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AGRICULTURAL EXPERIMENT STATION.

KANSAS STATE AGRICULTURAL COLLEGE.

The Milling and Baking Quality and Chemical Composition of Wheat and Flour as Influenced by

1. Different methods of handling and storing.
2. Heat and moisture.
3. Germination.

MANHATTAN, KANSAS.

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MANHATTAN, KAN., January 10, 1916.

The experiments reported in this bulletin were carried out in cooperation between the departments of chemistry and milling industry. They cover work done during the summers of 1911 and 1912. L. A. Fitz and C. O. Swanson planned and directed the work. The chemical determinations were made by John W. Calvin, formerly assistant chemist at this station, and Miss Leila Dunton. The milling and baking tests were made by Miss Dunton. The bulletin was prepared by C. O. Swanson, with the cooperation of L. A. Fitz and Miss Dunton.

W. M. JARDINE, *Director*.

Historical Document
Kansas Agricultural Experiment Station

SUMMARY.

The experiments reported in this bulletin are along three general lines: (1) To determine the effects of different methods of harvesting, stacking, and storing wheat; (2) to determine the aging effect of tempering with moisture and heat; (3) to determine the effect of germination on the wheat and on the flour.

The results of the experiments show the general methods which should be the guide in harvesting, stacking, and storing, in order to secure wheat and flour of good milling and baking quality.

The results show that it is entirely possible to treat new wheat; with moisture and heat and bring about an improvement in the milling quality similar to the natural aging of the wheat. The results of the experiments on heating wheat show that the degree of heat used for destroying mill and stored-grain insects does not in any way injure the wheat or the flour.

The results with germinated wheat show that the claims made in regard to the damage upon the milling and baking quality of wheat and flour from such wheat, when mixed with sound wheat, have been much exaggerated. Germination in. jures the milling quality of the wheat in that the flour yield is less and the flour is likely to have an inferior color. The injury is in proportion to the amount of germination. The gluten of flour from germinated wheat is weaker than the gluten from flour of sound wheat. A small amount of flour from germinated new wheat when mixed with flour from sound wheat has little or no deleterious effect on the baking qualities of the mixed flour when the same general methods of baking are followed as were used in these tests.

Historical Document
Kansas Agricultural Experiment Station

TABLE OF CONTENTS.

Historical Document
Kansas Agricultural Experiment Station

TABLES.

Historical Document
Kansas Agricultural Experiment Station

Historical Document
Kansas Agricultural Experiment Station

OBJECT OF EXPERIMENTS.

The object of these investigations was to ascertain the effect of the following factors on the milling quality of wheat and the baking quality of flour, and also on the chemical composition of wheat and flour: (1) methods of harvesting, stacking, and storing wheat; (2) heat and moisture as agents in treating new wheat so that it shall have the quality of old wheat; (3) germination of new wheat.

GENERAL PLAN.

In 1911 it was planned to make a particular study of the so-called "sweating" process in order to determine, if possible, just what changes take place during this process. This part of the plan had to be modified on account of the character of the season. The effect of adding different amounts of water to wheat and heating at different temperatures for different lengths of time was studied and the results were compared with the natural aging of the wheat in shock, stack, and bin. The results show that it is possible by means of heat and moisture to bring about, to a certain extent, the same effects that are brought about by aging in the stack or bin. These experiments are entirely of a preliminary nature and further studies are needed to corroborate the results and determine more closely the conditions.

Further study was also made of the effects of germination on the milling and baking of wheat and its chemical composition. The results corroborate those reported in Bulletin 177, and additional data were secured.

All these tests were made on the same original lot of wheat. A ten-acre field of fairly uniform character was obtained. One acre was cut at the beginning of the hard-dough stage, one when the wheat was dead ripe, and the rest when the wheat was in prime condition. As soon as the wheat was dry, a few bushels were threshed from the early and from the late cuttings, and thirty-five bushels from that cut in prime condition. Samples of the wheat from the three cuttings were taken to

Historical Document
Kansas Agricultural Experiment Station

the laboratory for immediate milling, baking and chemical tests. The wheat cut in prime condition was used for the study of the effect of germination, the process of sweating in the bin and for treatments with heat and water. The larger part of the ten-acre field was stacked. One acre was allowed to stand in the shock.

It was originally intended to have the wheat in the field undergo damage to different degrees by exposure to rain, but the climatic conditions were such that this part of the experiment could not be carried out.

The investigations during 1912 were a continuation of the work of the previous year. Additional data were sought on the effect of storing under different moisture conditions, effect of germination, and treatment with moisture and heat. All experiments for the year 1912 were made on the same lot of wheat. It proved impracticable to secure the coöperation of a farmer to get data on handling the wheat in the field by different methods of harvesting and stacking. Wheat from the same field used in the 1911 experiments was threshed from the shock and this was used in all of the tests.

Historical Document
Kansas Agricultural Experiment Station

EXPERIMENTS TO DETERMINE THE EFFECTS OF DIFFERENT METHODS OF HARVESTING, STACKING, AND STORING.

TEMPERATURE AND MOISTURE OBSERVATIONS MADE ON, THE STACKED WHEAT (1911).

The summer of 1911 was unusually hot and dry. Only 7.15 inches of rain fell from the first of March to the first of August. The temperature remained abnormally high during the whole summer. No rain fell from the time of cutting until the wheat was threshed and it was very dry when stacked. Five electrical resistance thermometers were installed in different parts of the stack. Readings were taken in the early forenoon for six consecutive weeks. The complete record is given in table I.

TABLE I. Temperature record of a stack of wheat, June 30 to August 15, 1911.

POSITION OF THERMOMETER[3]

No. 52. Outside tier, north side, six feat from ground.
No. 106. Center of stack three feet from top.
No. 311. West of center,seven feet from ground.
No. 324. Bottom of stack, in center
No. 325. East of center, eight feet from ground.

TEMPERATURE READINGS.

DATE, 1911.	Hour.	Therm. No. 52.	Therm. No. 106.	Therm. No. 311.	Therm. No. 324.	Therm. No. 325.	Temp. air at stack.
		Deg. F.	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
June 30	11:45 a. m.	95	98	92	87	92	....
July 3	9:00 a. m.	86	96	90	89	94	....
July 4	8:15 p. m.	93	103	96	93	97	....
July 5	9:30 a. m.	88.5	99.5	95	89	95	94
July 7	9:30 a. m.	86	91.5	94	91.5	93	85.5
July 9	9:30 a. m.	88	85	92	90.5	89	78
July 11	9:15 a. m.	88	86.5	91	90	90	89
July 13	9:15 a. m.	79.5	78	87.5	85.5	81	79
July 15	9:30 a. m.	74	79	82	80.5	80	83.5
July 18	10:00 a. m.	71	75	80	81	78	74.5
July 20	8:45 a. m.	76.5	80	85	82.5	81	76
July 22	9:00 a. m.	79	80	85	83	84	86
July 24	9:30 a. m.	66	66	67	70	70	68.5
July 26	9:15 a. m.	73	75	73	72	71	79
July 30	9:30 a. m.	84	84	85.5	82.5	83.5	82
August 1	8:50 a. m.	80	78	79	80	79	74
August 3	9:30 a. m.	78	75	73	78	82	71
August 5	10:00 a. m.	80	80	81	79	86	80
August 7	9:30 a. m.	84	82.5	86	84	86.5	86.5
August 9	8:45 a. m.	82.5	81	83.5	87	86.5	85.5
August 11	8:50 a. m.	82	83	82	81	83.5	78
August 13	8:50 a. m.	80	89.5	85.5	84.5	87.5	85
August 15	8:40 a. m.	81	91	83.5	81	87	85

The phenomena which are usually associated with sweating did not occur. There was no increase in temperature, and apparently no increase in moisture, judging by observation. That there actually was an increase in moisture was shown by chemical analysis. At the time of stacking some heads

Historical Document
Kansas Agricultural Experiment Station

were taken and placed in sealed tin cans. These were then taken to the laboratory, weighed and then thoroughly dried. The moisture content of these heads at the time of stacking was 8.50 percent. The moisture. content of the wheat after being in the stack six weeks, or at the time the temperature observations. ceased to be taken, was 12.4 percent. This increase in moisture content was not apparent to the sense of touch. The temperature records of the stack vary so much more in accordance with the temperature changes of the atmosphere that any temperature change resulting from the sweating process is entirely obscured.

TEMPERATURE AND MOISTURE OBSERVATIONS MADE ON WHEAT STORED IN A TIGHT BIN.

Of the wheat cut in prime condition about twenty bushels were stored in a tight bin made for the purpose. The bin was in a northwest room of a large stone building. The extreme dryness caused cracks in the bin. In this wheat were placed two electrical resistance thermometers, the readings from which are recorded in table II.

TABLE II. Temperature record of wheat stored in a tight bin. Wheat placed in bin July 6, 1911.

DATE, 1911.	Time.	Thermometer No. 109, West center.	Thermometer No. 203, East center.	Temperature of room.
		Deg. F.	*Deg. F.*	*Deg. F.*
July 7	10:00 a. m	93	93	98
July 8	8:30 a. m	92.5	92.5	98
July 9	8:30 a. m	93	93	....
July 10	8:30 a. m	93	92.5	96
July 11	10:00 a. m	92.5	92.5	96
July 12	8:30 a. m.	93	93	95
July 13	9:30 a. m.	92.5	92.5	92
July 14	10:00 a. m.	92	92	90
July 15	10:00 a. m.	92.5	92.5	92
July 17	10:00 a. m.	87	87	86
July 18	11:00 a. m.	86.5	86.5	84
July 19	1:00 p. m.	86	86	84
July 20	10:00 a. m.	84.5	84.5	84.5
July 21	10:00 a. m.	82.5	82.5	86
July 22	10:00 a. m.	82	82	88
July 24	10:00 a. m.	82	82	86
July 26	10:00 a. m.	81	81	83
July 31	10:00 a. m.	82	82	89
August 2	4:00 p. m.	82	82	88
August 4	10:00 a. m.	82	82	86
August 5	11:00 a. m.	83	83	87
August 7	3:00 p. m.	82	82	89
August 9	10:00 a. m.	82.5	82.5	90
August 11	10:00 a. m.	84	84	94
August 14	4:00 p. m.	87	87	94
August 17	11:00 a. m.	88	88	93
August 21	10:00 a. m.	88	88	90
August 23	10:00 a. m.	86.5	86.5	83

There was no manifestation that the wheat underwent any sweating process, and what was said of the changes in temperture of the stack can be said of the wheat in the bin. The moisture content of the wheat when put into the bin was 7.73

Historical Document
Kansas Agricultural Experiment Station

percent; when taken from the bin the wheat showed moisture content of 7.9 percent. This determination was made on the unground wheat, and as it is difficult to drive off all the moisture from unground grain these percentages are probably a little low. The determinations on the ground wheat, given further on, are a little higher, but a slight absorption of moisture during grinding is also possible. It is safe to conclude that there was no material increase in moisture content while the wheat was stored in the bin. The opposite was true of the wheat in the shock and stack. The moisture content of the wheat standing in the shock was 13 percent, and that in the stack was 12.4 percent at the time of threshing.

TEMPERATURE OBSERVATIONS ON WHEAT WITH WATER ADDED AT TIME OF STORAGE.

After the wheat cut in prime condition had been in the bin for ten weeks it was moistened with water sufficient to increase its moisture content to 15.2 percent. It was then placed in a bin in the greenhouse. The temperature readings were taken, the records of which are given in table III.

TABLE III. Temperature record of wheat after increasing its moisture content from 9.69 to 15.2 percent.

DATE, 1911.	Time.	Thermometer No. 109.	Thermometer No. 203.	Temperature of room.
		Deg. F.	*Deg. F.*	*Deg. F.*
September 12	4:30 p. m.	[illegible]	[illegible]	....
September 14	8:15 a. m.	98	98	....
September 15	8:15 a. m.	96	96	....
September 16	8:15 a. m.	90.5	90.7	72
September 17	9:30 a. m.	86.5	86.7	84
September 18	8:15 a. m.	85.5	85.5	66
September 19	8:15 a. m.	82	82	61
September 20	10:00 a. m.	78	78.5	63
September 22	8:15 a. m.	74	74	66
September 23	8:15 a. m.	74	74	75
September 25	8:15 a. m.	72	72	72
September 26	1:00 p. m.	73.5	73.5	90
September 27	8:15 a. m.	73.5	73.6	78
September 28	8:15 a. m.	76	76	79

The conditions for taking the readings were such that the heat changes in the room obscured any changes that may have resulted on account of the added water. The moisture content of the wheat at the end of the observation period was 13.74 percent, a decrease of 1.46 percent.

CHEMICAL ANALYSIS OF WHEAT SUBJECTED TO DIFFERENT TREATMENTS IN HARVESTING, STACKING AND STORING.

The chemical analysis of these wheats handled as previously described are recorded in Table IV.

Historical Document
Kansas Agricultural Experiment Station

TABLE IV. Chemical analysis of wheat subjected to different treatments in harvesting, stacking and storing.

Serial number.	TREATMENT.	Moisture.	Moisture-free basis.					
			Ash.	Protein.	Amino compounds.	Acidity.	Water-soluble phosphorus.	Total phosphorus.
418	Cut in prime condition	9.69	2.19	11.50	.414	.554	.235	.506
419	Cut under-ripe	9.33	2.33	12.88	.463	.596	.245	.545
420	Cut over-ripe	9.54	2.17	11.62	.381	.624	.232	.514
471	No. 418 stacked five weeks	11.63	2.22	11.52	.453	.627	.258	.515
472	No. 418 shocked five weeks	12.49	2.16	11.11	.469	.578	.255	.507
473	No. 418 stored in bin ten weeks	9.65	2.15	11.42	.375	.499	.237	.498
475	No. 418 moistened and stored ten weeks	13.54	2.19	11.49	.479	.573	.263	.515

Historical Document
Kansas Agricultural Experiment Station

The moisture determinations were made on the ground samples. Undoubtedly some moisture was taken up during the grinding process. Subsequent absorption was prevented by storing in sealed bottles. The percentages of the chemical constituents for the moisture-free substance were calculated on the basis of these moisture determinations.

The variations in chemical composition are too small and the samples too few for any definite conclusions. These figures merely indicate tendencies which need further investigation. The wheat cut under-ripe was highest in ash and protein content. As the wheat ripens ash assimilation decreases and the carbohydrate formation is so much more rapid than the protein formation that the percent of protein becomes less, although there is no decrease in the total amount of protein. The percentage of amino compounds decreased as the wheat ripened. The decrease of these compounds in the stored wheat is probably due to a continuance of the physiological process of ripening. The acidity increased, on the whole, as the wheat ripened, but it was least in the stored grain. The changes in the water-soluble and total phosphorus were too small to show any definite tendency.

Milling Tests of Wheat Subjected to Different Treatments in Harvesting, Stacking and Storing.

The milling tests on these wheats were made as soon as they were threshed or at the end of each treatment. The results are given in table V.

The data separately considered do not show very much, but when they are studied in connection with the data secured in the baking and the chemical tests valuable information is obtained. The amount of tempering water used should be noted. To the three samples threshed and milled immediately after harvesting, 3 percent of water was added. This comparatively large amount would not bring this wheat to the normal moisture content. The 1.6 percent added to the wheat threshed and milled later was sufficient to bring it to a normal moisture content. It is very probable that the wheat threshed and milled immediately after harvesting should have had a larger amount of tempering water added. This should have been added in installments and in such amounts as to bring the wheat to the normal moisture content.

Historical Document
Kansas Agricultural Experiment Station

TABLE V. Milling tests of wheat subjected to different treatments in harvesting, stacking and storing.

Serial number.	TREATMENT.	Weight milled, grams.	Tempering water, cc.	Loss in scouring, percent.	Loss in milling, percent.	Feed, percent.	Total flour, percent.	First-grade flour, percent.	Second-grade flour, percent.
418	Cut in prime condition	2,500	75	4.76	....	....	75.92	88.14	11.86
419	Cut under-ripe	2,500	75	1.84	....	....	73.72	89.53	10.47
420	Cut over-ripe	2,500	75	2.00	0.96 gain	21.32	77.64	85.42	14.58
471	No. 418 stacked five weeks	2,500	40	0.84	2.12	26.40	70.64	93.26	6.74
472	No. 418 shocked five weeks	2,500	40	0.80	0.56	25.00	73.64	91.20	8.80
473	No. 418 stored in bin ten weeks	2,500	40	1.04	0.20	22.96	75.80	87.02	12.98
475	No. 418 moistened and stored ten weeks	2,500	0	1.04	3.44	23.64	71.88	91.71	8.29

Historical Document
Kansas Agricultural Experiment Station

Chemical Analysis of the Flours from Wheat Subjected to Different Treatments in Harvesting, Stacking and Storing.

Moisture Content. Only the straight flours from these wheats were analyzed. The results are found in table VI. The moisture content from the wheats threshed and milled immediately after harvesting is much lower than from those threshed later from the shock and the stack. There is no doubt that the better milling qualities of the wheat which had been stacked are in part at least due to increased moisture content. The ash content of the flours from the wheat which had been stacked and from the wheat which had stood in the shock was much lower than that of those threshed immediately after harvesting. The drier condition of the latter caused a pulverization of the bran. It is evidently poor practice to mill wheat much below the normal moisture content. It is very difficult to temper such wheat sufficiently with one application of water to make it ready for the rolls. It would be better to add enough water to bring it up to the normal moisture content and store it in the bin for awhile. Then when it is milled it should receive the usual amount of tempering water.

Protein Content. The protein content varies approximately as the content of dry gluten. In view of the crude way in which the dry gluten must be determined, the close agreement is remarkable. The protein in gluten was determined on the dry sample. In these samples the dry gluten contains from 82.09 to 85.99 percent pure protein. Most of the material other than protein consists of such substances as fiber, ash and starch, which it is impossible to remove from the gluten in the process of washing. The pure gluten is calculated by multiplying the percentage of nitrogen in the crude gluten by 5.7.

Gluten Quality. The following notes on the gluten obtained from these flours were made at the time of the determination. Gluten from No. 418, the wheat cut in prime condition, was of a grayish-yellow color and somewhat harder than that which is usually considered the very best. The gluten from No. 419, the wheat cut green, did not have the gray tint of No. 418, but was yellow and much softer. No. 420, the wheat cut overripe, had a gluten darker and harder than No. 418. Gluten from No. 471, the wheat from the stack, was of excellent quality, much improved over No. 418. It was softer, more

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Kansas Agricultural Experiment Station

TABLE VI. Chemical analysis of flours.

Serial number.	TREATMENT.	Moisture-free basis. Percentages.												
		Moisture.	Ash.	Protein.	Protein in gluten.	Dry.	Gluten Pure.	Wet.	Sugar.	Acidity.	Amino compounds.	Water-soluble phosphorus.	Total phosphorus.	Percent H_2O soluble phosphorus in total.
418	Cut in prime condition........	11.17	0.63	9.99	84.46	9.79	8.27	28.29	2.23	0.180	0.145	0.068	0.144	47.22
419	Cut under-ripe..............	10.92	0.76	11.67	85.39	11.05	9.44	34.11	2.04	0.220	0.190	0.090	0.178	50.56
420	Cut over-ripe...............	10.78	0.74	10.08	83.63	9.97	8.34	29.34	1.90	0.185	0.125	0.073	0.153	47.71
471	No. 418 stacked five weeks....	13.55	0.54	9.91	82.09	9.94	8.16	30.63	2.16	0.166	0.147	0.053	0.134	39.35
472	No. 418 shocked five weeks....	13.86	0.52	9.34	84.42	9.51	8.03	30.28	2.11	0.146	0.174	0.046	0.122	37.70
473	No. 418 stored in bin ten weeks,	11.75	0.65	10.04	84.43	9.80	8.27	32.06	2.10	0.189	0.170	0.067	0.152	44.07
475	No. 418 moistened and stored ten weeks.................	13.71	0.65	10.62	83.59	10.19	8.52	33.41	1.88	0.156	0.200	0.053	0.132	40.15

Historical Document
Kansas Agricultural Experiment Station

elastic and of a clear yellow color. Gluten from No. 473, the wheat stored in thebin, was very much like that from No. 471. Thus as far as the improvement in gluten goes, the storing in the bin was not much different from that in the stack. However this was a very dry season and the results in a wet season might be different. Gluten from No. 472; the wheat standing in the shock, was very similar to that from Nos. 471 and 473 in color, but was a little harder and less elastic. Gluten from No. 475 was harder than that from No. 472 and somewhat more gray. From this it seems that the wheat undergoes a ripening or maturing process when it is properly stored after cutting. This may be either in the stack or the bin.

