then withdrawing an aliquot from the centrifuged suspension. As would be suspected from the work of Gortner Hoffman and Sinclair (1929) this protein extraction was more complete. The total protein in the germ was 25.07% on a 13.5% moisture basis. In Table XXI is given the percentage of protein soluble in these solutions.

Table XXI

Percentage of Salt and Alcohol Soluble Protein

Material	Treatment Temp.	Treatment Time	Protein Soluble in 5% K_2SO_4	70% Alcohol after 5% K_2SO_4	$\frac{N}{2}$ KI
Low Moist.	Control		14.80%	2.86%	19.55%
Nat. Moist	"		15.73%	2.57%	18.75
High Moist	"		15.30%	2.27%	17.96%
Low Moist	170	2	15.48%	2.82%	18.51%
Nat. Moist	170	2	10.59%	2.48%	12.84%
High Moist	170	2	9.16%	2.66%	11.61%
Low Moist	170	6	14.55%	2.75%	17.60%
Nat. Moist	170	6	9.53%	2.64%	11.88%
High Moist	170	6	8.32%	2.40%	10.57%
Low Moist	170	10	13.09%	2.38%	17.00%
Nat. Moist	170	10	7.84%	2.16%	10.52%
High Moist	170	10	7.08%	2.18%	9.54%

The process of denaturation is apparently a function of both moisture and degree of heat treatment. This is in agreement with the observation of Alsberg and Griffing (1927) that heat coagulation of proteins is progressive.

(g) Carbon dioxide Production and Retention

Bailey (1925) suggested that flour strength may be determined by the ratio between the rate of production in and the rate of loss of carbon dioxide from the fermenting mass of dough. A simple means of measuring the production and retention of carbon dioxide has been described by Bailey and Johnson (1924) and this type of apparatus and technique were used in measuring the gas production and retention of several flour samples. The loaf was made in the usual baking proportion on the basis of 25 grams of flour for each sample. All determinations were made in duplicate. The rate of gas production in the different samples of germ mixture showed little variation with the nature of the heat treatment, continuing to rise at first, then the rate of production decreased slowly. The volume of carbon dioxide retained rose to a constant amount, usually in less than three hours. In Table XXII are given the figures for the amounts of carbon dioxide retained in the "loaves" when they have ceased to increase in volume.

Table XXII

The Effect of Heat Treatment, Moisture, and of Potassium Bromate on the Volume of Carbon Dioxide Retained in Fermentation

(a) The Effect of Heating Natural Moisture Germ at 170°F

Time	Volume of Gas Retained
Control	101.5 cc.
2 hours	105.5 cc.
6 hours	106 cc.
10 hours	107 cc.

Table XXIII (cont.)

(b) The Effect of Moisture on a Sample Heated at 170°F for 2 Hrs.

Moisture Content	Volume of Gas Retained
Low Moisture	101.5 cc.
Nat. Moisture	105.5 6c.
High Moisture	113.8 cc.

(c) The Effect of $KBrO_3$

Material and Treatment	Volume of Gas Retained Standard Proc.	Bromate Proc.
Low Moisture Raw Germ	100.5 cc.	107.0 cc.
Nat. Moisture Raw Germ	101.5 cc.	107.8 cc.
High Moisture Germ, Heated at 170°F for 6 hours	115.0 cc.	105.0 cc.

The very close correlation between these figures and the baking results indicated that the variation in baking scores was due more to the effect of the germ on the gas-retentive power of the dough rather than to any deficiency in gas production.

The presence of potassium bromate caused a sufficient change in the loaf volume that it was determined to see whether it had any effect on the rate of gas production in germ mixtures. In order to make any possible difference more evident, the following method was used. A mixture of 40 cc. of a $\frac{M}{2.5}$ phosphate-phthalate buffer at a pH= 6.0, 40 cc. of a solution 6% in sucrose and 1% in salt, 20 cc. of a yeast suspension made with 12 g. of yeast per 100 cc. of suspension, and 10 grams of raw germ of low moisture, was placed in a 300 cc. Erlenmeyer flask,: another mixture was made similar to the first except that it contained

0.001 gram of potassium bromate in addition to the other ingredients. The flasks were closed with single-holed rubber stoppers, through which a tube led to a 100 cc. gas burette which was placed in a cylinder of saturated salt solution. By raising or lowering the outer cylinder atmospheric pressure could be maintained in the system from flask to burette. A side tube on the burette allowed the escape of gas without removing any stoppers or connections. The two flasks were agitated mechanically in a 30°C. constant temperature bath during the course of five hours, readings of the gas volume being taken every half hour. These are given in Table XXIV

Table XXIV

Volume of Gas Produced by Yeast in a Sugar and Raw Germ Suspension, with and without $KBrO_3$

Time (inhours)	Volume of Gas Liberated Without Bromate	With Bromate
0	0 cc.	0 cc.
0.5	47.4 cc.	41.0 cc.
1.0	115.2 cc.	108.0 cc.
1.5	203.4 cc.	194.0 cc.
2.0	292.2 cc.	289.0 cc.
2.5	407.2 cc.	408.0 cc.
3.0	541.8 cc.	540.2 cc.
3.5	693.6 cc.	693.6 cc.
4.0	802.9 cc.	803.0 cc.
4.5	824.2 cc.	827.2 cc.
5.0	856.4 cc.	837.2 cc.

