EFFECTS OF LENGTH OF THE TEMPERING PERIOD ON THE PROCESSES OF MILLING

by

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INTRODUCTION

Tempering may be defined as the process of preparing wheat for milling by the addition or removal of moisture. The purpose is to facilitate the separation of the endosperm, or floury portion of the grain, from the bran and germ or embryo.

The natural physical properties of these three parts of the wheat kernel are quite different, the endosperm friable, or easily granulated, the bran and germ fibrous and tough. This leads to the easy separation of the desirable food portion from the less desirable portion of the grain. It has been learned that a certain amount of moisture, with sufficient time to allow the moisture to penetrate the kernel completely and uniformly, greatly increases the differences in physical characteristics of the various portions of the wheat kernel, increasing the friability of the endosperm, rendering it more easily reduced, adding to the natural toughness of the bran causing it to hold more firmly together preventing abrasion, and increasing the toughness of the germ so that it may be more readily removed without pulverization. It is a known fact that the presence of the moisture added in tempering increases the yield of flour somewhat and that it gives us a flour of better quality, in color, ash content and baking results. Because of the great variation in different wheats, it is practically impossible to formulate any fixed rule for the amount of moisture or the length of time which will give the best results. As a general proposition enough moisture should be added, and sufficient time should be allowed to accomplish the purpose for which tempering is undertaken: that is, to facilitate the removal of the endosperm from the bran and germ in the purest possible condition and at the same time increase the friability of the middlings.

The amount of moisture to be added in tempering varies with the amount of moisture in the wheat. It has been found from experience that 15 per cent is probably the best moisture content for hard wheat as it enters the rolls. This moisture content is nearly as high as the miller can use and yet have the moisture content of his products according to specifications.

The amount and method for applying water to the wheat in tempering is a great deal more uniform than the time allowed for the moisture to penetrate the kernel before it is milled. The moisture determination methods in use today make it very easy for the miller to control the moisture content of his wheat before it enters the rolls. The period of time needed for tempering to produce the best milling results of hard wheat seems to be a question upon which millers fail to agree. This paper deals with the length of the tempering period and its effect upon the milling process.

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REVIEW OF CURRENT TEMPERING PRACTICES

To obtain information on length of the tempering period used by hard wheat millers in various sections of the country, questionnaires were sent in the spring of 1929, to 140 mill superintendents.

When gathering information on any technical question, it is very difficult to include everything which must be considered in order that results may have a definite meaning. This is especially true of the data which are secured by means of a questionnaire, since the conditions under which one operator is working may be entirely different from those of another. This will cause certain variations in data which are difficult to explain.

To obtain as much information as possible on tempering conditions other than time, several additional questions were included in order to obtain a general view of the practices used by the miller in conditioning his wheat for grinding. The questionnaire included the following inquiries:

1. What kind of wheat do you mill?
2. How long do you temper?
3. Do you wash your wheat?
4. Do you use heat in any form in wheat conditioning?
5. What is capacity of your mill, barrels per 24 hours?
6. Name of mill.
7. Name of superintendent.
8. General remarks.

The information obtained from the answers to these questions has been assembled and presented in Table I. From the replies obtained it was learned some mills were using soft wheat, hard winter wheat, and hard spring wheat with several of them milling all three types of wheat. But from the replies it was found that seventy-six mills were using exclusively, or mostly, hard wheat.

Of the mills using hard wheat very striking differences were found in the length of tempering period. These differences may be illustrated by use of a curve letting the ordinate represent the different ranges of time and abscissa represent the number of millers tempering in the various ranges.

This comparison shows that there were six millers tempering 10 hours or less, 20 tempering between 10 and 20 hours, 34 tempering between 20 and 30 hours, 4 between 40 and 50 hours, and no mill replying was using a temper between 50 and 60 hours while one mill was found to be using a temper between 60 and 70 hours. This report as may be seen by the curve shows a decided favor being shown among the millers to a tempering time ranging from 10 to 30 hours.