That the quantity of gluten is less important than the quality is seen by a comparison of the figures on protein and gluten content and the notes on gluten. The better quality is frequently found in connection with less quantity. The wet gluten averages a little more than three times the amount of the dry gluten.

SOLUBLE CARBOHYDRATE CONTENT. Under the term sugars are included all the water-soluble carbohydrates. The methods used for the determination of soluble carbohydrates are such that small differences obtained do not point to any definite conclusions unless these occur in a regular order. The amylases present in the wheat are so active that they may easily increase the amount of soluble carbohydrates during the process of extraction. This subject needs further study.

ACIDITY, AMINO COMPOUNDS, AND PHOSPHORUS. The acidity value was lowest in the flours from wheats which had been in the stack or the shock and in the shock-threshed wheat that was moistened when stored. The percentages of acidity, amino compounds, and water-soluble phosphorus* were low in those flours where the ash was low, and high where the ash was high. The water-soluble phosphorus varies as the acidity, and undoubtedly the degree of acidity is determined by the amount of water-soluble phosphorus. The amount of water-soluble phosphorus depends somewhat on the amount of total phosphorus, but not altogether, as may be seen from the figures

* By water-soluble phosphorus is meant the phosphorus in such compounds as will pass through a filter paper. The determination of this phosphorus is made with the same solution as is used for the determination of acidity. A portion of the flour is shaken up with water and after standing the required time, is filtered. The phosphorus in this filtrate is called water-soluble phosphorus. Whether this is in the form of a phosphate or in organic form was not determined.

Historical Document
Kansas Agricultural Experiment Station

in the last column. The percentage of phosphorus which is soluble is least in the samples of flours from the wheats which had acquired a normal moisture content. The amino compounds are highest in the flour from the wheat stored and moistened. That these variations in acidity, soluble phosphorus, and amino compounds are more pronounced in the flours than in the wheats from which the flours were milled, is seen from the composition of these wheats given in table IV. The wheats themselves varied comparatively little in these respects. It seems, therefore, safe to conclude that the wheats which had been so handled that they were better fitted for milling produced flours which contained smaller percentages of undesirable constitutents which tend to lower the grade of flour. This is brought out more strongly by a comparison of the ash figures. It was shown in Bulletin 202 that the amount of water-soluble phosphorus varies as the total ash and that the acidity is influenced more by the percentage of water-soluble phosphorus than by any other constituent.

This points to a profitable line of investigation. What is the proper moisture content of wheat for good milling? How does this differ for different wheats? Should each type of wheat have a definite percent of moisture in order to mill to best advantage? If the wheat is below normal moisture content, should sufficient water be added to secure normal moisture content and the wheat again stored until ready to mill and the proper amount of tempering then given? Likewise, if the wheat contains too much moisture, should it be dried and then stored? How do the various types of wheat differ in these respects?

Baking Tests of the Flours

The results of the baking tests are found in table VII. The photographs of the loaves are found in plates I and II. No. 418 was baked thirteen weeks after milling. At this time the flour gave the best test. The variation in time of rising showed no correlation with the treatments. The maximum expansion of the dough and the rise in the oven were distinctly influenced by the method of treatment before milling. In the tests on the flours from new wheat the total expansion of the dough and the rise in the oven were distinctly less than when the wheat was older at the time of milling. That the same improvement

Historical Document
Kansas Agricultural Experiment Station

TABLE VII. Baking tests of the flours.

Serial number.	TREATMENT OF WHEAT.	Percentage moisture.	Percentage absorption.	Water for loaf, cc.	Time for proving, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams.	Loss in baking and cooling, grams.	Weight of loaf, grams.	Volume of loaf, cc.	Texture of crumb. 100=Perfection.	Color of loaf. 100=Perfection.
					1st rise.	2d rise.	3d rise.	Total.								
418	Cut in prime condition	11.17	55	187	50	70	35	155	2,100	1.5	7	59	496	1,520	83	89
419	Cut under-ripe	10.92	55	187	47	67	31	155	1,950	1.4	7	56	499	1,510	83	87
420	Cut over-ripe	10.78	55	187	55	65	36	156	2,000	1.6	10	53	499	1,550	85	90
418	Baked thirteen weeks after milling	....	60	204	80	115	50	245	2,450	3.8	2	58	519	1,820	99	95
471	No. 418 stacked five weeks	13.55	55	187	84	111	50	245	2,350	3.6	1	60	503	1,800	98	95
472	No. 418 shocked five weeks	13.86	55	187	100	117	60	277	2,200	3.0	0	53	509	1,740	98	95
473	No. 418 stored in bin ten weeks	11.75	56.6	192	82	98	47	227	2,100	2.0	6	50	511	1,640	97	95
475	No. 418 moistened and stored ten weeks	13 71	55	187	81	92	47	220	2,200	2.5	2	53	507	1,710	97	95

Historical Document
Kansas Agricultural Experiment Station

occurs in the flour also is seen from the results obtained on No. 418, baked thirteen weeks after milling.

The volume and color of loaf as well as the texture of crumb showed the influence of treatment previous to milling. These results are so distinct that they can in no way be accidental. As far as these results go, the wheat aged in the shock or in the stack shows a greater improvement than that stored in the bin. The greatest improvement was in the flour stored for thirteen weeks, but the longer time partially accounts for this. The improvement is not only in loaf volume but also in texture and color as well.

The loaves from flour from new wheat had a heavy, close, undesirable texture. This disappeared with the aging of the wheat and the flour. The lesser improvement shown for the dry wheat stored in the bin is no doubt due to the unfavorable conditions. Had this wheat been brought to a normal moisture content before being placed in the bin it is probable that the results would have shown as great improvement as the wheat from the stack and the shock.

FURTHER EXPERIMENTS TO DETERMINE THE EFFECT OF DIFFERENT CONDITIONS OF STORAGE (1912).

Because of the extremely low moisture content of the wheat used in these investigations in 1911 it was determined to secure a new supply from the same field in 1912 and try the effect of adding moisture, before storing, to this wheat threshed from the shock, with the view of producing suitable conditions for sweating.

METHOD OF CONDUCTING THE STORAGE EXPERIMENTS.

For the storage experiments, a tight bin holding about twenty bushels of shock-threshed wheat was placed in the attic of Agricultural Hall. It was desired to have this in a warm place where sweating of the wheat would occur. A wheat sampler was inserted in this wheat and a thermometer placed inside. From time to time this thermometer was compared with one in the room. The two thermometers were previously tested to see if the readings agreed. The temperatures of the wheat in the box apparently fluctuated with that

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Kansas Agricultural Experiment Station

in the room, but there was no increase that could be traced to any change in the wheat so far as could be detected by the methods used. No moistening of the wheat, such as accompanies sweating, could be observed. The only inference that could be drawn was that, if the wheat underwent any change, it did so without any such phenomena as usually accompany the sweating process.

Wheat was also stored after adding various amounts of water to differents lots. Two sets were used, five lots in each set. To lot 1, no water was added; to lot 2, enough water was added to make the moisture content 12 percent; to lot 3, 13.5 percent; to lot 4, 15 percent, and to lot 5, 16.5 percent. Each of these lots of wheat was placed in a two-bushel galvanized iron can having a close-fitting cover. A thermometer was placed in each can. These cans were then stored in large boxes and covered with sawdust and shavings. One set of five cans was placed on the ground floor of a stone building and the other set was placed in an attic. The thermometers were read from time to time. There was no increase in the temperature in any of the wheat, so far as could be detected by the methods used. After a while, however, the wheat having 15 and 16.5 percent of moisture began to be moldy and the growth of mold was greater in the set placed in the attic.

ANALYSIS OF WHEAT STORED UNDER DIFFERENT CONDITIONS, AND OF THE RESULTING FLOURS.

After these wheats had been stored nearly three weeks they were milled. The wheat was analyzed for moisture, acidity and soluble carbohydrates and the flour was analyzed for moisture. The data are presented in table VIII. The results from the wheat stored in the twenty-bushel bin are also included.

The moisture content of the flour showed very little relation to the amount of water which had been added to the wheat. The amount of water used in tempering partly accounts for this, since to the samples which had received little or no water before storing, more was added in tempering, while to those which had received the larger amounts of water none was added. The wheat itself does not show the amount of moisture which would be expected. Wheat gains or loses moisture depending upon the relation of its moisture content

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Kansas Agricultural Experiment Station

TABLE VIII. Analysis of wheat stored under different conditions and percentage of moisture in the resulting flour.

Serial No.	Amount of water added.	Conditions of storage.	Wheat.			Moisture in flour.
			Acidity.	Soluble carbo-hydrates.	Moisture.	
513	0	Bin in attic..........................	0.42	2.70	12.00	12.66
514	0	2-bushel container in attic.............	0.42	2.67	12.13	12.73
515	1	2-bushel container in attic.............	0.42	2.67	12.69	13.09
516	2.5	2-bushel container in attic.............	0.43	2.75	12.53	12.60
517	4	2-bushel container in attic.............	0.42	2.75	11.84	12.47
518	5.5	2-bushel container in attic.............	0.40	....	12.38	12.98
519	0	2-bushel container on ground floor.......	0.40	2.75	12.36	12.71
520	1	2-bushel container on ground floor.......	0.46	2.66	12.58	12.93
521	2.5	2-bushel container on ground floor.......	0.46	2.73	13.61	12.19
522	4	2-bushel container on ground floor.......	0.45	2.70	13.72	11.91
523	5.5	2-bushel container on ground floor.......	0.39	2.61	14.73	12.48

to that of the air. It appears that some moisture at least had escaped from the wheat in the cans, as these were not air-tight. This may explain why no heating was observed.

The acidity shows no variation corresponding to the difference in treatment. This statement is true also of the soluble carbohydrates. The amount of water. added was not sufficient to influence enzyme activity.

BAKING TESTS OF FLOURS FROM WHEAT STORED UNDER DIFFERENT CONDITIONS.

The flours were baked immediately after milling. The results are found in table IX. The figures obtained in these baking tests show very little correspondence with the difference in treatment. The percentage of absorption is very nearly the same. The strength of the flour had not suffered from this large application of water to the wheat, but was rather in proportion to the amount of moisture in the flour. The maximum expansion shows a slight decrease where the wheat had received the larger application of water. This is also true of the loaf volume. That is, there was a slight injury to the baking quality, but not nearly as much as would be expected. It is only with the fine measurements employed that any differences are apparent at all. The texture and the evenness of the loaves were the same for all.

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Kansas Agricultural Experiment Station

TABLE IX. Baking tests of flours from wheat stored for nineteen days with different moisture content (baked immediately after milling.)

Serial number	PLACE OF STORAGE.	Amount of water added to wheat, percent	Percent absorption	Time of proving, minutes.				Maximum expansion of dough, cc	Rise in oven, cm	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc	Evenness of texture. 100=Perfection	Thinness of wall. 100=Perfection
				1st rise	2d rise	3d rise	Total								
513	Attic, bin	0	58.3	135	57	30	222	2,150	5.1	4	46	523	1,810	97	95
514	Attic, 2-bushel container	0	60.0	168	39	25	232	2,400	4.2	9	61	509	1,800	97	95
515	Attic, 2-bushel container	1	59.0	160	47	29	236	2,250	4.9	6	61	509	1,780	97	95
516	Attic, 2-bushel container	2.5	59.0	132	45	27	204	2,250	5.0	+1	50	527	1,830	97	95
517	Attic, 2-bushel container	4	58.3	123	50	30	203	2,200	5.0	3	49	521	1,830	97	95
518	Attic, 2-bushel container	5.5	58.3	119	48	30	197	2,200	5.4	5	47	521	1,870	97	95
519	Ground floor	0	60.0	116	44	27	187	2,300	5.0	5	62	512	1,850	97	95
520	Ground floor	1	59.0	115	54	34	203	2,150	4.2	6	51	519	1,750	97	95
521	Ground floor	2.5	59.0	118	44	27	189	2,150	4.6	7	51	518	1,820	97	95
522	Ground floor	4	59.0	130	52	35	217	2,150	3.4	3	66	506	1,770	97	95
523	Ground floor	5.5	58.3	122	51	34	207	2,100	4.2	3	63	507	1,760	97	95

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Additional Analyses and Baking Tests.

These flours were tested again about sixty days after they were milled. The results are found in table X. Only the five samples from the wheat stored in the cans in the attic were tried. All these flours gave as nearly identical results as are possible to obtain even when the test is made on the same flour. The flours had undergone distinct improvement during this sixty days. Additional samples of the lots of wheat stored in the attic were milled after being stored for a little more than two months. The results of the analyses of the flour are found in table XI. There is a slight decrease in gluten content in the flour from those wheats which were moldy and which had received the largest amounts of water, but the amount of decrease is not in proportion to what would be expected from the appearance of the wheat. The acidity shows no increase, but, a decrease in the samples to which the larger amounts of water had been added. Where the acidity shows a decrease there is an increase of amino compounds, but this is not regular. The variation in the water-soluble phosphorus is proportionate to the variation in the acidity value.

The results of the baking tests of these flours from the second milling are found in table XII. The flour from the wheat stored in the bin made the best showing, and the flour from the wheats which had received the largest amount of water and were moldy, the poorest, but the differences in the results are very small. The color and texture of all these loaves was very nearly the same.

While these storage experiments were completed on a small scale, the results were definite. Experiments on a larger scale are needed. Too few data are at hand regarding conditions for storage of wheat which will give it the best milling quality and will give the best baking quality to the flour.

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Kansas Agricultural Experiment Station

TABLE X. Baking tests of flours from wheat stored for nineteen days with different moisture content (baked sixty days after milling).

Serial number	Place of Storage.	Amount water added to wheat, percent	Percent absorption	Time of proving, minutes. 1st rise	2d rise	3d rise	Total	Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc.	Evenness of texture. 100=Perfection	Thinness of wall. 100=Perfection	Color of loaf. 100=Perfection
513	Attic, bin	0	58.3	110	50	29	189	2,450	5.0	11	53	509	1,820	97	98	100
514	Attic, 2-bushel container	0	60.0	110	43	28	181	2,500	4.9	10	54	515	1,860	97	98	100
515	Attic, 2-bushel container	1	59.3	115	49	28	192	2,350	5.3	8	49	519	1,890	97	98	100
516	Attic, 2-bushel container	2.5	59.3	113	46	27	186	2,400	4.5	12	49	515	1,760	97	98	100
517	Attic, 2-bushel container	4	58.3	119	48	23	190	2,350	5.2	8	43	522	1,870	97	98	100
518	Attic, 2-bushel container	5.5	58.3	120	44	31	195	2,200	5.1	7	53	513	1,910	98	98	100

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Kansas Agricultural Experiment Station

Table XI. Chemical analysis of flours from wheat stored for sixty-eight days after adding different amounts of water.

Serial number.	Water added to wheat, percent.	Moisture in flour.	Ash.	Protein.	Gluten.		Acidity.	Amino compounds.	Water-soluble phosphorus.	Total phosphorus.
					Dry.	WET				
512	....	....	....	....	....	....	....	0.77	0.043	....
513	0	12.54	0.582	11.63	12.20	39.60	0.162	0.98	0.052	0.124
514	0	12.78	0.574	10.94	11.36	37.39	0.157	0.88	0.051	0.116
515	1	12.93	0.606	11.51	12.37	42.24	0.162	1.33	0.056	0.126
516	2.6	13.30	0.584	11.29	12.21	40.28	0.158	0.94	0.054	0.127
517	4	14.15	0.572	11.14	12.02	38.92	0.140	1.10	0.047	0.111
518	5.5	13.30	0.612	11.34	12.08	35.66	0.126	1.51	0.042	0.111

TABLE XII. Baking tests of flours from wheat stored sixty-eight days after adding different amounts of water.

Ser. number	Place of Storage.	Amount of water added to wheat, percent....	Percent absorption....	Time for proving, minutes.				Maximum expansion of dough, cc..........	Rise in oven, cm.....	Loss in mixing and rising, grams........	Loss in baking and cooling, grams..........	Weight of loaf, grams.	Volume of loaf, cc...	Evenness of texture. 100=Perfection......	Thinness of wall. 100=Perfection......	Color of loaf. 100=Perfection......
				1st rise.	2d is	3d ri e.	Total									
513	Attic, bin..................	0	59	118	40	28	186	2,300	5.0	+1	55	521	1,900	98	98	100
514	Attic, 2-bushel container........	0	60	115	49	32	196	2,350	4.7	4	49	526	1,840	98	98	100
515	Attic, 2-bushel container..........	1	60	112	45	29	186	2,300	4.9	+5	56	528	1,850	98	97	100
516	Attic, 2-bushel container..........	2.5	60	113	45	30	188	2,300	4.7	2	57	520	1,850	98	98	100
517	Attic 2-bushel container..........	4	59	110	44	32	186	2,350	5.5	+7	58	524	1,880	98	98	100
518	Attic: 2-bushel container..........	5.5	59	105	42	29	176	1,900	4.5	3	55	517	1,800	98	97	99

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EXPERIMENTS TO DETERMINE AGING EFFECT OF TEMPERING WITH MOISTURE AND HEAT (1911).

When wheat undergoes the process known as ("sweating," whether in the stack or bin, there is a rise in temperature, and it feels moist to the touch. If this increase in temperature is too great, serious injury to the wheat results. The heat generated in the wheat during the normal process of sweating, as well as the increase in moisture, if it occurs, is beneficial to the wheat, but the greater degree of heat generated during the process of stack- or bin-burning is very harmful. If the normal sweating process is accompanied by an increase of heat, and if this process will not take, place unless the wheat has the proper amount of moisture, it would seem possible to bring about artificially the same results as are produced by the process of sweating. In order to determine the limits and the conditions of this treatment, the following experiments were undertaken.

METHOD OF APPLYING MOISTURE AND HEAT.

For this investigation, shock-threshed wheat cut in prime condition was used. The apparatus for heating consisted of two concentric cylinders so constructed that the wheat was held between the two in a layer one inch thick. The inside cylinder was 30 centimeters high and 25 centimeters in diameter. The outer cylinder was 32 centimeters high and 30 centimeters in diameter. The inside cylinder was fitted with a top and no bottom. The space between the cylinders was fitted with a bottom. Over the two was fitted a loose cover. The cylindrical space thus enclosed held about 6200 cc., or about five kilograms. The whole apparatus was placed in water of the desired temperature. As the water was inside the inner cylinder and outside the outer one, and as the layer of wheat was only one inch thick, a quick and uniform heating was possible. The amount of water to be used for the different treatments was added and thoroughly mixed with the wheat before it was put into the receptacle.

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Kansas Agricultural Experiment Station

AMOUNTS OF WATER AND DEGREES OF TEMPERATURE USED

Three-kilo samples of wheat were treated with moisture and heat. In treating these, three different temperatures, three different amounts of water, and four different lengths of time were used. The temperatures utilized were 45° C., 70° C. and 98° C. The amounts of water used were 25 cc., 50 cc., and 100 cc. per kilo.

The treatment at 45° C. (113° F.) with 25 cc. of water per kilo was for 6, 12, 24 and 48 hours; wit 50 cc. of water per kilo, for 3, 6, 12 and 24 hours; and with 100 cc. of water per kilo, for 1½, 3, 6 and 12 hours.

The treatment at 70° C. (158° F.) with 25 cc. of water per kilo was for 3, 6, 12 and 24 hours; with 50 cc. of water per kilo, for 1½, 3, 6 and 12 hours; and with 100 cc. of water, for ¾, 1½, 3 and 6 hours.

Treatment at 98° C. (208° F.) with 25 cc. of water per kilo was for ¾, 1½, 3 and 6 hours; with 50 cc. of water per kilo, for 3/8, ¾, 1½, and 3 hours; and with 100 cc. of water per kilo, 3/16, 3/8, ¾ and 1½ hours.

This gave twelve samples for each temperature, or thirty-six samples in all, and afforded a very wide range of conditions. As soon as a sample was treated it was dried as quickly as possible. Some were dried in the sun, and others in an artificial drier constructed for the purpose.

MILLING TESTS OF SPECIALLY TEMPERED WHEAT.