From these figures, which would show any change more easily than than the usual gas production data, it seems evident that potassium bromate causes a very slight diminution in the rate of production of gas in the earlier stages, but in the last part of the run, there is no appreciable difference. A similar determination of the amount of gas formed during fermentation was made on samples of these same solutions but without the germ present, and the same reduced rate of gas production in the bromate flask was noted. At the end of two hours, the lag due to bromate had disappeared. The effect of bromate on bread seems to be due not to its effect on gas production, but to its effect on retention. The increased acidity found by some investigators in dough containing potassium bromate may be due to more retained carbon dioxide.

Summary and Tentative Conclusions

The baking results on a series of samples of wheat germ at different moisture levels heated for different lengths of time at 170°F and at different temperatures for three hours, then mixed in 10% strength with fifth middlings flour, show,

(1) The samples of germ which had been kept at higher moisture levels had much less deleterious effect on the baking quality of the fifth middlings flour, the sample of germ at 17% moisture baking into a loaf about 56% greater in single figure estimate than the corresponding raw germ which had only 7.5% moisture.

(2) Heat treatment improves the baking quality of the germ, the improvement depending on the temperature and the time of treatment. In general, germ brought to a higher moisture content before its heat treatment will have its optimum treatment at a lower temperature or for a shorter time than if the material contained less moisture. Due to the non-linear variation of the heat effect with time or temperature, it is impossible to make any comparison between the relative effects of these two variables.

(3) Ether extraction, in the manner described, had a very slight deleterious effect on the baking quality. As the amount of lipoid phosphorus showed practically no change during extraction, the bulk of the extracted

lipoid must have been neutral fats and fatty acids. When these fats are present, the bread is improved in quality and volume.

(4) Wetting with ether made a very slight improvement in the volume and texture of the bread, possibly due to the slightly higher moisture content of the wetted germ as compared to the control.

(5) The effect of several flour "improvers" on germ mixtures was not proportional to their oxidizing power, but seemed to be a specific effect of the salt used.

(6) Increased acidity due to the addition of lactic acid, shortened the optimum fermentation time, especially when the germ had been previously subjected to heat treatment. The effect does not seem to be due solely to the development of an optimum pH.

(7) The chief chemical changes noticed in the pure germ due to its different treatments were a decrease in the amount of lipoid phosphorus, and in the state of aggregation of the proteins. The differences in lipoid phosphorus would probably be due to the destruction of phosphatides or phytin, the chief organic phosphorus compounds in wheat, possibly by hydrolysis. The writer has been unable to find any published report of the effect of phytin on flour strength, and this point should be given further attention. From the nature of the evidence gathered by other workers, it seems evident that the chief effect of phosphatides is on the colloidal structure of the gluten strands. The introduction of germ to a

fifth middlings flour adds these deleterious substances which prevent the development of the natural strength of the dough. The various methods of improvement of such a loaf, (1) allowing the germ to stand in storage at higher moisture levels, (2) heat treatment, (3) the use of longer fermentation times, (4) the use of increased acidity, or (5) the addition of chemical improvers like potassium bromate, must either remove the harmful phosphorus compounds or have such a beneficial effect on the other constituents of the dough that the harmful effect is masked by a concurrent improvement. The very pronounced moisture effect in reducing the amount of lipoid phosphorus suggests that hydrolysis is the probable method of phosphatide or phytin removal, liberating fats, fatty acids, alcohols, inositol, and phosphoric acid. The latter would readily form salts with the mineral constituents. In a private communication to the author, Mr. A. W. Alcock # reported the result of several experiments he had made with sponge doughs, mixing his germ and middlings flour separately. The presence of potassium bromate mixed with the middlings flour gave a much better loaf than when the bromate was allowed to stand in contact with the germ. This evidence, together with the fact that potassium bromate causes such a marked effect on the loaves made

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with a high moisture germ, strongly heated, (which should consequently have a low phosphatide or phytin content) would indicate that the effect of potassium bromate is directly on the colloidal nature of the gluten proteins, and the effect which it has on loaves baked with phosphatides present is concurrent with the effect of those substances rather than directly on them.

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