Of the 76 hard wheat mills 24 were using one temper, 49 two tempers, and 3 were using 3 tempers. Since a large per cent of the mills use a second temper it would seem that

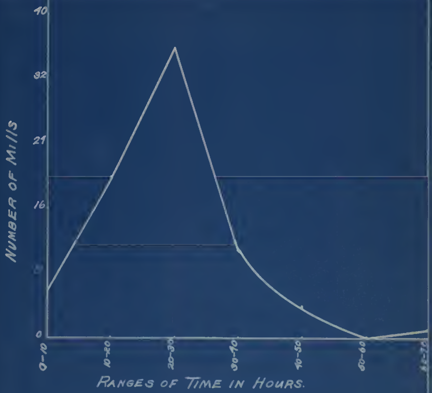

FIG I. RANGES OF TIME IN HOURS
VS.
NUMBER OF MILLS TEMPERING
IN THESE RANGES.

many of the millers desire a first wetting in order to get the tempering water more uniformly distributed in the wheat and a second temper to bring the moisture content up to the optimum amount for milling. Another advantage to be obtained from the second temper when a long first temper is used is to produce a tougher bran coat before the wheat enters the first break roll. The second temper allows a larger per cent of the moisture to remain in the bran coat or close to the surface of the bran coat. This is true only if the second temper is of short duration.

The report on washing showed that there were 15 mills washing all or part of their wheat. Some millers remarked that they considered the washer very valuable while others remarked that they washed only No. 2 and 3 wheats and any smutty wheat which they had received.

The reports on heating practices seemed to contradict the reasons for heating, because it is generally understood that with the use of heat one may reduce his tempering time, but many of the mills using heat were tempering as long and in some cases longer than the average mill not using heat.

The above reports show a very wide range of practices used to accomplish the same result in their effect on the milling processes.

Table I. Tempering practices in flour mills using hard winter wheat.

Mill Name	Number of tempers	Length of temper hours 1st.	2nd.	3rd.	Total	Capacity of mill barrels	Heat	Washed
M.D. King Mlg. Co.	2	48 H.P. 30 L.P.	3		51 H.P. 33 L.P.	500	warm H20	No
Hecker Jones Jewell Mlg. Company	2	24	7		31	10000	Yes	No
Elreno Mill & Elev.	3	8	12	4	24	1150	Yes	No
Hays City Flour Mills	2	24	1		25	1000	No	No
Rodney Milling Company	2	9	9		18	1500	No	No
Kansas Milling Company	1	16			16	1800	No	No
Larabee-Wellington	2	16	3		19	1000	No	No
Consolidated Flour Mill	1	48			48	4350	No	No
Wichita Flour Mill Co.	2	12	6		18		No	No
Goerz Flour Mills Co.	1	24			24	1200	No	No
Hunter Milling Company	2	8	10		18	1250		
Red Star Milling Co.	3	24	24	12	60	4650	Yes	No
Weber Flour Mills	1	18-24			18-24	1650	Yes	No

Kan. Flour Mill Corp.	2	8	4		12	3000	No	When needed
Canadian Mill & Elev.	1	30			30	800	In winter	No
Wichita Mill & Elev.	1	24			24	2800	No	No
Plant Flour Mills Co.	2	12	3/4		24 3/4	3600	No	No
New Era Milling Co.	2	17	3/4		17 3/4	1600	No	Yes
Gooch Mill & Elev. Co.	2	20	3/4		20 3/4	2000	No	Smutty
Walnut Creek Mlg. Co.	2	12	12		24	1000	No	No
Wolf Milling Co.	1	30			30	800	Yes	No
Keystone Milling Co.	2	30	15		45	750	No	Yes
Lawrenceburg Roller Mills	2	18-24	6-8			2000	Yes	Yes
Hungarian Flour Mills	1	18-24			18	1250	No	Yes
Colburn Brothers Co.	3	24-72	2	½		500	No	No
Wm. Kelly Milling Co.	1	9			9	1000	Yes	No
Wolf Milling Company	1	12-18				450	No	No
Noblesville Milling Co.	2	4½	1/6		4 2/3	1200	No	No
Waco Mill & Elevator Company	1	24			24	850	No	No
Blackwell Mill & Elev.	2	10	10		20	900	No	No
Meyer Milling Co.	2	24	12		32	800	Yes	No