When these samples were air-dry they were tempered and milled on the experimental mill. The results of this test are given in table XIII. The amount of wheat treated was about three kilos. The gain was computed from the increase in weight of air-dry wheat after treatment. The increased weight was due to an increase in moisture content, since this wheat before treatment had less than a normal amount of moisture. The amount milled from each sample was 2500 grams. All these samples milled as normal wheats. The variation in the losses, the amount of feed, and the amount of flour showed no definite correlation to the different treatments. The quality of the flour from the wheat treated at higher temperatures was inferior to the flour obtained from the wheat treated at the lower temperatures. Milling is a mechanical

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TABLE XIII. Milling tests of wheat tempered with moisture and heat.

Serial number.	Water added per kilo and temperature employed.	Hours tempered.	Percent gain or loss.	Tempering water per 2500 grams.	Loss in scouring.	Loss in milling.	Feed.	Total flour.	First-grade flour.	Second-grade flour.
428	25 cc. at 45° C	6	+2.08	35 cc.	3.00	2.92	19.20	74.88	88.67	11.33
429	25 cc. at 45° C	12	+1.84	40 cc.	2.24	1.60	23.16	73.00	90.41	9.59
430	25 cc. at 45° C	24	+1.88	40 cc.	2.60	0.84	22.16	74.40	88.60	11.40
431	25 cc. at 45° C	48	+1.80	40 cc.	2.32	1.48	21.88	74.32	89.66	10.34
432	50 cc. at 45° C	3	+2.96	20 cc.	2.80	1.92	21.44	73.84	87.76	12.24
433	50 cc. at 45° C	6	+2.84	25 cc.	2.80	2.08	20.40	74.72	88.27	11.73
434	50 cc. at 45° C	12	+2.24	25 cc.	2.40	2.20	20.20	75.20	88.03	11.97
435	50 cc. at 45° C	24	+2.68	25 cc.	2.48	4.04	19.00	74.48	87.65	12.35
436	100 cc. at 45° C	1.5	+2.16	40 cc.	2.88	1.88	20.28	74.96	87.75	12.25
437	100 cc. at 45° C	3	+2.12	40 cc.	2.88	0.32	21.48	75.32	87.63	12.37
438	100 cc. at 45° C	6	+2.00	40 cc.	3.04	*7.04	28.48	75.52	86.92	13.08
439	100 cc. at 45° C	12	+2.56	40 cc.	1.72	4.00	21.20	73.08	90.48	9.52
440	25 cc. at 70° C	3	+1.20	30 cc.	2.64	1.68	20.04	75.64	87.78	12.22
441	25 cc. at 70° C	6	+1.08	30 cc.	2.84	0.92	19.04	77.20	87.82	12.18
442	25 cc. at 70° C	12	+1.52	60 cc.	2.76	1.40	21.04	74.80	88.61	11.39
443	25 cc. at 70° C	24	+1.28	30 cc.	2.28	2.28	20.36	75.08	88.00	12.00
444	50 cc. at 70° C	1.5	+2.56	30 cc.	1.72	1.88	21.96	74.44	88.72	11.28
445	50 cc. at 70° C	3	+2.56	60 cc.	2.36	3.64	19.12	74.88	89.04	10.76
446	50 cc. at 70° C	6	+2.32	30 cc.	2.76	*3.16	23.00	77.40	86.82	13.18
447	50 cc. at 70° C	12	+1.52	30 cc.	2.92	1.80	19.28	76.00	86.84	13.16
448	100 cc. at 70° C	.75	+3.24	20 cc.	2.24	1.20	21.32	75.24	88.13	11.87
449	100 cc. at 70° C	1.5	+1.08	20 cc.	2.60	3.88	18.92	74.60	88.52	11.48
450	100 cc. at 70° C	3	+1.60	20 cc.	2.64	3.08	18.16	76.12	86.23	13.77
451	100 cc. at 70° C	6	+2.60	30 cc.	3.16	5.12	18.08	73.64	92.99	7.01
452	25 cc. at 98° C	.75	+0.08	75 cc.	7.60		15.64	76.76	85.82	14.18
453	25 cc. at 98° C	1.5	+0.08	100 cc.	5.04		20.76	74.20	87.06	12.94
454	25 cc. at 98° C	3	0	75 cc.	3.08	1.04	19.60	76.28	86.72	13.28
455	25 cc. at 98° C	6	+0.12	75 cc.	3.00	0.72	15.72	76.56	86.88	13.12
456	50 cc. at 98° C	⅜	+1.88	40 cc.	2.68	1.28	19.72	76.32	89.94	10.06
457	50 cc. at 98° C	.75	+2.04	40 cc.	2.92	2.36	19.64	75.08	88.65	11.35
458	50 cc. at 98° C	1.5	+2.04	40 cc.	1.52	2.00	20.44	76.04	86.58	13.42
459	50 cc. at 98° C	3	+0.88	40 cc.	2.56	2.44	20.52	74.48	88.39	11.61
460	100 cc. at 98° C	3/16	+2.76	25 cc.	3.72	4.56	19.28	72.44	89.34	10.66
461	100 cc. at 98° C	⅜	+1.92	45 cc.	4.20	1.84	19.08	74.88	87.93	12.07
462	100 cc. at 98° C	¾	+2.92	25 cc.	2.80	2.80	12.32	75.00	88.27	11.73
463	100 cc. at 98° C	1.5	+3.48	25 cc.	1.72	3.28	20.28	73.52	88.41	11.59

* Gain.

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operation. If the wheat is so conditioned that the bran is properly toughened, and the interior of the kernel sufficiently mellowed, very little bran' powder is produced and a large amount of clean middlings obtained. Such wheat is of good milling quality as far as relates to the mechanical operation, This treatment with heat and water did not injure the wheat from a mechanical standpoint sufficiently to affect the milling process. In bin burning and stack burning the degree of heat is greater and the result is entirely different from that produced here.

BAKING TESTS OF FLOURS FROM SPECIALLY TEMPERED WHEAT.

The results of the baking tests of flours from wheat tempered by heat and moisture are found in table XIV, *a, b, c.* The photographs of the loaves are shown in plates III, IV, V, VI, VII, VIII, IX, X, XI.

The variation in moisture content of the flour is due to the different amounts of water which were used in the different treatments, though the correlation is neither uniform nor proportional. The flours which had the poorest baking qualities, all things considered, had the highest absorption. That this higher absorption was both absolute and relative is shown by the fact that the flours of poorest baking quality were as high or higher in moisture content than those which had good baking qualities. While the time for "proving" showed no uniform increase,or decrease corresponding to the treatment, it was shortest for the flours from the wheats treated at the higher temperature and with the greater amount of moisture.

The maximum expansion was also least in these same flours. The treatment at 70° with 25 cc. of water from six to twenty-four hours and with 50 cc. of water from one and one-half to six hours gave the greatest total expansion. When 100 cc. of water at 70° was used the total expansion was much decreased. The rise in the oven gave the best results with the treatment at 45° with 50 and 100 cc. of water. The same statement holds true with loaf volume. The maximum expansion of the dough, the rise in the oven, and the loaf volume point to the following conclusions :

When new wheat is treated with moisture and heat, the gluten is modified so as to produce a larger expansion while the dough is rising, but if this treatment is too severe the

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Kansas Agricultural Experiment Station

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TABLE XIVa. Baking tests of flours from wheat tempered with moisture and heat at 45° C. (113° F.).

Serial number	Amount of water added per kilo	Number of hours heated	Percent moisture	Percent absorption	Water for loaf, cc.	Time for proving, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc.	Texture of crumb	Color of loaf
						1st rise	2d rise	3d rise	Total								
418	....	....	11.17	55.0	187	62	68	36	166	2,000	1.3	17	41	504	1,520	83	89
428	25 cc.	6	11.64	55.0	187	65	75	40	180	2,050	2.2	9	49	504	1,540	87	90
429	25 cc.	12	11.30	60.0	204	60	74	39	173	2,050	1.8	9	55	515	1,600	86	88
430	25 cc.	24	11.43	60.0	204	60	67	39	166	2,050	2.8	8	52	519	1,680	88	91
431	25 cc.	48	11.43	60.0	204	57	76	37	170	2,300	2.5	8	55	516	1,670	92	94
432	50 cc.	3	11.58	60.0	204	63	74	36	173	2,100	2.0	10	52	517	1,620	91	93
433	50 cc.	6	11.98	60.0	204	64	70	43	177	2,150	3.0	12	48	519	1,750	90	92
434	50 cc.	12	11.68	60.0	204	56	70	39	165	2,200	3.0	11	48	520	1,750	89	92
435	50 cc.	24	11.26	60.0	204	59	68	40	167	2,050	2.1	13	46	520	1,610	87	88
436	100 cc.	1½	11.46	60.0	204	58	65	33	156	2,000	2.4	18	47	514	1,660	90	*.......
437	100 cc.	3	11.48	60.0	204	57	72	35	164	2,200	2.6	8	46	525	1,730	91	....
438	100 cc.	6	12.40	60.0	204	63	67	36	166	2,150	3.3	13	49	517	1,720	91	....
439	100 cc.	12	12.37	60.0	204	55	68	33	156	2,200	2.9	14	50	515	1,670	88	....

* No change in color except that due to change in texture.

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Kansas Agricultural Experiment Station

TABLE XIVb. Baking tests of flours from wheat tempered with moisture and heat at 70° C. (158° F.).

Serial number	Amount of water added per kilo	Number of hours heated	Percent moisture	Percent absorption	Water for loaf, cc.	Time for proving, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc.	Texture of crumb	Color of loaf
						1st rise	2d rise	3d rise	Total								
418	....	....	11.17	55.0	187	62	68	36	166	2,000	1.3	17	41	504	1,520	83	89
440	25 cc.	3	11.10	56.6	192	61	70	36	167	2,050	1.8	8	46	513	1,600	89	* ......
441	25 cc.	6	11.52	56.6	204	53	81	37	171	2,300	2.3	13	46	520	1,660	92	....
442	25 cc.	12	11.32	60.0	204	54	72	36	162	2,200	2.2	13	45	521	1,620	94	....
443	25 cc.	24	10.89	60.0	204	54	74	36	164	2,300	2.0	13	53	513	1,600	94	....
444	50 cc.	1½	12.10	60.0	204	58	80	42	180	2,400	2.2	14	50	515	1,630	−95	....
445	50 cc.	3	11.21	60.0	204	55	80	39	174	2,300	2.4	17	45	517	1,720	95	....
446	50 cc.	6	11.55	60.0	204	55	74	35	164	2,300	2.0	13	46	520	1,630	92	....
447	50 cc.	12	11.47	60.0	204	60	75	38	173	2,200	1.8	15	47	517	1,590	93	....
448	100 cc.	¾	12.09	56.6	192	60	75	38	173	2,150	2.2	6	46	515	1,610	90	....
449	100 cc.	1½	12.53	56.6	192	65	71	36	172	1,850	0.9	12	45	510	1,380	86	....
450	100 cc.	3	11.93	56.6	192	63	66	38	167	1,650	−0.1	11	52	504	1,340	70	....
451	100 cc.	6	11.77	60.0	204	64	57	42	163	1,400	−0.85	19	51	509	1,170	50	....

* No difference in color except that due to difference in texture.

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Kansas Agricultural Experiment Station

TABLE XIV*c*. Baking tests of flours from wheat tempered with moisture and heat at 98° C. (208° F.).

Serial number	Amount of water added per kilo	Number of hours heated	Percent moisture	Percent absorption	Water for loaf, cc.	Time for proving, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc.	Texture of crumb	Color of loaf
						1st rise	2d rise	3d rise	Total								
418	....	....	11.17	55.0	187	62	68	36	166	2,000	1.3	17	41	504	1,520	83	89
452	25 cc.	¾	10.45	60.0	204	58	72	36	166	2,050	1.4	11	46	522	1,300	90	*.......
453	25 cc.	1½	11.07	60.0	204	58	66	36	160	1,700	−0.5	11	41	527	1,280	70	....
454	25 cc.	3	11.05	61.6	209	64	52	36	152	1,400	−0.3	10	44	530	1,180	50	....
455	25 cc.	6	11.57	63.3	215	64	56	23	143	1,200	−0.1	13	46	531	1,070	40	....
456	50 cc.	⅜	11.77	61.6	209	59	59	36	154	2,150	2.4	11	50	523	1,630	85	....
457	50 cc.	¾	12.20	61.6	209	65	54	31	150	1,600	0.4	6	53	525	1,320	60	....
458	50 cc.	1½	11.92	61.6	209	66	50	31	147	1,300	−0.1	9	49	526	1,130	50	....
459	50 cc.	3	11.06	63.3	215	62	46	32	140	1,200	0	2	51	537	1,045	30	....
460	100 cc.	$\frac{3}{16}$	11.26	61.6	209	70	44	34	148	1,750	2.7	2	58	524	1,640	88	....
461	100 cc.	⅜	12.08	61.6	209	70	37	35	142	1,500	0	1	55	528	1,360	60	....
462	100 cc.	¾	12.57	61.6	209	62	38	34	134	1,250	−0.2	3	49	532	1,120	50	....
463	100 cc.	1½	12.48	63.3	215	55	45	26	126	1,250	0	6	42	542	1,040	30	....

* No difference in color except that due to difference in texture.

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Kansas Agricultural Experiment Station

dough does not have sufficient gas-retaining capacity and the expansion is less. There must be a proper relation between the gas-retaining capacity and the expansibility of the dough. If the former is sufficient to hold the gas, and the dough expands easily, there will be a large volume. A dough may have a large gas-retaining capacity, but if it is too stiff there will be small volume. Fermentation of the dough modifies the gluten so as to make it more expansible. If a strong dough is allowed to expand to its maximum once, then worked down and allowed to expand again, it will expand further the second time. But this process can not be continued indefinitely. The third rise will probably be equal to the second rise, but the point will soon be reached when the gas-retaining capacity has been so weakened that the maximum expansion possible will be small as compared with the second or third rise. Overfermentation causes "falling dough." If dough is allowed to rise to the point where it will not rise further, then worked down and the process repeated, the largest loaf volume is possible, if the baking is done just after the maximum rise. Further fermentation weakens the dough, and a large oven expansion and loaf volume is less likely to be secured.

To get a large loaf the dough should be baked when the gluten has been modified to such an extent that its resistance against the expanding gases will allow a large expansion but not enough so that the gas-retaining capacity has been injured. If the latter has taken place the bread will be full of large holes. It is not only desirable to have a large loaf, but it must have a fine, even texture and give a velvety "feel." The holes must be small and uniform and the cell walls thin. This will be produced when the dough has been fermented to such an extent that expansibility and the gas-retaining capacity balance each other. If the process goes further, the cell walls can not retain the gas and one hole will coalesce into another. On the other hand, if the expansibility is too small the bread will be heavy; that is, the cell walls are thick although the holes are small and uniform.

Quality of Dough and Gluten of Flours from Specially Tempered Wheat.

The figures for the quality of gluten and that of the dough are given in table XV. The quality figure chosen is entirely arbitrary. The figure 0 represents the best quality of dough

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Kansas Agricultural Experiment Station

TABLE XV. The quality of dough and gluten.

Water added per kilo.	Treatment at 45° C.					Treatment at 70° C.					Treatment at 98° C.				
	Serial number.	Hours heated.	Quality figure.	Texture.	Loaf volume.	Serial number.	Hours heated.	Quality figure.	Texture.	Loaf volume.	Serial number.	Hours heated.	Quality figure.	Texture.	Loaf volume.
25 cc.	428	6	4	87	1,540	440	3	3	89	1,600	452	¾	−2	90	1,300
25 cc.	429	12	3	86	1,600	441	6	2	92	1,660	453	1½	−5	70	1,280
25 cc.	430	24	2	88	1,680	442	12	1	94	1,620	454	3	−8	50	1,180
25 cc.	431	48	2	92	1,670	443	24	−3	94	1,600	455	6	−10	40	1,070
50 cc.	432	3	2	91	1,620	444	1½	1	95	1,620	456	⅜	−3	85	1,630
50 cc.	433	6	1	90	1,750	445	3	0	95	1,720	457	¾	−6	60	1,320
50 cc.	434	12	0	89	1,750	446	6	−2	92	1,630	458	1½	−9	50	1,130
50 cc.	435	24	−2	87	1,610	447	12	−4	93	1,590	459	3	−12	30	1,045
100 cc.	436	1½	2	90	1,660	448	¾	−2	90	1,610	460	$\frac{3}{16}$	−4	88	1,640
100 cc.	437	3	0	91	1,730	449	1½	−4	86	1,380	461	⅜	−7	60	1,360
100 cc.	438	6	−1	91	1,720	450	3	−6	70	1,340	462	¾	−10	50	1,120
100 cc.	439	12	−3	88	1,670	451	6	−8	50	1,170	463	1½	−12	30	1,040

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Kansas Agricultural Experiment Station

and the quality of the gluten follows these figures very closely on the plus side. The figure 2 represents probably the best quality in gluten. Thus with the treatment at 25° C. there is constant improvement in the dough from 4 to 0, while from 0 to —3 there is a deterioration in quality. Thus +3 and —3 represent about the same quality of dough, with this difference: + 3 needs treatment to make it softer and more pliable, while —3 has gone beyond the stage where it was at its best. The treatment with heat and moisture so modifies the gluten that it becomes more elastic and expands more readily under the influence of the action of the yeast. It also gives a uniform dough with less kneading. But if the treatment is carried too far, the dough begins to behave like a dough or batter containing a large amount of shortening, such as is used for baking cakes and pie crust.

The figures for texture and loaf volume are given for easy comparison. The best texture is found when the dough begins to weaken. It is very probable that this was obtained because of the method of baking used. It happened that this method was best adapted to the condition of these flours. A longer period of rising would probably have given a better texture to the dough, the quality of which is indicated by —1 or 0.

THE CHEMICAL ANALYSIS OF FLOURS FROM SPECIALLY TEMPERED WHEAT.

The results of the chemical analysis of flour from wheat tempered by moisture and heat are shown in table XVI.

The ash content is influenced by the milling tests, which are not entirely uniform. This unfortunately influences the percentages for acidity, amino compounds and phosphorus. Below an effort is made to correct for the variation in ash. The figures for protein are fairly uniform and the small amount of variation is due to the cause just mentioned.

The soluble carbohydrates show no regular increase corresponding to the treatments given. As far as this investigation goes, they have little, if any, effect on the results obtained. The percentages of amino compounds do not show any great, variation except where the treatment was so severe as to injure the baking qualities of the flour. The small variation is not in accordance with the different treatments and in all probability is due to variation in milling, as the presence of a small amount of bran fiber will influence the percentage of amino compounds.

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Kansas Agricultural Experiment Station

TABLE XVI. Chemical analysis of flours from wheat tempered with moisture and heat.

Serial number.	Water added per kilo and temperature employed.	Hours heated.	Ash.	Protein.	Protein in gluten.	Gluten.			Moisture-free basis.					
						Dry.	Pure.	Wet.	Carbohydrates.	Acidity.	Amino compounds.	Water-soluble phosphorus.	Total phosphorus.	Percent water-soluble phosphorus in total.
....	....	....	0.63	9.99	84.46	9.79	8.27	28.29	2.23	0.180	0.145	0.068	0.144	47.22
428	25 cc. at 45 C.	6	0.67	10.02	86.00	9.73	8.37	31.05	2.02	0.180	0.141	0.069	0.150	46.00
429	25 cc. at 45 C.	12	0.72	10.11	79.96	11.21	8.96	34.99	2.36	0.197	0.150	0.081	0.159	50.94
430	25 cc. at 45 C.	24	0.65	10.00	83.29	9.99	8.32	30.77	2.22	0.181	0.130	0.064	0.146	43.83
431	25 cc. at 45 C.	48	0.63	10.00	87.71	9.48	8.32	29.41	1.99	0.177	0.140	0.068	0.139	48.92
432	50 cc. at 45 C.	3	0.64	10.01	89.87	9.10	8.18	29.38	2.40	0.181	0.154	0.071	0.145	48.96
433	50 cc. at 45 C.	6	0.64	10.06	83.16	10.17	8.45	33.06	2.24	0.173	0.141	0.064	0.137	47.71
434	50 cc. at 45 C.	12	0.65	10.03	82.46	10.24	8.45	34.64	2.17	0.185	0.129	0.069	0.149	46.30
435	50 cc. at 45 C.	24	0.65	10.00	83.74	10.02	8.39	33.39	2.12	0.188	0.158	0.071	0.151	47.01
436	100 cc. at 45 C.	1½	0.62	10.03	85.14	10.16	8.65	34.55	2.15	0.178	0.147	0.065	0.143	45.45
437	100 cc. at 45 C.	3	0.56	9.94	86.77	9.65	8.37	32.68	2.15	0.166	0.130	0.056	0.138	40.58
438	100 cc. at 45 C.	6	0.50	9.87	87.93	9.87	8.68	31.49	2.32	0.149	0.123	0.052	0.122	42.62
439	100 cc. at 45 C.	12	0.56	10.01	....	9.58	....	31.26	2.05	0.173	0.141	0.063	0.136	46.32
440	25 cc. at 70 C.	3	0.66	10.05	86.20	9.78	8.44	33.78	2.09	0.190	0.149	0.067	0.152	44.07
441	25 cc. at 70 C.	6	0.66	10.14	90.05	9.44	8.50	29.38	2.02	0.183	0.147	0.070	0.148	47.29
442	25 cc. at 70 C.	12	0.64	9.73	84.58	10.03	8.48	27.72	1.83	0.158	0.135	0.061	0.144	42.36
443	25 cc. at 70 C.	24	0.64	10.06	83.15	10.10	8.40	29.34	2.06	0.177	0.145	0.064	0.144	44.44
444	50 cc. at 70 C.	1½	0.55	9.74	82.16	10.52	8.65	32.29	2.05	0.156	0.138	0.057	0.126	45.23
445	50 cc. at 70 C.	3	0.64	10.07	83.53	10.25	8.55	30.80	2.05	0.168	0.154	0.059	0.140	42.14
446	50 cc. at 70 C.	6	0.72	10.36	84.61	9.77	8.26	26.84	2.44	0.186	0.162	0.066	0.158	41.77
447	50 cc. at 70 C.	12	0.68	9.97	87.72	9.48	8.32	26.25	2.22	0.170	0.174	0.061	0.147	41.49
448	100 cc. at 70 C.	¾	0.65	10.07	87.21	9.49	8.28	26.61	2.15	0.164	0.179	0.063	0.139	45.32
449	100 cc. at 70 C.	1½	0.59	9.99	84.55	10.23	8.65	29.38	2.32	0.146	0.171	0.056	0.126	44.44
450	100 cc. at 70 C.	3	0.69	10.22	....	7.32	....	20.54	2.24	0.183	0.255	0.066	0.149	44.29
451	100 cc. at 70 C.	6	0.74	10.30	....	....	....	....	2.67	0.174	0.323	0.054	0.160	33.75
452	25 cc. at 100 C.	¾	0.60	10.17	90.44	9.65	8.73	27.12	2.03	0.147	0.143	0.049	0.129	37.98
453	25 cc. at 100 C.	1½	0.56	9.82	87.72	8.94	7.84	24.05	2.26	0.128	0.143	0.043	0.123	34.95
454	25 cc. at 100 C.	3	0.64	10.05	....	....	....	....	2.23	0.134	0.152	0.048	0.136	35.29
455	25 cc. at 100 C.	6	0.63	10.01	....	....	....	....	2.23	0.122	0.193	0.044	0.134	32.83
456	50 cc. at 100 C.	⅜	0.62	10.04	87.32	9.86	8.61	28.33	2.24	0.143	0.143	0.056	0.137	40.87
457	50 cc. at 100 C.	¾	0.59	9.98	90.94	3.93	3.58	9.27	2.03	0.118	0.159	0.053	0.135	39.25
458	50 cc. at 100 C.	1½	0.65	10.02	....	....	....	....	2.22	0.123	0.192	0.042	0.138	30.43
459	50 cc. at 100 C.	3	0.66	9.96	....	....	....	....	2.18	0.114	0.202	0.030	0.141	21.27
460	100 cc. at 100 C.	3/16	0.59	9.91	87.73	9.51	8.34	26.52	2.12	0.136	0.159	0.051	0.128	39.84
461	100 cc. at 100 C.	⅜	0.69	10.20	87.27	9.44	8.24	28.60	2.44	0.149	0.198	0.058	0.153	37.90
462	100 cc. at 100 C.	¾	0.65	9.89	....	....	....	....	2.33	0.125	0.234	0.034	0.143	23.77
463	100 cc. at 100 C.	1½	0.74	9.79	....	....	....	....	2.12	0.130	0.260	0.030	0.151	19.86

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Kansas Agricultural Experiment Station

TABLE XVII. Chemical analysis of flours from wheat tempered with moisture and heat. Corrected for variation in percentages of ash.

Serial No.	Water added per kilo and temperature employed.	Hours heated.	Percentages.			
			Acidity.	Amino compounds.	Water-soluble phosphorus.	Total phosphorus.
428	25 cc. at 45° C.......	6	0.269	0.210	0.103	0.224
429	25 cc. at 45° C.......	12	0.274	0.208	0.113	0.221
430	25 cc. at 45° C.......	24	0.278	0.200	0.098	0.225
431	25 cc. at 45° C.......	48	0.281	0.222	0.108	0.221
432	50 cc. at 45° C.......	3	0.283	0.241	0.111	0.226
433	50 cc. at 45° C.......	6	0.270	0.220	0.100	0.214
434	50 cc. at 45° C.......	12	0.285	0.198	0.106	0.229
435	50 cc. at 45° C.......	24	0.289	0.243	0.109	0.232
436	100 cc. at 45° C.......	1½	0.287	0.237	0.105	0.231
437	100 cc. at 45° C.......	3	0.296	0.232	0.100	0.246
438	100 cc. at 45° C.......	6	0.298	0.246	0.104	0.244
439	100 cc. at 45° C.......	12	0.309	0.252	0.113	0.243
440	25 cc. at 70° C.......	3	0.288	0.226	0.102	0.230
441	25 cc. at 70° C.......	6	0.277	0.223	0.106	0.224
442	25 cc. at 70° C.......	12	0.247	0.211	0.095	0.225
443	25 cc. at 70° C.......	24	0.276	0.226	0.100	0.225
444	50 cc. at 70° C.......	1½	0.284	0.251	0.104	0.229
445	50 cc. at 70° C.......	3	0.262	0.241	0.092	0.219
446	50 cc. at 70° C.......	6	0.258	0.225	0.092	0.219
447	50 cc. at 70° C.......	12	0.250	0.256	0.090	0.216
448	100 cc. at 70° C.......	¾	0.252	0.275	0.097	0.214
449	100 cc. at 70° C.......	1½	0.247	0.290	0.095	0.214
450	100 cc. at 70° C.......	3	0.265	0.360	0.096	0.216
451	100 cc. at 70° C.......	6	0.235	0.436	0.073	0.216
452	25 cc. at 98° C.......	¾	0.245	0.238	0.082	0.215
453	25 cc. at 98° C.......	1½	0.229	0.255	0.077	0.220
454	25 cc. at 98° C.......	3	0.209	0.237	0.075	0.212
455	25 cc. at 98° C.......	6	0.194	0.306	0.070	0.213
456	50 cc. at 98° C.......	⅜	0.231	0.231	0.090	0.221
457	50 cc. at 98° C.......	¾	0.200	0.270	0.090	0.229
458	50 cc. at 98° C.......	1½	0.189	0.295	0.065	0.212
459	50 cc. at 98° C.......	3	0.173	0.306	0.045	0.214
460	100 cc. at 98° C.......	$\frac{3}{16}$	0.231	0.270	0.086	0.217
461	100 cc. at 98° C.......	⅜	0.216	0.287	0.084	0.222
462	100 cc. at 98° C.......	¾	0.192	0.360	0.052	0.220
463	100 cc. at 98° C.......	1½	0.176	0.351	0.041	0.204

To overcome the influence of the variation in flours due to milling, table XVII was worked out. Each percentage for acidity, amino compounds and water-soluble and total phosphorus was divided by the percentage of ash. From a study of this table the following conclusions can be drawn:

The treatment at 45° C. caused no apparent change in the amount of acidity, of amino compounds or of water-soluble phosphorus.

The treatment at 70° C. caused no notable change in the amount of acidity. There was a tendency to decrease, but the amount was within experimental error. There was no change in the amount of amino compounds with the 25 and 50 cc. of water; with 100 cc. there was a distinct increase proportional to the time the wheat was treated. By a reference to the table on the baking results, it will be seen that where there was this distinct increase of amino compounds the quality of the dough

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Kansas Agricultural Experiment Station

and the resulting bread was inferior; that is, as soon as there was an increase in amino compounds the gluten quality was injured. There was no marked change in the amount of water-soluble phosphorus.

The treatment at 98° C. caused a distinct decrease in the amount of acidity. The greater the amount of water or the longer the time the less the acidity. This decrease in the amount of acidity can be accounted for by the decrease in the amount of water-soluble phosphorus. The two follow each other closely, and as acidity is largely due to the presence of water-soluble phosphorus the decrease of the acidity is easily explained. Why there should be a decrease in the amount of water-soluble phosphorus is not apparent. The amino compounds showed a slight increase for the three amounts of water used proportional to the time of the treatment. What was said in regard to the amino compounds above, under the treatment at 70° C., applies with even greater force here.

While the skilled professional baker knows how to suit his fermentation processes to the differences in the flours he uses and the miller has very little trouble from such customers, yet he must make a flour suited to the methods of bread makers who are not professionals. While flour troubles which' follow the milling of new wheat could possibly be remedied by the professional baker, it is desirable that the miller should so modify his wheat that these troubles would be eliminated entirely.

When wheat undergoes the process of aging, the gluten undergoes this desirable transformation. It becomes more elastic and pliable. The dough from flour made of such wheat, is more easily handled, requires less fermentation and gives a loaf of larger volume and better texture.

That this desired effect was produced by this water and heat treatment is evident. The best loaves were obtained from the wheat treated at 70° with 25 cc. of water for 12 to 24 hours and with 50 cc. of water for 3 hours; that is, if more water were present, the effect took place in a shorter time, The treatment at 45° did not seem to have the desired effect on the gluten. While the volumes were large, the heaviness of the texture showed that the gluten was stiff and unyielding. The 100 cc. of water at 70° C. was harmful and the injury proportionate to the time of treatment. The treatment at 98° was in

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Kansas Agricultural Experiment Station

all cases harmful. The shortest time used was evidently much too long, and if a very short time had been used it is quite probable that the results would have been different.

From the above results it seems entirely possible that if wheat is treated with a certain amount of moisture and then subjected to heat for a short time this will have the same effect as natural aging. The amount of moisture added should have a definite relation to the moisture content; the higher the moisture content the less the amount of water needed. Further experiments will be necessary to determine the requisite amount of moisture.

FURTHER EXPERIMENTS TO DETERMINE THE AGING EFFECT OF TEMPERING WITH MOISTURE AND HEAT (1912).

TEMPERATURES AND METHOD USED.

As the extremes of moisture and heat which can be used were determined in the 1911 tests, it was decided to omit extremes and to use temperatures and quantities of moisture which would more closely determine the exact conditions. The previous determinations indicated that Kansas hard wheat should have a moisture content of very nearly 13.5 percent for best milling results. Consequently, water was added to the wheat to bring it to that moisture content before treating with heat. The time of heating and the temperaures employed were according to the following scheme:

50° C. (122°F.)	60° C. (140°F.)	70° C. (158°F.)	88° C. (190.4° F.)
6 hours	2 hours	1 hour	3 minutes
10 "	4 "	2 "	6 "
14 "	6 "	3 "	9 "
18 "	8 "	4 "	12 "
22 "	10 "	5 "	5 "
26 "	12 "	6 "	18 "

MILLING TESTS OF SPECIALLY TEMPERED WHEAT

These samples were milled soon after heating. As in the previous year, there were no notable changes in the milling qualities which could be traced to the difference in treatment at the temperatures 50° C., 60° C., and 70° C. The samples treated at the temperature of 88° C. milled more easily. The apparatus for heating was the same as used the previous

Historical Document
Kansas Agricultural Experiment Station

year, the temperature recorded being that of the surrounding water, on the assumption that the wheat temperature was the same as that of the water. But as it would take a little time for the wheat to come to the same temperature as the water, the samples heated only a few minutes did not receive quite a proportionate amount of heating. All samples had to stand at room temperature for a few hours after heating before the milling could be done. This also, no doubt, had its influence on the samples heated only a few minutes.

CHEMICAL ANALYSIS OF SPECIALLY TEMPERED WHEAT AND THE RESULTING FLOURS.

The wheat was analyzed for moisture, acidity and water-soluble carbohydrates, and the results are recorded in table XVIII. The flours from these samples were analyzed for

TABLE XVIII.- Analysis of wheat treated by heat and percentage of moisture in the resulting flour.

Serial number.	Time heated.	Temperature.	Wheat.			Moisture in flour.
			Acidity.	Soluble carbo-hydrates.	Moisture.	
512	0 hours	....	....	....	11.47	....
527	6 hours	50° C	0.45	2.54	13.25	13.00
528	10 hours	50° C	0.42	2.75	12.94	13.11
529	14 hours	50° C	0.42	2.78	12.77	12.62
530	18 hours	50° C	0.49	....	12.65	12.56
531	22 hours	50° C	0.46	2.70	12.34	12.86
532	26 hours	50° C	0.42	2.82	12.50	12.55
533	2 hours	60° C	0.46	2.79	13.23	12.89
534	4 hours	60° C	0.43	....	12.88	12.02
535	6 hours	60° C	0.42	2.84	12.32	12.71
536	8 hours	60° C	0.42	2.67	12.49	12.92
537	10 hours	60° C	0.42	2.71	12.19	12.65
538	12 hours	60° C	0.42	2.75	11.76	13.05
539	1 hour	70° C	0.44	2.77	12.14	12.14
540	2 hours	70° C	0.44	2.67	12.16	11.93
541	3 hours	70° C	0.40	2.67	12.71	11.90
542	4 hours	70° C	0.39	2.58	12.33	11.77
543	5 hours	70° C	0.37	2.73	12.06	11.60
544	6 hours	70° C	0.39	....	12.15	12.15
545	3 minutes	88° C	0.42	2.67	13.04	12.80
546	6 minutes	88° C	0.43	....	12.37	12.44
547	9 minutes	88° C	0.43	2.72	11.80	12.85
548	12 minutes	88° C	0.42	2.77	11.16	12.47
549	15 minutes	88° C	0.41	2.82	11.55	12.55
550	18 minutes	88° C	0.42	2.73	12.40	12.08

moisture only and the results are given in the last column of table XVIII. Previous work had shown that further chemical determinations would be unnecessary. Where the wheat was heated for the longer periods there is a loss of moisture both in the wheat and flour proportionate to the length of time

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Kansas Agricultural Experiment Station

these samples were heated. In the shorter periods of heating the gains or losses seem to fall within the experimental error. The percentage of acidity shows no change which can be correlated with the difference in treatment. The same statement is also true of the water-soluble carbohydrates. Because the acidity content showed no notable change, the amounts of amino nitrogen and phosphorus were not determined. The previous year's work had shown that there was no change in the content of the water-soluble carbohydrates in the flour. But because flour does not show such a change it does not follow that the change may not occur in that portion of the wheat kernel which goes into the bran and shorts. To determine this point the whole wheat was analyzed for soluble carbohydrates. The results show that the quality changes due to heating of wheat are not brought about by such diastatic action as affects the amount of soluble carbohydrates, but the changes, where they occur, are confined to the protein compounds which form the gluten.

Baking Tests of Flours from Wheat Specially Tempered with Moisture and Heat.

The results of baking tests on flours from wheat treated by moisture and heat are found in table XIX. There are no notable results from the treatments except where the highest temperature was used, and here the best results were obtained where the heating extended from three to twelve minutes. The improvement in quality was shown in the larger loaf volume accompanied by a good texture. Treatment beyond that time shows the beginning of the deterioration which was so apparent in the former trial when a higher temperature was used.

The conclusion reached from these tests, so far as can be judged from experiments carried out on the small scale, is that wheat has an optimum moisture content for the best milling results. From this work it appears to be very nearly 13.5 percent for Kansas hard wheat. Later investigations indicate that under commercial conditions this moisture content should be 14.5 to 15 percent. The moisture will to a large extent determine the amount of water needed for tempering. If the moisture content is very low, as happens in dry years, it will not be practicable to add enough water at one time to bring the moisture content up to the optimum. Part of the water can be applied; then, after this has thoroughly soaked in, the rest of the

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Kansas Agricultural Experiment Station

TABLE XIX. Baking tests of flours from wheat tempered with moisture and heat.

Serial number	Time treated.	Temperature	Percent absorption	Time of proving, minutes.				Maximum expansion of dough, cc.	Rise in oven, cm.	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc.	Evenness of texture. 100=Perfection	Thinness of wall. 100=Perfection
				1st rise	2d rise	3d rise	Total								
527	6 hours	50° C.	60	130	46	32	208	2,300	4.7	18	49	512	1,870	93	93
528	10 hours	50° C.	60	122	47	31	200	2,350	4.6	14	54	511	1,850	93	93
529	14 hours	50° C.	60	114	48	32	194	2,300	4.8	11	52	516	1,870	93	94
530	18 hours	50° C.	60	107	47	34	188	2,300	3.9	13	59	507	1,820	91	91
531	22 hours	50° C.	60	125	37	29	191	2,350	4.7	11	58	510	1,780	95	96
532	26 hours	50° C.	60	122	49	29	200	2,250	5.5	11	55	513	1,840	96	96
533	2 hours	60° C.	60	118	44	34	196	2,350	5.0	6	57	516	1,850	93	92
534	4 hours	60° C.	60	115	42	29	186	2,350	4.5	7	56	516	1,740	93	92
535	6 hours	60° C.	60	113	46	26	185	2,150	3.2	7	60	512	1,560	90	90
536	8 hours	60° C.	60	105	54	28	187	2,250	4.6	7	57	515	1,770	95	93
537	10 hours	60° C.	60	102	49	29	180	2,350	4.6	6	66	507	1,830	94	93
538	12 hours	60° C.	60	94	52	30	176	2,150	5.5	5	60	514	1,850	94	94
539	1 hour	70° C.	60	115	50	28	193	2,350	5.3	8	50	521	1,820	94	92
540	2 hours	70° C.	60	110	48	28	186	2,350	4.3	2	53	524	1,770	94	92
541	3 hours	70° C.	60	117	45	26	188	2,500	5.0	4	53	522	1,870	94	93
542	4 hours	70° C.	60	110	44	28	182	2,350	4.4	+1	56	524	1,810	94	93
543	5 hours	70° C.	60	125	43	29	197	1,900	3.0	+6	58	527	1,590	90	90
544	6 hours	70° C.	60	128	48	30	206	2,100	4.0	+5	54	530	1,740	94	94
545	3 minutes	88° C.	60	119	47	30	196	2,500	5.6	+9	52	536	1,910	96	96
546	6 minutes	88° C.	60	122	45	31	198	2,500	5.5	+1	48	532	1,920	96	96
547	9 minutes	88° C.	60	114	47	30	191	2,300	5.4	+6	56	529	1,900	99	100
548	12 minutes	88° C.	60	105	48	26	179	2,500	5.2	+5	56	528	1,830	100	99
549	15 minutes	88° C.	60	112	44	33	189	2,500	4.9	+10	58	531	1,820	98	96
550	18 minutes	88° C.	60	126	49	30	205	2,350	5.1	+15	56	538	1,800	98	94

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Kansas Agricultural Experiment Station

water can be added. The wheat used in the present experiment was only a little below the normal moisture content and of excellent quality. Consequently, no such great improvement from the treatment used could be expected as from wheat that is not so good.

CONCLUSIONS REGARDING THE TEMPERING OF WHEAT.

The experiments show that heat, especially when used on new wheat, improve the milling quality of the wheat and the baking qualities of the flour. The interval that should elapse between the time the wheat is moistened and heated and the time that it is milled depends on the hardness of the wheat and the amount of moisture added. If the wheat has nearly the normal moisture content and is of good quality this "curing" process does not seem to be so important. But where a large amount of moisture needs to be added it seems that this longer tempering is very beneficial. This was shown in the previous experiments. The miller should have at his command such facilities that he can treat the wheat with successive amounts of moisture, heat the wheat to any desired temperature, and allow it the necessary period of "curing" before milling. These would place the miller in a position in which he is not the victim of circumstances but master of the situation.

It should be remembered that these experiments were conducted on a small scale. Investigations more nearly approximating commercial tempering conditions are needed to corroborate the results.

EXPERIMENTS TO DETERMINE THE EFFECTS OF GERMINATION ON BOTH WHEAT AND FLOUR.

The effects of germination on the milling and baking qualities of wheat were first studied at this station in the summer of 1907, and the results were published in Bulletin 177. The following is a brief summary of these results:

"There was a progressive increase in milling loss proportional to the time the wheat was germinated. The chemical analyses showed an increase in acidity and amino compounds corresponding to the length of time the wheat was treated. These results were to be expected. But the baking test showed a slight improvement for a small amount of germination. The texture improved in quality and the volume of the loaf increased with the time of germination up to the third day, after which there was a distinct deterioration in texture and a decrease in

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Kansas Agricultural Experiment Station

loaf volume. It was apparent that germination, to a slight extent, may perform some useful function in modifying the baking qualities of flour, provided that this beneficial result was not more than offset by milling loss and decrease of gluten strength."

The germination trials here reported were undertaken partly to corroborate the results given in Bulletin 177 and partly to obtain additional data.

Methods Used.

The wheat used in this test was from shock-threshed wheat cut in prime condition. It was the same lot as was used in the storage experiment previously described and also in the special tempering tests. It represented wheat which had had no opportunity to undergo the sweating process. The time between threshing and starting the experiment was about three days and would correspond to the shortest time possible between the cutting of the wheat and its arrival at the mill. The wheat was clean and of very good quality.

Observations on the First Trial.

The first germination trial was carried on at the greenhouse. The wheat was spread on muslin laid on clean sand. A square yard was allowed for each kilogram of wheat. Canton flannel was placed over the wheat. The wheat and all the cloth was soaked in a two percent solution of formaldehyde previous to starting the experiment. This was only partially successful in preventing the growth of mold. As much water as the wheat and sand would absorb was applied several times a day.

The wheat was divided into seven lots, and the original plan was to germinate each lot for different lengths of time, beginning with one day and extending the time to seven days.

This plan was partially modified, as the lots did not germinate evenly. Each lot of the air-dry wheat was weighed before starting the experiment and after the treatment it was spread on a bench in the greenhouse, where it became air dry very soon, in which condition it was again weighed. All lots but one in the first trial showed a gain. The wheat was below normal moisture when the experiment started. Consequently, the air-dry wheat after the treatment contained more moisture than before treatment. This explains the gain.

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Kansas Agricultural Experiment Station

421. This sample was germinated 24 hours with no signs of germination.

422. This sample was germinated 36 hours with no signs of germination.

423. This sample was germinated 60 hours with a few signs of germination.

424. This sample was germinated 89 hours. A very few kernels showed signs of germination.

425. This sample was germinated 101 hours. The kernels were all swollen and a few germinated.

426. This sample was germinated 120 hours. More kernels germinated than in 425. The grain was rather moldy.

427. This sample was germinated 130 hours. More kernels germinated than in any of the previous lots. The grain was rather moldy.

The first trial of germination was not successful. The heat in the greenhouse was too intense for germination to occur properly. For this reason the trial was repeated; this time in a basement where the temperature was about 85° F. The samples from the first test were used, nevertheless, for the milling and baking work, to compare with the samples in the second trial.

OBSERVATIONS ON THE SECOND TRIAL.

464. Lot 1 was germinated 28 hours. All kernels were swollen and soft.

465. Lot 2 was germinated 43 hours. Germination started, and sprouts one-eighth inch long appeared on about one-fifth of the kernels. No roots developed. The remainder were swollen and appeared to be ready to sprout.

466. Lot 3 was germinated 67 hours. It showed a marked development in root system as compared with lot 2. The roots varied from one-fourth to one inch in length. The sprouts were from one-eighth to one-fourth inch long. Some kernels were moldy.

467. Lot 4 was germinated 76 hours. The roots were from one-fourth to one inch long and the wheat was moldy.

468. Lot 5 was germinated 91 hours. The sprouts were from one-half to one inch long, while the roots averaged three-fourths inch long. The wheat was very moldy.

469. Lot 6 was germinated 99 hours. The sprouts were from one to one and three-fourths inches long, and the roots

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Kansas Agricultural Experiment Station

one to one and one-third inches long. The wheat was not moldy and growth was very rank, the sprouts taking on a dark green color and the leaves beginning to open.

470. Lot 7 was germinated 119 hours. The roots averaged two inches long and the sprouts one and three-fourths to two inches in length. No mold was present. The percent of germination was less in this lot than in 6.

MILLING TESTS OF GERMINATED WHEAT.

The results of the milling tests on the germinated wheat from both trials appear in table XX. In the second trial the

TABLE XX. Milling tests of germinated wheat.

Serial number.	Hours germinated.	Percent weight gained or lost.	Tempering water for 2,500 grams.	Percentages.					
				Loss in scouring.	Loss in milling.	Feed.	Total flour.	First-grade flour.	Second-grade flour.
First trial:									
421	24	+2.60	50 cc.	1.88	0.68	24.40	74.70	88.62	11.38
422	36	+1.76	30 cc.	2.68	1.36	23 48	72.48	88.96	11.04
423	60	+1.92	30 cc.	3.20	1.88	22.64	72.28	88.21	11.79
424	89	+0.32	30 cc.	4.44	2.60	22.52	70.44	87.39	12.61
425	101	−0.04	30 cc.	5.36	3.84	24.60	66.20	83.44	16.56
426	120	+0.36	30 cc.	6.16	2.08	26.52	65.24	80.32	19.68
427	130	+0.80	25 cc.	12.00	3.44	23.40	61.16	87.88	12.12
Second trial:									
464	28	+4.96	20 cc.	6.20	1.80	21.80	70.20	87.07	12.93
465	43	+1.72	20 cc.	2.92	2.92	23.08	71.08	86.77	13.23
466	67	+4.92	20 cc.	8.36	5.64	20.40	65.60	91.46	8.54
467	76	−3.24	20 cc.	14.68	3.44	20.24	61.64	85.20	14.80
468	91	0	20 cc.	16.00	1.60	20.04	62.36	82.30	17.70
469	99	−2.88	20 cc.	23.92	2.56	20.16	53.36	89.06	10.94
470	119	−7.44	20 cc.	33.60	1.60	18.40	46.40	88.70	11.30

samples germinated for a shorter period showed a gain in weight. Those germinated for a longer period showed a loss. The gain in the samples was due to absorption of moisture, but later this gain was more than offset by the metabolic processes in the sprouting kernels. From a milling standpoint the process of germination is detrimental. The loss in scouring even slightly germinated wheat is greater than that of normal sound wheat and the percentage loss increases with the amount

Historical Document
Kansas Agricultural Experiment Station

of germination. This was true for both sets of samples, but more evident for the second set. The mere exposure to moisture and a high degree of heat, such as was found in the greenhouse at this time, did not do as great damage as when this was accompanied by the process of germination. The amount of flour, both first grade and total, decreased. The term "first grade" is used here simply to distinguish the better from the poorer grade. Strictly speaking, from the samples germinated several days, no first-grade flour could be obtained. The second set of germinated samples showed a larger decrease in the amount of flour obtained than did the first set.

Chemical Analysis of Germinated Wheat.

Only the samples from the second set of geminated wheats were analyzed. The results are given in table XXI. The percentage of ash was corrected for the amount of sand

TABLE XXI. Chemical analysis of germinated wheat.

Serial number.	Hours germinated.	Moisture.	Percentage, moisture-free basis.				
			Ash.	Protein.	Amino compounds.	Acidity.	Total phosphorus.
464	28	10.47	2.15	11.15	0.369	0.488	0.514
465	43	11.38	2.12	11.12	0.412	0.483	0.497
466	67	13.30	2.11	11.33	0.538	0.633	0.488
467	76	11.69	2.17	11.35	0.549	0.846	0.523
468	91	11.83	2.19	11.12	0.704	0.843	0.502
469	99	10.49	2.23	11.36	1.127	0.945	0.525
470	119	10.90	2.48	11.93	1.253	1.080	0.542

present. The increase in ash in the samples germinated longer was probably due to a proportionately greater loss of organic material as compared with the inorganic.

The greatest change occurred in the percentage of amino compounds and in the acidity value. Both these showed increases corresponding to the length of time germinated. The increase in acidity may be due to the increase in amino compounds, but it is not likely due to the presence of a larger amount of soluble phosphates, as the total amount of phosphorus is not increased. Unfortunately, the water-soluble phosphorus was not determined. In the flour, as will be shown later, there was a close relation between the soluble and the total phosphorus.

Historical Document
Kansas Agricultural Experiment Station

CHEMICAL ANALYSIS OF FLOURS FROM GERMINATED WHEAT.

The data for the chemical analysis of flours from germinated wheats are given in table XXII. There is no material change in protein content other than can be accounted for by the variation in quality of the flour due to difference in milling, except in the samples from the wheats germinated the longest, where the decrease of protein is so pronounced that it must be due to the effects of germination.

GLUTEN CONTENT. The amount of dry gluten decreases in proportion as the germinated period increases, and the decrease is most pronounced in the samples germinated longest. Germination can proceed until gluten can not be formed from flour made from such wheat. The deterioration in quality was more pronounced than the decrease in quantity. A slight amount of germination in new wheat has a softening influence on the gluten very similar to the aging process such as takes place when the wheat undergoes sweating. So far germination does no harm to the baking qualities of the flour, but germinated wheat is not so valuable as sound wheat, even if the amount of germination is slight, because the milling value is decreased, the flour yield is less and the gluten decreases in quantity and strength proportionate to the amount of germination. Yet the experiment shows that a small amount of germination in wheat does not unfit the flour for use.

The protein in the crude gluten was found by determining the nitrogen in the crude gluten and multiplying the result by 5.7, the protein factor. The figures show that dry gluten consists of from 80 to 88 percent pure protein. The figures for dry gluten and the protein agree quite closely. The difference between the pure gluten and the dry gluten is made up of compounds other than protein, such as crude fiber, starch and some fat and ash.

CONTENT OF SUGAR OR SOLUBLE CARBOHYDRATES. The samples from the first trial showed a slight decrease in the content of soluble carbohydrates. As the wheat did not germinate there was little or no diastatic activity and hence there would be no increase in soluble carbohydrates. The slight decrease may be due to leaching or to experimental error though the regular decrease would suggest the former. In the second trial the increase in soluble carbohydrate content is

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Kansas Agricultural Experiment Station

TABLE XXII. Chemical analysis of flours from germinated wheat.

Serial number.	Time germinated, hours.	Moisture.	Moisture-free basis, percentages.											
			Ash.	Protein.	Protein in gluten.	Gluten.			Sugar.	Acidity.	Amino compounds.	Water-soluble phosphorus.	Total phosphorus.	Percent water-soluble phosphorus in total.
						Dry.	Pure.	Wet.						
First trial:														
418	0	11.17	0.63	9.99	84.46	9.79	8.27	28.29	2.23	0.180	0.145	0.068	0.144	47.22
421	24	12.29	0.59	10.03	79.98	10.66	8.53	31.69	2.33	0.190	0.135	0.067	0.146	45.89
422	36	12.25	0.60	9.89	87.53	9.40	8.23	27.45	2.26	0.186	0.123	0.066	0.140	47.14
423	60	12.46	0.53	9.79	87.33	9.25	8.08	26.04	2.03	0.175	0.096	0.061	0.131	46.56
424	89	12.16	0.64	9.68	86.77	9.22	8.00	27.26	1.89	0.196	0.093	0.072	0.146	49.31
425	101	12.57	0.46	9.40	85.77	8.69	7.45	25.95	1.87	0.185	0.114	0.063	0.128	49.21
426	120	12.42	0.56	9.19	87.11	8.61	7.51	23.68	1.79	0.176	0.110	0.057	0.127	44.88
427	130	12.82	0.53	9.37	87.46	8.77	7.67	24.43	1.93	0.184	0.164	0.061	0.131	46.56
Second trial:														
464	28	11.95	0.58	9.66	87.82	9.08	7.97	26.62	1.91	0.178	0.093	0.054	0.133	40.60
465	43	11.87	0.56	9.65	87.60	9.02	7.90	24.49	2.10	0.192	0.101	0.065	0.139	46.76
466	67	12.70	0.59	9.51	86.72	8.87	7.69	22.90	2.14	0.235	0.143	0.076	0.151	50.33
467	76	11.06	0.74	9.72	87.58	7.87	6.89	20.34	2.46	0.350	0.220	0.107	0.182	58.79
468	91	11.82	0.59	8.97	88.29	6.24	5.51	16.56	2.69	0.281	0.255	0.076	0.145	52.41
469	99	10.95	0.54	8.78	....	1.12	....	2.92	3.69	0.303	0.265	0.079	0.147	53.06
470	119	11.41	0.46	9.08	82.55	3.38	2.79	9.31	3.93	0.263	0.376	0.065	0.135	48.14

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Kansas Agricultural Experiment Station

regular in proportion to the time of germination. An analysis of the entire kernel would doubtless have shown larger increases as that part of the kernel which was changed most was removed in the scouring process.

CONTENTS OF ACIDITY, AMINO COMPOUNDS, AND PHOSPHORUS. The amounts of acidity, amino compounds, and phosphorus present in flour are more or less determined by the same factors that determine the amount of ash. To overcome variation due to these factors the percentage of each of these constitutents was divided by the percentage of ash. While this does not remove all the disturbing influences, figures are obtained which are more comparable among themselves. The figures thus obtained are given in table XXIII. In the first

TABLE XXIII. Chemical analysis of flours from germinated wheat, percentages of acidity, amino compounds and phosphorus corrected for different amounts of ash.

Serial number.	Time germinated.	Acidity.	Amino compounds.	Water-soluble phosphorus.	Total phosphorus.
First trial:					
418	....	0.286	0.230	0.108	0.229
421	24 hours.	0.322	0.229	0.114	0.247
422	36 hours.	0.310	0.205	0.110	0.233
423	60 hours.	0.330	0.181	0.115	0.247
424	89 hours.	0.306	0.145	0.112	0.228
425	101 hours.	0.402	0.248	0.137	0.278
426	120 hours.	0.314	0.196	0.102	0.227
427	130 hours.	0.347	0.309	0.115	0.247
Second trial:					
464	28 hours.	0.307	0.160	0.093	0.229
465	43 hours.	0.343	0.180	0.116	0.248
466	67 hours.	0.398	0.242	0.129	0.256
467	76 hours.	0.473	0.297	0.145	0.246
468	91 hours.	0.476	0.432	0.129	0.246
469	99 hours.	0.561	0.491	0.146	0.272
470	119 hours.	0.572	0.817	0.141	0.293

set of germinated samples there was no regular increase or decrease in the amount of any of these compounds. In the second set there was an increase in the acidity value and the amount of amino compounds corresponding to the length of time germinated. The amount of water-soluble phosphorus shows an increase the first four days, after which there is no further increase. If these figures represent the true con-

Historical Document
Kansas Agricultural Experiment Station

dition it means that the soluble phosphates were used by the new vegetative cells after the first four days as fast as formed. The constant increase in the percentage of acidity and of amino compounds, while the soluble phosphorus showed no such increase, shows that the increased acidity is not due to the increase in water-soluble phosphorus, but, as was suggested in the case of the wheat, to the presence of large amounts of amino compounds.

BAKING TESTS OF FLOUR FROM GERMINATED WHEAT.

The results of the baking tests of flours from germinated wheat are shown in table XXIV and the photographs are shown on plates XII, XIII, XIV and XV. On the whole the first set of germinated samples did not show the effects of germination as much as the second set. The effects of germination were shown in decreased total expansion, rise in the oven, and loaf volume; and poorer color and texture corresponding with the length of time germinated. As in the former trial, reported in Bulletin 177, a slight amount of germination resulted in an increased loaf volume. Thus the loaf volume of the flour from new but sound wheat was 1520 cc., while from that germinated one and two days it was 1810 cc. This was very nearly the volume obtained from the flour of the same sound wheat thirteen weeks after milling, when the flour had undergone the natural aging process.

The loaf volume obtained depends partly upon the resistance the dough offers to the expansion of gases formed by the action of the yeast, and partly upon the gas-retaining capacity of the gluten. Flour from new wheat forms a dough that is very stiff; that is, the gluten offers such resistance that the gas produced by the yeast is unable to expand the dough to the desired volume. The bread has a heavy texture. Germination tends to soften the gluten, hence a slight amount of germination produces a larger loaf. On the other hand, if the gluten is weakened too much, it lacks in gas-retaining capacity; the bubbles formed by the gas coalesce and the resulting bread has a coarse texture.

When germination had proceeded beyond the second day, the gluten began to weaken too much and the resulting texture was unsatisfactory. When the gluten weakens too much it

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Kansas Agricultural Experiment Station

TABLE XXIV. Baking tests of flours from germinated wheat.

Serial number	Time germinated, hours	Percent moisture	Percent absorption	Water for loaf, cc	Time for proving, minutes. 1st rise	2d rise	3d rise	Total	Maximum expansion of dough, cc	Rise in oven, cm	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc	Texture of crumb. 100=Perfection	Texture of loaf. 100=Perfection
First trial:																
418	0	11.17	55.0	187	62	68	36	166	2,000	1.3	17	41	504	1,520	83	89
421	24	12.29	56.6	192	63	67	35	165	2,100	1.9	5	51	511	1,590	83	89
422	36	12.25	56.6	192	55	67	37	159	2,200	2.1	13	45	509	1,670	83	89
423	60	12.46	56.6	192	65	70	41	176	2,100	2.2	16	40	511	1,600	83	89
424	89	12.16	56.6	192	68	67	42	177	2,000	1.8	15	44	508	1,650	80	87
425	101	12.57	56.6	192	66	86	40	192	2,150	3.1	13	51	503	1,700	82	87
426	120	12.42	56.6	192	74	72	47	193	1,900	2.1	9	64	494	1,660	70	77
427	130	12.82	56.6	192	75	63	45	183	1,850	2.2	10	66	491	1,690	60	77
Second trial:																
464	28	11.95	56.6	192	67	73	40	180	2,200	3.1	9	57	501	1,810	90	89
465	43	11.87	56.6	192	67	68	37	172	2,150	3.4	11	58	498	1,810	89	87
466	67	12.70	56.6	192	70	72	38	180	2,150	3.2	17	54	496	1,780	88	80
467	76	11.06	55.0	187	72	72	44	188	1,900	2.0	13	54	495	1,580	70	75
468	91	11.82	53.3	181	86	51	47	184	1,650	1.4	16	53	487	1,550	60	70
469	99	10.95	53.3	181	93	54	38	185	1,500	0.8	14	57	485	1,200	40	60
470	119	11.41	53.3	181	87	57	31	175	1,400	1.1	5	53	498	1,220	50	65

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loses its gas-retaining capacity and a large loaf becomes impossible; hence, there was a progressive decrease in the volume accompanied by a poorer texture. The poorer texture was also accompanied by a darker color.

EFFECT OF MIXING FLOUR FROM GERMINATED WHEAT WITH FLOUR FROM SOUND WHEAT.

The effects of mixing flour from germinated wheat with flour from sound wheat are shown by the figures given in table XXV. The photographs of loaves are shown in plates XVI, XVII, XVIII, XIX, XX, XXI, XXII.

Flour made entirely from germinated wheat is never found on the market. A small percent of sprouted kernels is sometimes found in wheat that is being milled. Consequently, the resulting flour contains a small amount of flour made from germinated wheat. To determine the effect of a small amount of .germinated wheat in the milling blend, flours from the wheat germinated in the second trial were mixed in four different proportions with a standard patent flour. The amounts of flour from germinated wheat, mixed with the standard, were 3 per cent, 6¼ percent, 12½ percent and 25 percent. Thus there were four separate mixtures from each of the flours from germinated wheat. Samples were baked on two separate days in order to confirm the results. The two sets of bakings were as near duplicates as is possible to obtain in baking tests.

The result was a surprise. The presence of flour from germinated wheat did not seem to have any deleterious effect even when this amounted to 25 percent of the mixture. The flour from the wheat germinated six and seven days tended to increase the rise in the oven and loaf volume, but this was accompanied by a slight impairment in texture and color. As much as 25 percent of germinated wheat would seldom be found mixed with sound wheat under practical conditions; also it would very infrequently happen that wheat would be germinated to such an extent as it was in this trial. So far as influencing the baking qualities, the slight amount of germination which would take place in the shock during wet weather would have practically no effect. It should be remembered, however, that the standard flour used in this test was a very good representative of a strong flour.

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TABLE XXV. Baking tests of standard patent flour and of blends of this flour with flour from germinated wheat.

Serial number	Hours germinated	Percent of flour from germinated wheat	Percent absorption	Water for loaf, cc	Time for proving, minutes. 1st rise	2d rise	3d rise	Total	Maximum expansion of dough, cc	Rise in oven, cm	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc	Texture of crumb. 100=Perfection	Color of loaf. 100=Perfection
Standard.	0	0	56.6	192	73	86	36	195	2,600	5.1	8	53	507	1,865	96	100
464*a*	28	3.00	56.6	192	66	83	26	175	2.700	5.0	3	60	504	1,910	98	99
464*b*	28	6.25	56.6	192	61	84	32	177	2,650	4.8	14	53	500	1,870	94	98
464*c*	28	12.50	56.6	192	66	86	32	184	2,600	5.1	2	53	512	1,840	98	99
464*d*	28	25.00	56.6	192	67	91	36	194	2,500	4.7	11	55	501	1,880	97	99
465*a*	43	3.00	56.6	192	65	93	32	190	2,750	4.8	13	54	500	1,890	98	99
465*b*	43	6.25	56.6	192	65	93	32	190	2,600	4.8	12	48	507	1,890	98	99
465*c*	43	12.50	56.6	192	73	81	38	192	2,500	5.4	1	49	517	1,890	98	98
465*d*	43	25.00	56.6	192	68	87	35	190	2,550	4.4	14	46	507	1,890	97	98
466*a*	67	3.00	56.6	192	72	89	33	194	2,700	5.1	12	51	504	1,940	98	99
466*b*	67	6.25	56.6	192	80	92	35	207	2,600	5.3	11	54	502	1,870	98	99
466*c*	67	12.50	56.6	192	75	89	34	198	2,600	5.7	+1	59	509	1,920	97	98
466*d*	67	25.00	56.6	192	75	90	37	202	2,450	5.4	16	45	506	1,980	97	97
467*a*	76	3.00	56.6	192	72	91	34	197	2,500	5.1	9	42	516	1,880	98	99
467*b*	76	6.25	56.6	192	72	91	31	194	2,550	5.0	12	46	509	1,860	98	99
467*c*	76	12.50	56.6	192	72	91	37	200	2,400	4.7	7	59	501	1,900	97	98
467*d*	76	25.00	56.6	192	72	92	32	196	2,600	4.7	11	58	498	1,890	97	97
468*a*	91	3.00	56.6	192	73	95	36	204	2,500	5.3	11	60	496	1,860	98	99
468*b*	91	6.25	56.6	192	85	96	37	218	2,450	5.1	11	61	495	1,870	96	98
468*c*	91	12.50	56.6	192	82	91	37	210	2,400	4.9	8	62	497	1,850	96	98
468*d*	91	25.00	56.6	192	84	88	34	206	2,500	4.7	12	57	498	1,850	96	96
469*a*	99	3.00	56.6	102	90	89	36	215	2,500	5.5	9	56	502	1,940	98	99
469*b*	99	6.25	56.6	192	82	92	32	206	2,500	5.2	11	58	498	1,930	97	98
469*c*	99	12.50	56.6	192	85	92	33	210	2,500	5.8	7	59	501	1,950	96	97
469*d*	99	25.00	56.6	192	86	90	34	210	2,500	5.4	6	65	496	1,940	95	96
470*a*	119	3.00	56.6	192	82	98	37	217	2,550	5.2	8	61	498	1,950	96	99
470*b*	119	6.25	56.6	192	80	100	33	213	2,550	5.5	9	60	498	1,940	96	98
470*c*	119	12.50	56.6	192	90	85	35	210	2,400	5.6	10	57	500	1,940	94	97
470*d*	119	25.00	56.6	192	90	87	33	210	2,400	6.1	8	62	497	1,960	94	96

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The results here obtained differ materially from those obtained in a former trial.* There were three important differences between the present trial and the one just referred to: in the earlier trial the wheat used was old, it was not scoured before milling, and the standard flour used was not as strong as that used in the present experiment.

The greatest damage from germination comes in decreasing the milling value of the wheat. The yield of flour is not so great and it is more difficult to get flour of a good color. There is also a decrease in the quantity and strength of the gluten. Thus while germination is harmful to this extent, slightly germinated wheat mixed with sound wheat is not entirely unfit for flour-making purposes nor should flour made from such mixture be unconditionally condemned.

FURTHER EXPERIMENTS TO DETERMINE THE EFFECT OF GERMINATION ON BOTH WHEAT AND FLOUR (1912).

The experiments with germinated wheat the previous year were so interesting that it was deemed worth while to continue the trial for one more season. This time the wheat was germinated in three stages in a manner similar to the previous trials. The first was germinated for 32 hours, the second for 71 hours, and the third for 94 hours. The percentage of kernels germinated in the first lot was 18.6, in the second 36.6, and in the third 39.9. In the first lot the sprouts averaged about one-eighth of an inch long, in the second one-fourth of an inch long, and in the third one-half inch. As will be noted from the proportion of kernels that germinated, many kernels had not sent out any sprouts and those which had germinated were in all stages. When the wheat was dry these small sprouts and the roots dried up and appeared very insignificant. The percentage of germination was determined on the dried wheat, because it is in that condition when received by the grain men.

The main object of this test was to determine if these germinated wheats and the flour from them deteriorate relatively faster than sound wheat or flour from sound wheat. The results as far as carried out show that the mere process

* Bulletin 190, Kansas Experiment Station.

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Kansas Agricultural Experiment Station

of germination does not injure the keeping qualities of the flour.

The analyses of these germinated wheats are found in table XXVI. The only distinct change is the increase of the content of soluble carbohydrates, which corresponds to the length of time germinated. The amino compounds, contrary to the results of previous trials, show no change.

TABLE XXVI. Analysis of germinated wheat and percentage of moisture in the resulting flour.

Serial number.	Time germinated.	Wheat.				Moisture in flour.
		Acidity.	Sugar.	Amino compounds. N × 5.7.	Moisture.	
524	32 hours.	0.46	2.63	0.52	13.87	13.71
525	71 hours.	0.49	2.74	0.52	11.91	12.72
526	94 hours.	0.52	2.97	0.58	12.78	12.20

Baking Tests of Flours From Germinated Wheat.

There were three sets of bakings made on the flour from this wheat. The results are shown in table XXVII. The first milling was done eighteen days after germination and the flour was baked sixteen days later. The flour from the wheat germinated thirty-two hours produced a loaf which was in every way the equal, if not the superior, of that produced from standard flour. The longer periods of germination produced deleterious effects corresponding to their length.

The second baking test was made on the flour from the first milling test, fifty days after the flour was milled. There was a distinct improvement in all the loaves, but the greatest improvement was in the flour which made the poorest showing in the first test. In evenness of texture and thinness of cell wall, these loaves were good. There was much less difference among the loaves in this trial than in the first. The flour from the wheat longest germinated produced the largest loaf. The color of all the loaves was poor. This is due to the fact that the bran from these germinated wheats is very brittle, and the flour is consequently specky.

A second milling test was made sixty-seven days after germination. After the flour had been stored twenty-five days, the baking test was made. Results were as good as in the second test.

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TABLE XXVII. Baking tests on flours from germinated wheat.

Serial number	Time germinated, hours	Percent absorption	Time of proving, minutes.				Maximum expansion of dough, cc	Rise in oven, cm	Loss in mixing and rising, grams	Loss in baking and cooling, grams	Weight of loaf, grams	Volume of loaf, cc	Evenness of texture. 100=Perfection	Thinness of wall. 100=Perfection	Color of loaf. 100=Perfection
			1st rise	2d rise	3d rise	Total									
First set:															
524	32	59.0	149	53	33	235	2,350	5.8	13	53	510	1,930	95	96	....
525	71	59.0	144	53	37	234	2,250	4.6	5	56	515	1,860	90	90	....
526	94	58.3	135	52	35	222	2,150	4.0	9	49	515	1,700	80	80	....
Second set:															
524	32	56.0	137	53	30	220	2,850	5.9	3	50	512	1,930	93	93	85
525	71	56.0	135	47	30	212	2,700	6.2	2	51	512	1,981	92	91	85
526	94	56.0	126	48	30	204	2,500	6.1	1	51	513	2,030	92	90	84
Third set:															
524	32	56.0	132	55	38	225	2,650	6.1	6	55	504	1,950	93	94	85
525	71	56.0	130	53	41	224	2,500	5.9	2	53	510	1,960	92	92	85
526	94	56.0	122	48	35	205	2,450	5.8	5	51	509	1,930	92	92	84

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These results show that germinated wheat does not deteriorate on storing, but undergoes the same improvement as sound wheat. The same is true of the flour.

CHEMICAL ANALYSIS OF FLOURS FROM GERMINATED WHEAT.

The flours from the last milling test were analyzed. The results are found in table XXVIII.

There is a decrease in the quantity of gluten corresponding to the length of the germinating period. The acidity and the amino compounds show a slight increase.

TABLE XXVIII. Analysis of flours from germinated wheat, the wheat having been stored 67 days, and the flour 25 days.

Serial number.	Moisture in flour.	Ash.	Protein.	Gluten.		Acidity.	Amino nitrogen.	Soluble phosphorus.	Total phosphorus.
				Dry.	Wet.				
524	13.93	0.508	10.60	14.31	38.64	0.144	0.54	0.0459	0.1108
525	12.68	0.512	10.83	10.89	37.09	0.156	0.74	0.0472	0.1152
526	12.99	0.500	10.49	10.35	34.59	0.159	0.67	0.0467	0.1051

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PLATE I. Loaves of bread baked from flour which had not undergone an aging process. (Note the coarse texture.)

1*a*. Standard patent flour for comparison.
418. Flour from wheat cut in prime condition.
419. Flour from wheat cut underripe.
420. Flour from wheat cut overripe.

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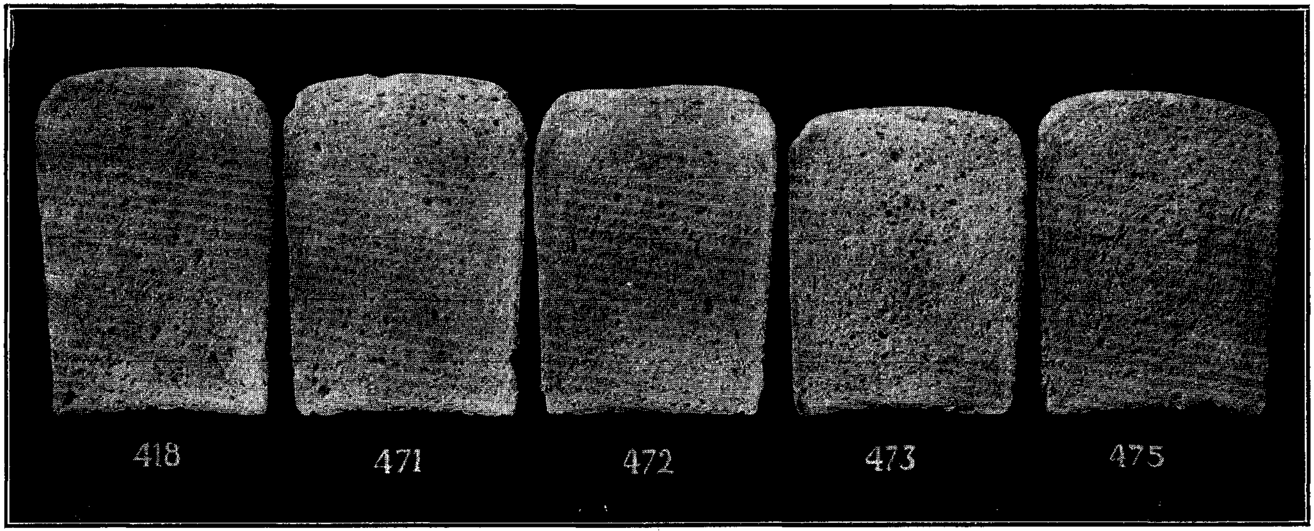

PLATE II. Loaves of bread baked from aged flour and from flour from aged prime wheat. (Note the fine texture.)

418. Flour thirteen weeks after milling.
471. Flour from wheat in stack.
472. Flour from wheat in shock.
473. Flour from wheat stored in tight bin.
475. Flour from wheat moistened and stored.

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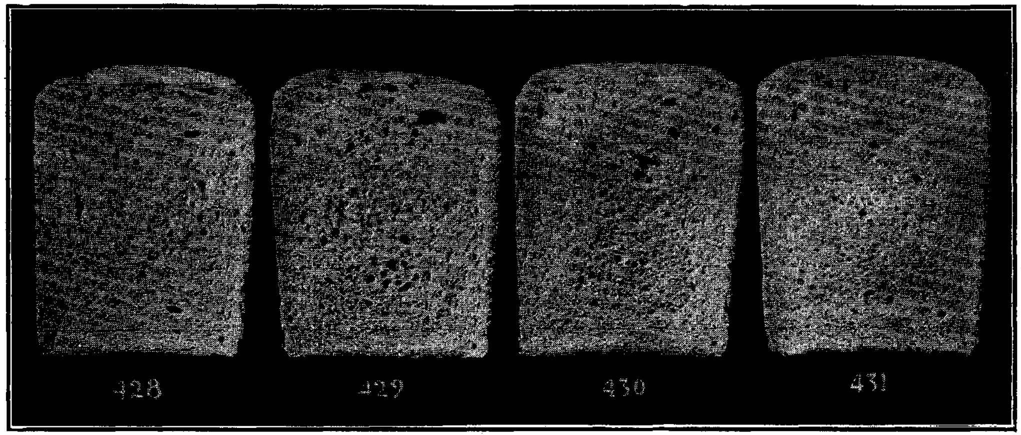

PLATE III. Loaves of bread baked from flour from wheat tempered by adding 25 cc. of water per kilo and heating at 45° C. (113° F.)

428. Wheat tempered for six hours.
429. Wheat tempered for twelve hours.
430. Wheat tempered for twenty-four hours.
431. Wheat tempered for forty-eight hours.

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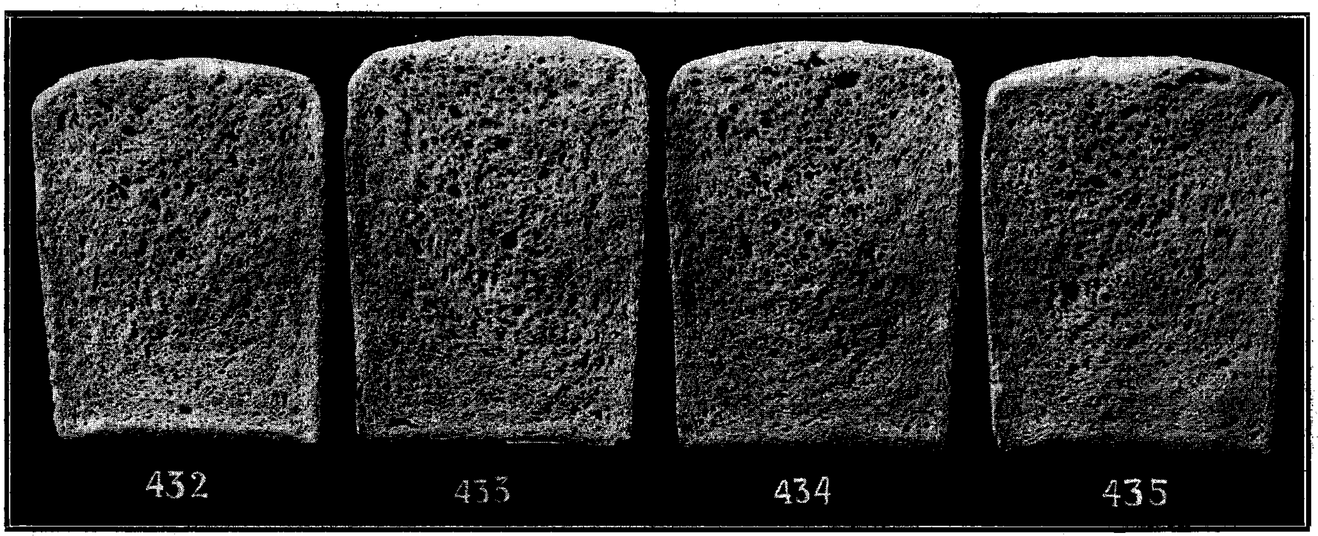

PLATE IV. Loaves of bread baked from flour from wheat tempered by adding 50 cc. of water per kilo and heating at 45° C. (113° F.)

432. Wheat heated for three hours.
433. Wheat heated for six hours.
434. Wheat heated for twelve hours.
435. Wheat heated for twenty-four hours.

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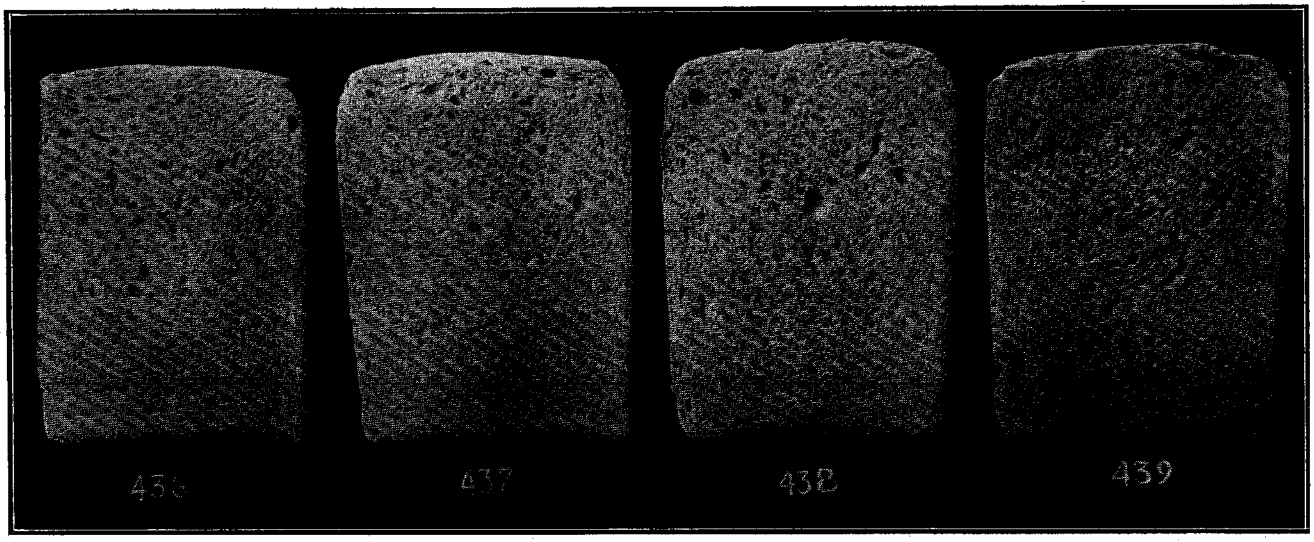

PLATE V. Loaves of bread baked from flour from wheat tempered by adding 100 cc. of water per kilo and heating at 45° C. (113° F.)

436. Wheat heated for one and one-half hours.
437. Wheat heated for three hours.
438. Wheat heated for six hours.
439. Wheat heated for twelve hours.

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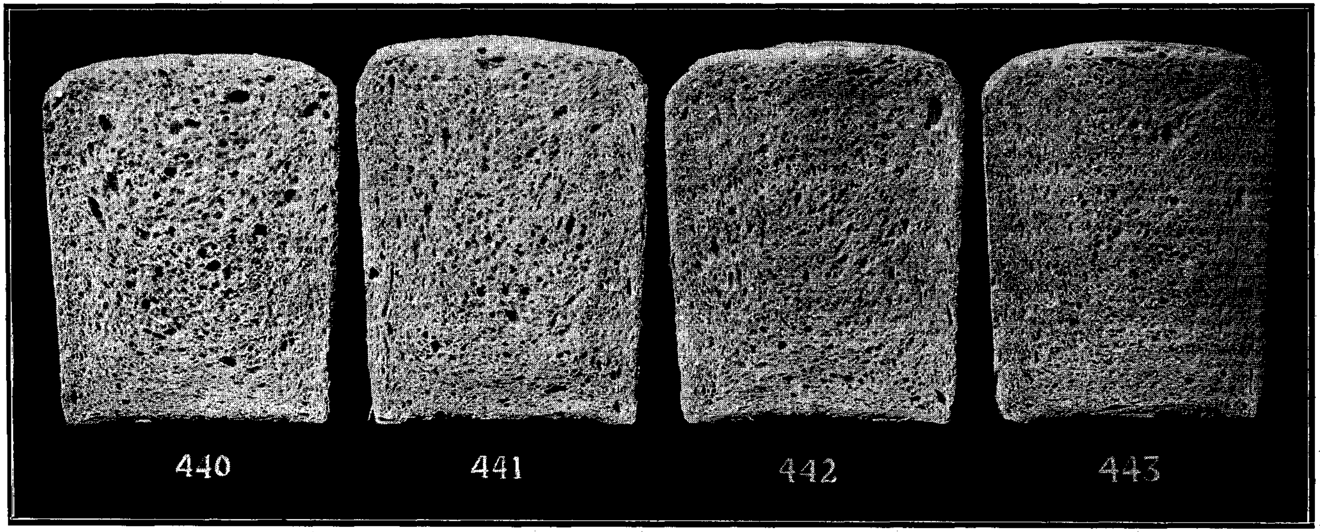

PLATE VI. Loaves of bread baked from flour from wheat tempered by adding 25 cc. of water per kilo and heating at 70° C. (158° F.)

440. Wheat heated for three hours.
441. Wheat heated for six hours.
442. Wheat heated for twelve hours.
443. Wheat heated for twenty-four hours.

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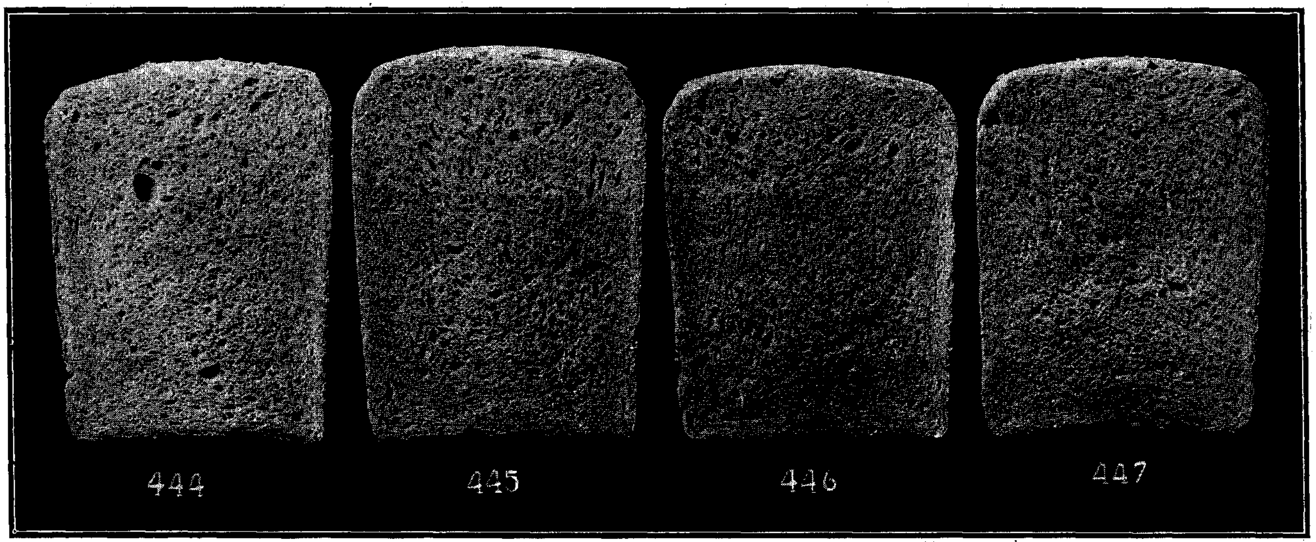

PLATE VII. Loaves of bread baked from flour from wheat tempered by adding 50 cc. of water per kilo and heating at 70° C. (158° F.)

444. Wheat heated for one and one-half hours.
445. Wheat heated for three hours.
446. Wheat heated for six hours.
447. Wheat heated for twelve hours.

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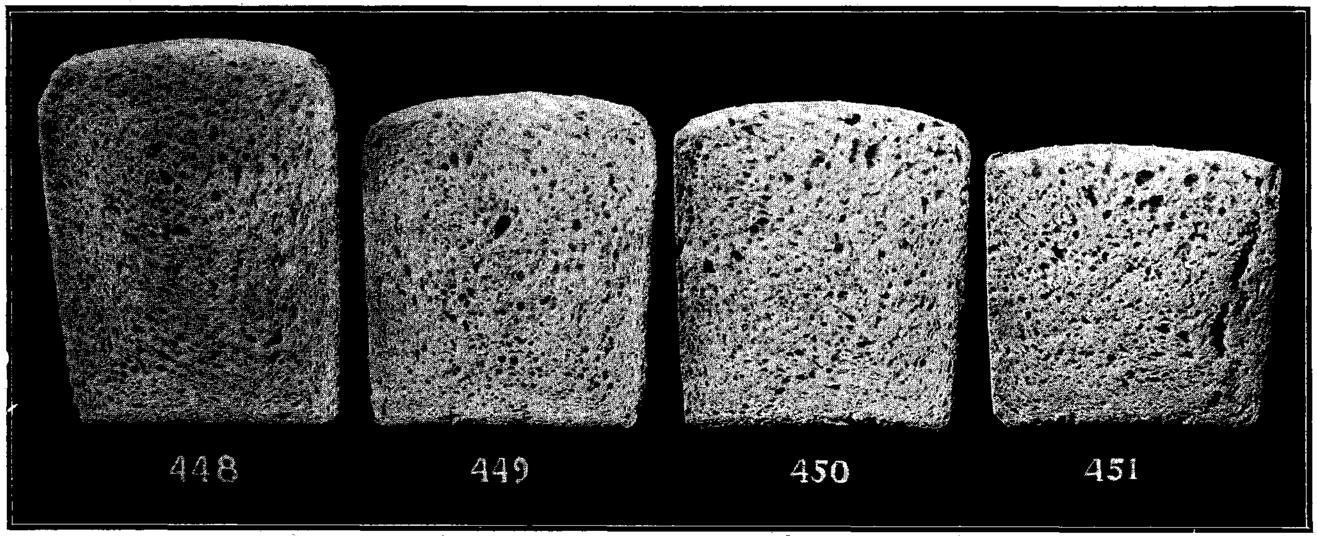

PLATE VIII. Loaves of bread baked from flour from wheat tempered by adding 100 cc. of water per kilo and heating at 70° C. (158° F.)

448. Wheat heated for three-fourths hour.
449. Wheat heated for one and one-half hours.
450. Wheat heated for three hours.
451. Wheat heated for six hours.

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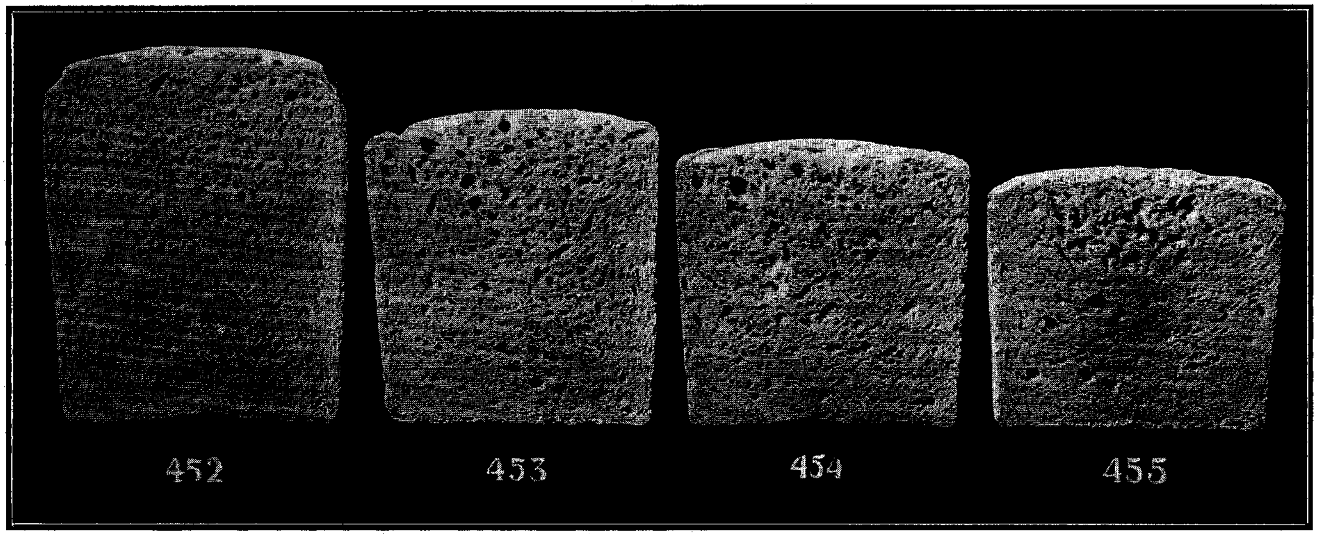

PLATE IX. Loaves of bread baked from flour from wheat tempered by adding 25 cc. of water per kilo and heating at 98° C. (208° F.)

452. Wheat heated for three-fourths hour.
453. Wheat heated for one and one-half hours.
454. Wheat heated for three hours.
455. Wheat heated for six hours.

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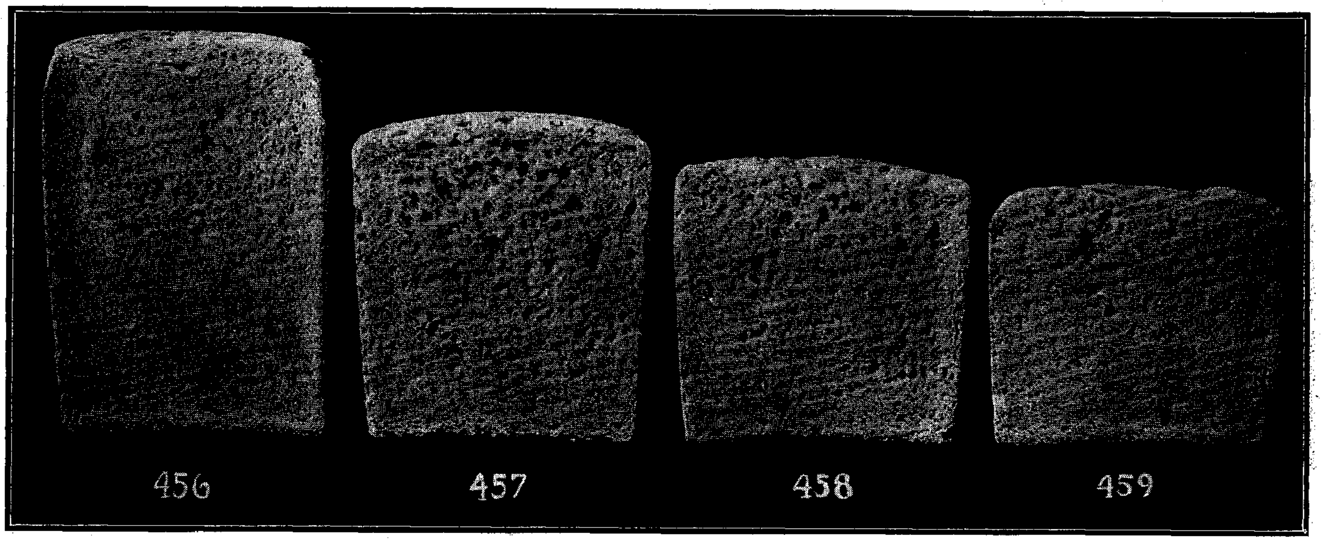

PLATE X. Loaves of bread baked from flour from wheat tempered by adding 50 cc. of water per kilo and heating at 98° C. (208° F.)

456. Wheat heated for twenty-two minutes.
457. Wheat heated for three-fourths hour.
458. Wheat heated for one and one-half hours.
459. Wheat heated for three hours.

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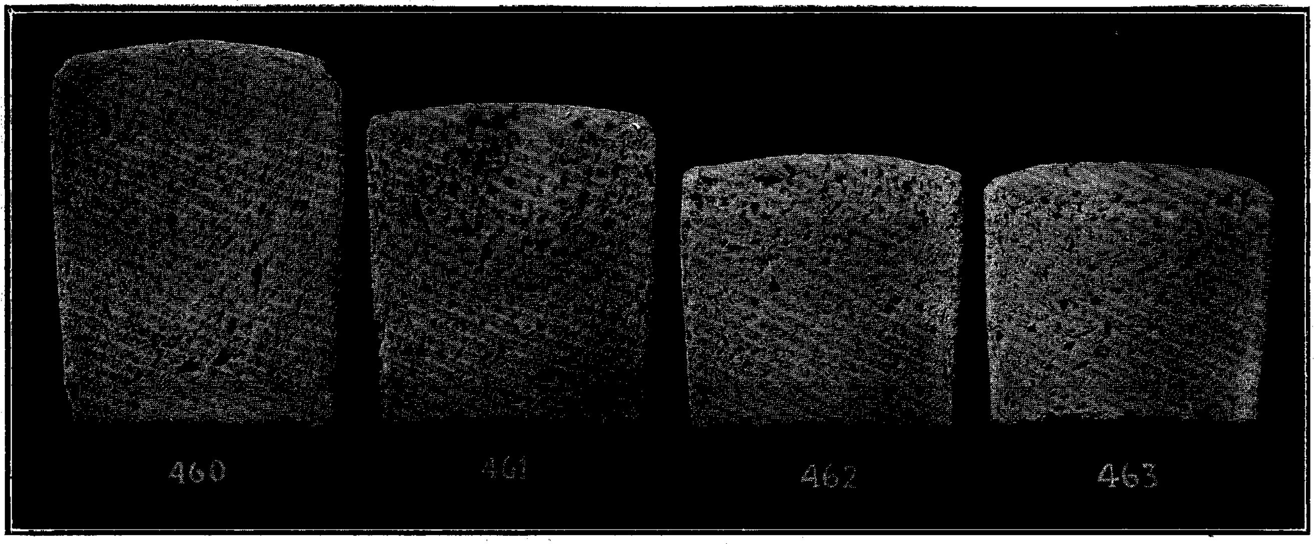

PLATE XI. Loaves of bread baked from flour from wheat tempered by adding 100 cc. of water per kilo and heating at 98° C. (208° F.)

460. Wheat heated for eleven minutes.
461. Wheat heated for twenty-two minutes.
462. Wheat heated for three-fourths hour.
463. Wheat heated for one and one-half hours.

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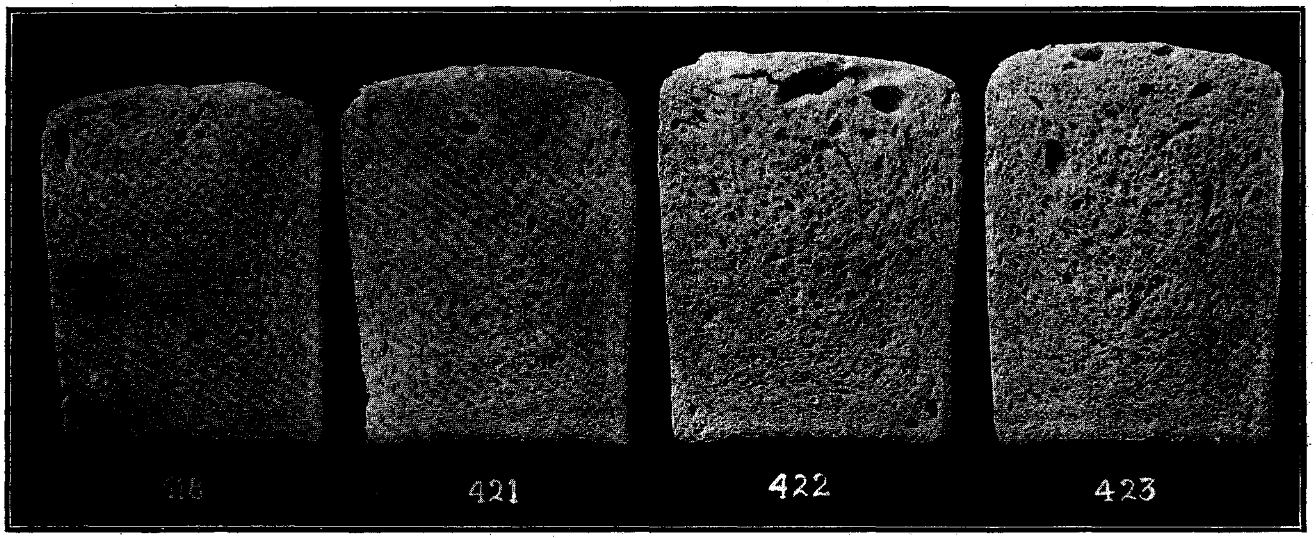

PLATE XII. Loaves of bread baked from flour of germinated wheat.

418. Flour from new wheat. (Same as in Plate I.)
421. Flour from wheat germinated twenty-four hours.
422. Flour from wheat germinated thirty-six hours.
423. Flour from wheat germinated sixty hours.

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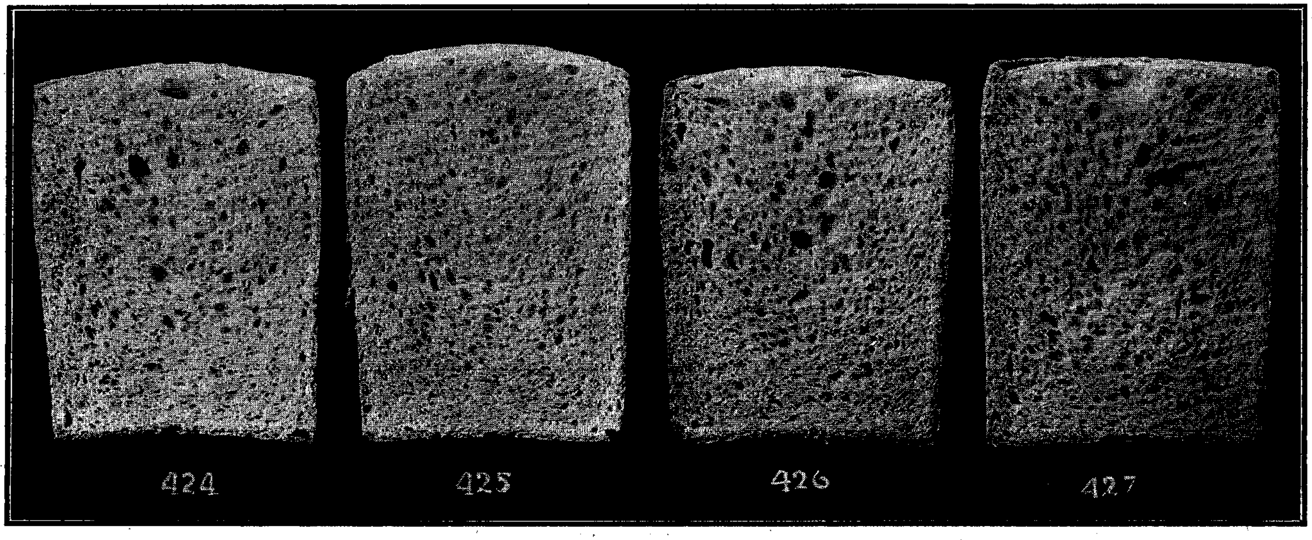

PLATE XIII. Loaves of bread baked from flour of germinated wheat.

424. Flour from wheat germinated eighty-nine hours.
425. Flour from wheat germinated 101 hours.
426. Flour from wheat germinated 120 hours.
427. Flour from wheat germinated 130 hours.

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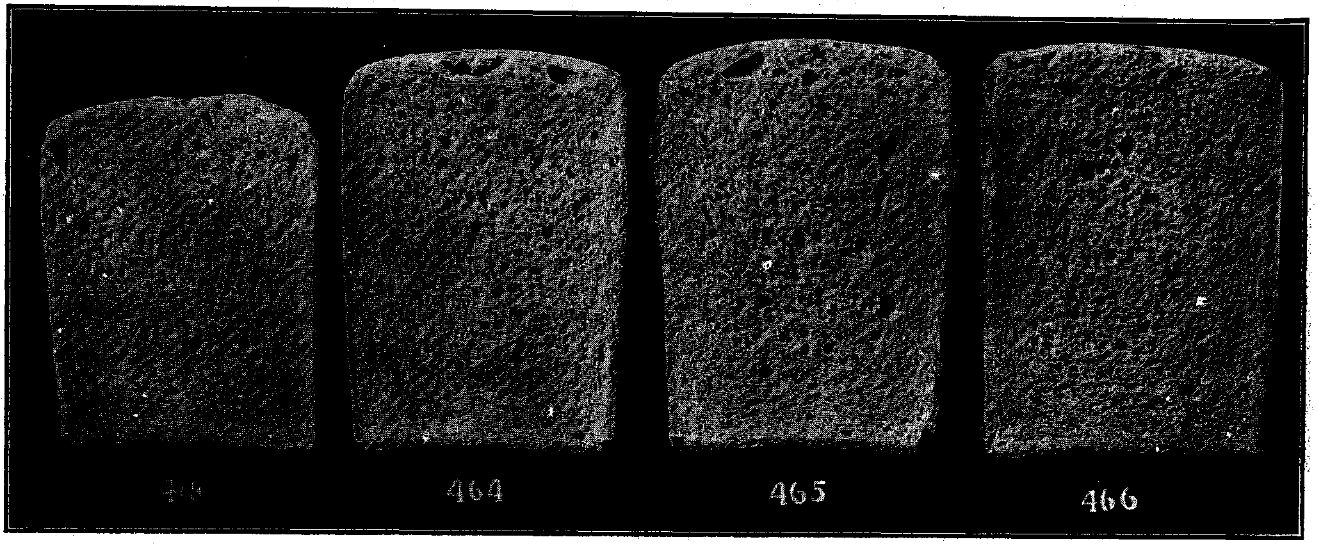

PLATE XIV. Loaves of bread from flour of germinated wheat.

418. Flour from new wheat. (Same as in Plate I.)
464. Flour from wheat germinated twenty-eight hours.
465. Flour from wheat germinated forty-three hours.
466. Flour from wheat germinated sixty-seven hours.

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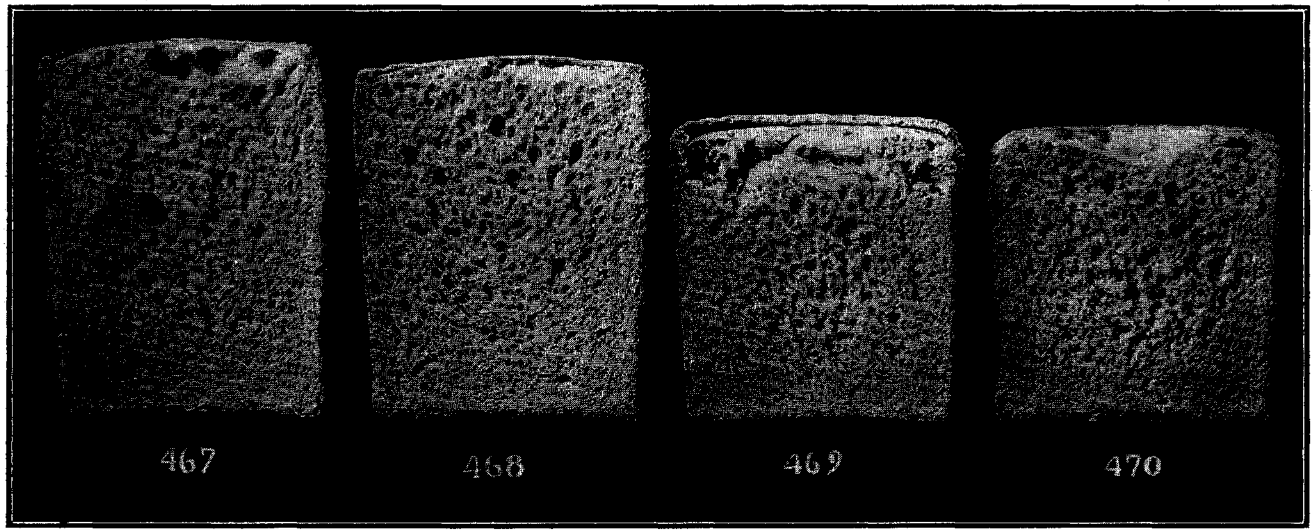

PLATE XV. Loaves of bread from flour of germinated wheat.

467. Flour from wheat germinated seventy-six hours.
468. Flour from wheat germinated ninety-one hours.
469. Flour from wheat germinated ninety-nine hours.
470. Flour from wheat germinated 119 hours.

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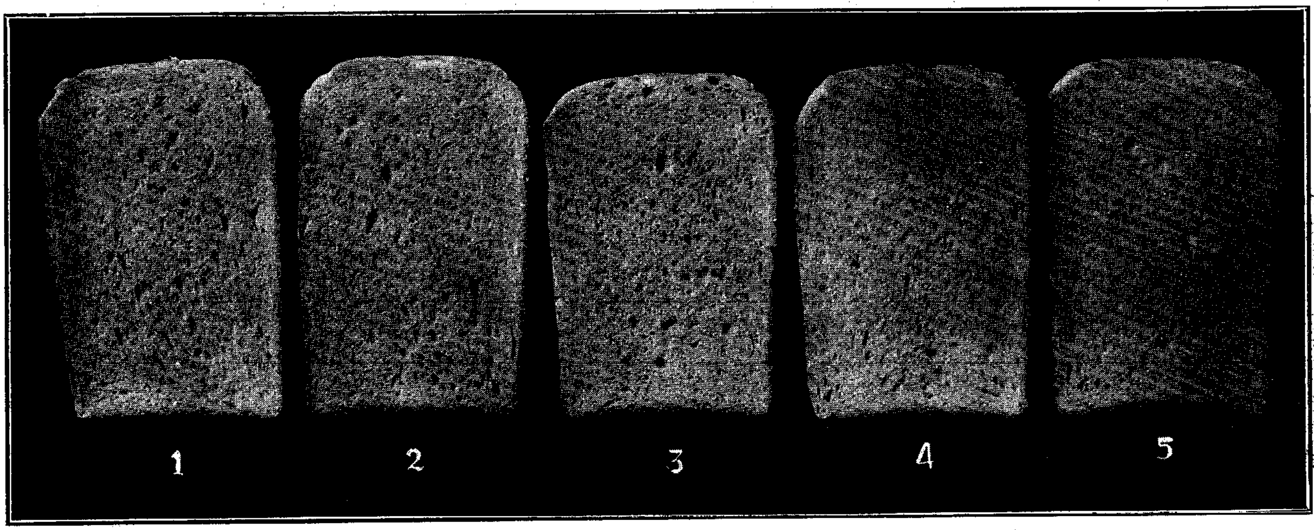

PLATE XVI. Loaves of bread baked from standard patent flour and various amounts of flour from wheat germinated twenty-eight hours. Kernels swollen and soft.

1. All standard patent flour.
2. 97 percent standard, 3 percent germinated.
3. 93¾ percent standard, 6¼ percent germinated.
4. 87½ percent standard, 12½ percent germinated.
5. 75 percent standard, 25 percent germinated.

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PLATE XVII. Loaves of bread baked from standard flour and various amounts of flour from wheat germinated forty-three hours. Some sprouts one-eighth inch long.

1. All standard patent flour.
6. 97 percent standard, 3 percent germinated.
7. 93¾ percent standard, 6¼ percent germinated.
8. 87½ percent standard, 12½ percent germinated.
9. 75 percent standard, 25 percent germinated.

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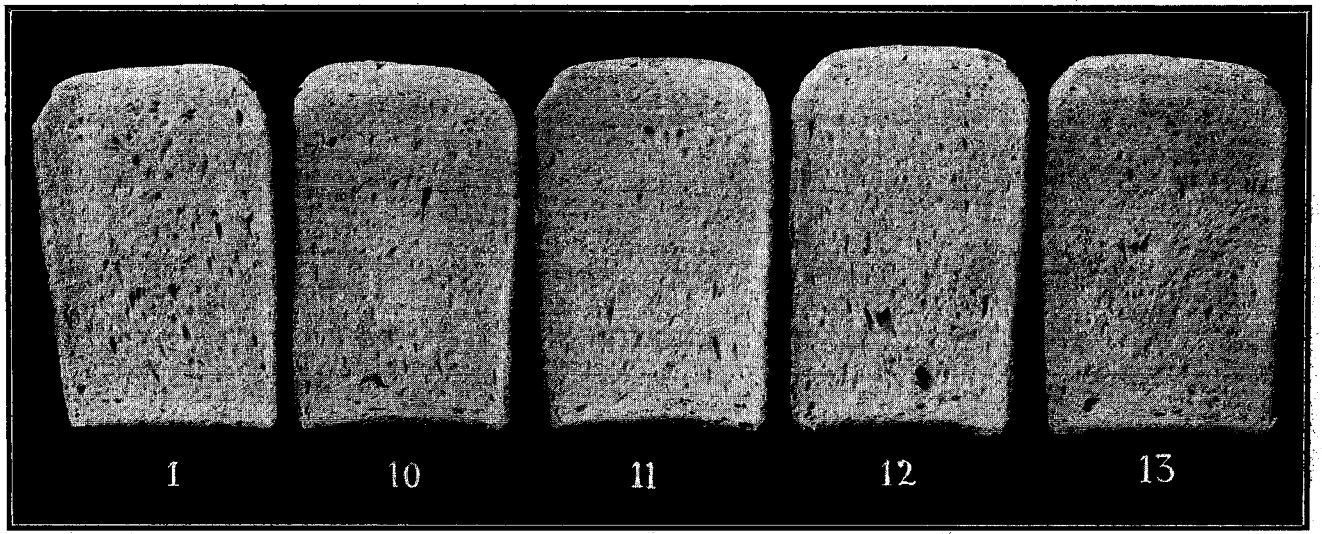

PLATE XVIII. Loaves of bread baked from standard flour and various amounts of flour from wheat germinated sixty-seven hours. Sprouts from one-eighth to one-fourth inch long.

1. All standard patent flour.
10. 97 percent standard, 3 percent germinated.
11. 93¾ percent, 6¼ percent germinated.
12. 87½ percent standard, 12½ percent germinated.
13. 75 percent standard, 25 percent germinated.

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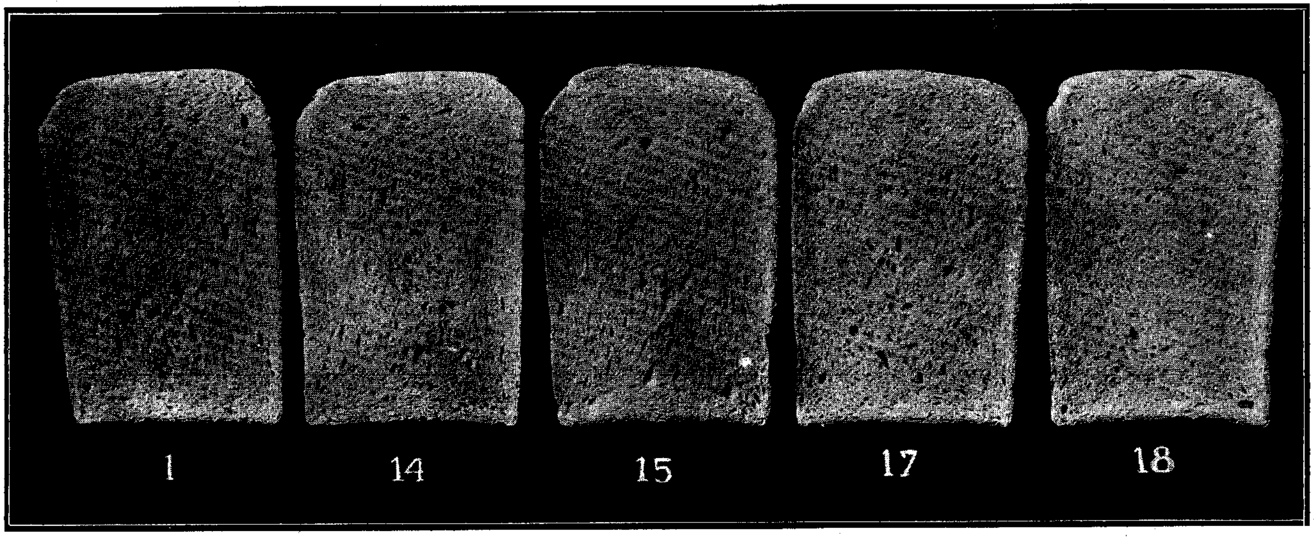

PLATE XIX. Loaves of bread baked from standard flour and various amounts of flour from wheat germinated seventy-six hours. Sprouts from one-fourth to one inch long.

1. All standard patent flour.
14. 97 percent standard, 3 percent germinated.
15. 93¾ percent standard, 6¼ percent germinated.
17. 87½ percent standard, 12½ percent germinated.
18. 75 percent standard, 25 percent germinated.

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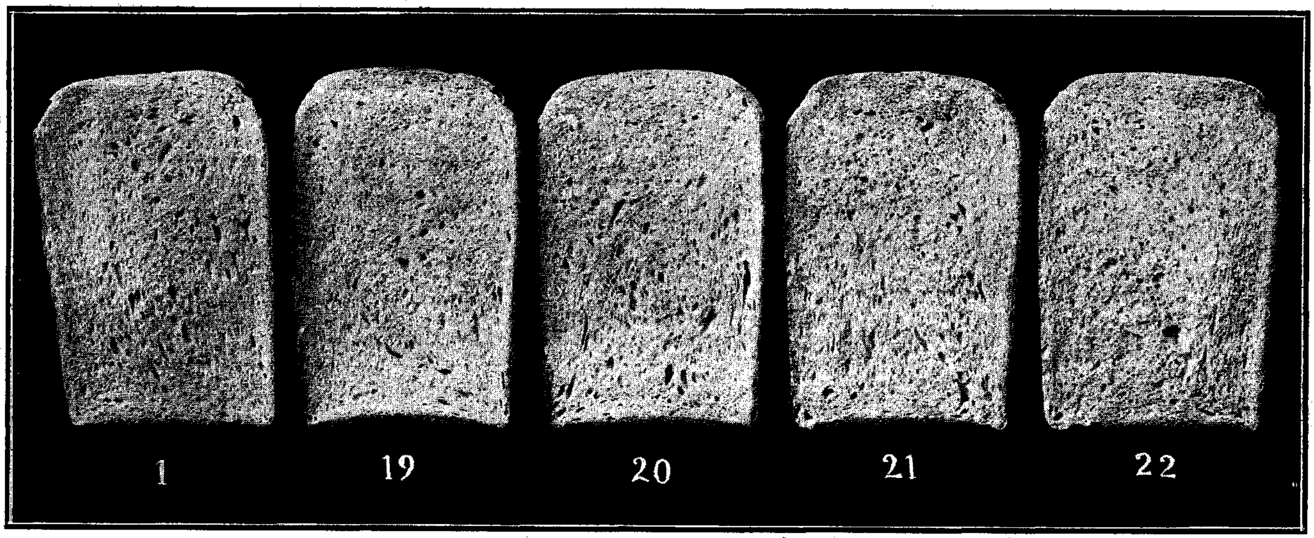

PLATE XX. Loaves of bread baked from standard flour and various amounts of flour from wheat germinated ninety-one hours. Sprouts from one-half to one inch long.

1. All standard patent flour.
19. 97 percent standard, 3 percent germinated.
20. 93¾ percent standard, 6¼ percent germinated.
21. 87½ percent standard 12½ percent germinated.
22. 75 percent standard, 25 percent germinated.

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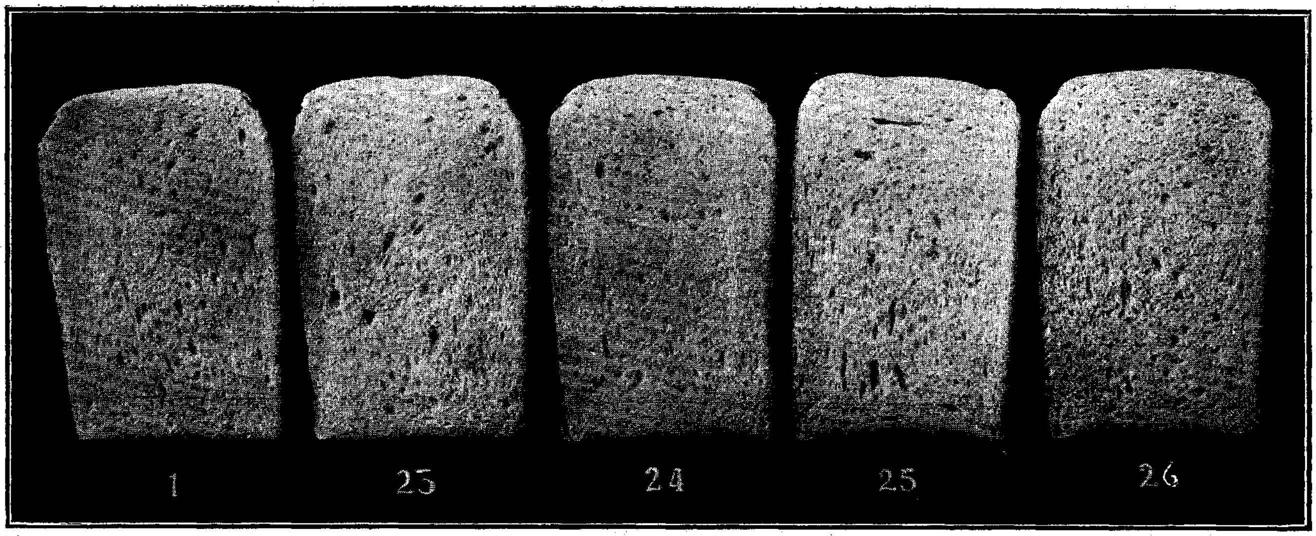

PLATE XXI. Loaves of bread baked from standard flour and various amounts of flour from wheat germinated ninety-nine hours. Sprouts from one to one and three-fourths inches long.

1. All standard patent flour.
23. 97 percent standard, 3 percent germinated.
24. 93¾ percent standard, 6¼ percent germinated.
25. 87½ percent standard, 12½ percent germinated.
26. 75 percent standard, 25 percent germinated.

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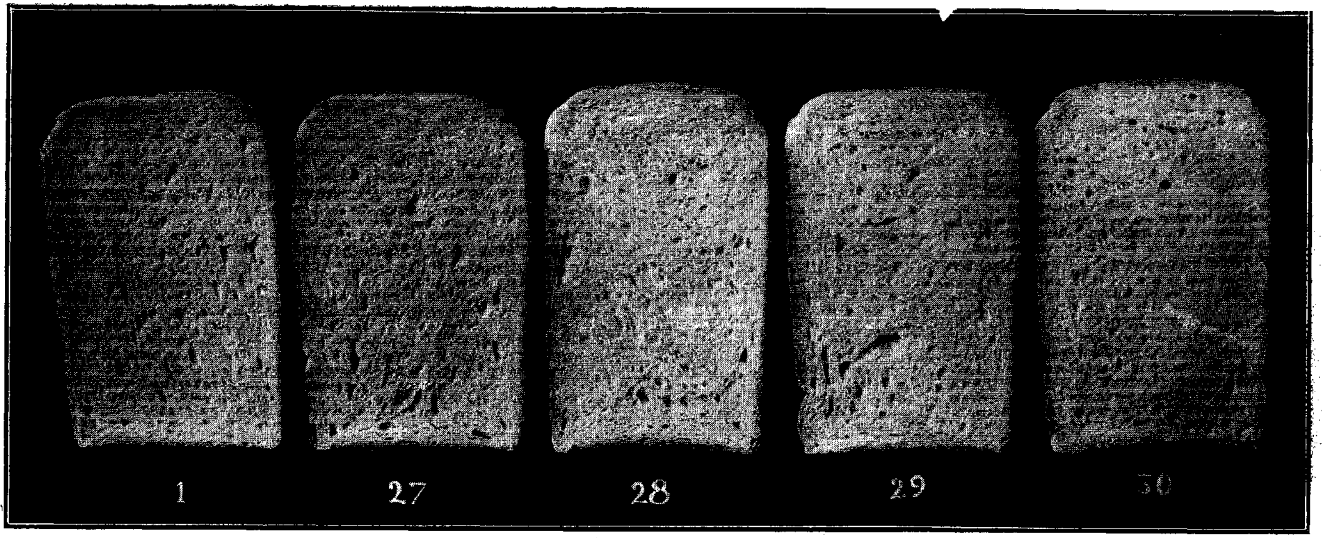

PLATE XXII. Loaves of bread baked from standard flour and various amounts of flour from wheat germinated 119 hours. Sprouts from one to two inches long.

1. All standard patent flour.
27. 97 percent standard, 3 percent germinated.
28. 93¾ percent standard, 6¼ percent germinated.
29. 87½ percent standard, 12½ percent germinated.
30. 75 percent standard, 25 percent germinated.