Majestic Milling Co.	2	36	2		38	1000	Yes	No
Neosho Milling Co.	1	12			12	240	Yes	No
Southwestern Mlg. Co.	2	5	2		7	6000	No	No
Slater Mill & Elev.	2	24	1		25	500	Yes	No
Patterson Milling Co.	2	24	9		33	2000	No	No
Central Kan. Mlg. Co.	2	12	½		12½	560	No	No
Hogan Milling Co.	3	24	24	1	49	550	Yes	No
The Security Flour Mill	2	24	2		26	1000	No	No
Western Star Milling Co.	1	22			22	1225	No	No
Commercial Milling Co.	2	16	6		22	2500	Yes	No
Texas Star Flour Mills	2	12	12		24	3100	No	No
Sedalia Milling Co.	1					200	Yes	No
St. John Mills	2	24	10		34	650	Yes	No
J.F. Imbs Milling Co.	2	12	½		12½	1700	Yes	No
Anti's Flour Mills	2	18	5		23	700	No	No
Eagle Roller Mill Co.	2	8	¾		8¾	3300	Yes	Yes
The Crete Mills	2	12	7		19	1200	No	No
Midland Flour Mlg. Co.	2	9	11		20	1850	No	Yes

Shellabarger Milling Co.	2	24	2		26	1800	No	No
Ross Milling Company	2	25	½		25½	600	No	No
Brand Dunwoody Mill	2	48-72	3-4			800	No	No
Bowerson Milling Co.						1500	No	No
Claflin Flour Mills	1	18 L.P. 24 H.P.			12 L.P. 24 H.P.	600	No	No
The Fremont Mills	1	24				450	Yes	No
Nebraska Consolidated Mill	1	17			17	1000	Yes	No
Cain Bros. Milling Co.	1	24-36				850	No	Yes
Bob White Flour Mills	1	24			24	1000	Yes	No
Enid Milling Co.	1	24			24	1000	No	No
The Arnold Milling Co.	2	4	4		8	750	Yes	No
Zenith Milling Co.	1	7			7	1100	No	Yes
Wells Abbott Numan Co.	1	36			36	3000	Yes	No
Morrow Milling Company	1	12			12	200	Yes	No
Inland Milling Co.	2	10	6		16	1150	Yes	Yes
Halls Milling Company	2	8-24	½			3000	No	No
Kansas Mill & Elevator Co.	2	24	1		25	2000	No	No
Enns Milling Co.	2	12	4		16	425	Yes	No

Pillsbury Flour Mill Co.	2	8	7		15	2550	Yes	No
Lindsborg Mill & Elev. Company	2	18	8		26	700	No	No
Abilene Flour Mills Company	1	30			30	1000	No	No
Larabee at St. Joseph	2	18	6		24	6500	Yes	Yes
Aunt Jemima Mills Co.	2	16	2-4		19	1600	Yes	Yes
H.D. Lee Flour Mills Company	2	6	1		7	2500	No	No
Ismert-Hincke Milling Company	2	24	$2\frac{1}{2}$		$26\frac{1}{2}$	2400	Yes	Part
Robinson Milling Co.	2	15	12		27	1300	No	No
Blair Milling Company	1	24			24	1400	Yes	Yes
J.C. Lysle Milling Co.	2	12	15		27	1500	Yes	No
Hoffman Mills	2	24			26	1000	Yes	No
Williamson Milling Co.	1	48			48	600	No	No
Flack Bros. Milling Co.	1	20			20	550	No	No
Moore Lowry	2	15	9		24	1300	No	No
Crown Mills	2	16	8		24	2500	Yes	Yes

H.P. = High protein
L.P. = Low protein

REVIEW OF LITERATURE

There is no place in milling literature where a complete bibliography of tempering and its effect upon the milling process can be found. While no claim is made for completeness the writer feels that the major papers presented in the last few years on the length of tempering period have been discussed in this review of literature.

Dunham (1925) states that the bran coat is not permeable to water but that all water entering the wheat kernel enters through the germ and through the hairs or brush end. His conclusions were drawn from the fact that if the bran coat was permeable to water the kernel would rot during its germination period. Tests were made using dye and allowing only portions of the kernel to come in contact with the dye.

Cereal Chemist (1929) states that wheat conditioning has two principal objects: first to bring the wheat into suitable condition for mechanical treatment in the mill, and second to improve the baking quality of the flour. Separate conditioning of the different wheats making up the blend was advocated. Care must be taken to apply the proper amount of moisture and insure that it is properly distributed throughout the kernel.

The time factor is extremely important in the conditioning process. Time temperature curves coupled with fluctuating moisture contents would make a very profitable subject for research.

Spehr (1923) states that the time wheat should be tempered for best milling results is a matter for the individual miller to determine for himself, having in view the conditions under which he operates. Time enough should be allowed to permit the whole of the endosperm to receive the benefit of the mellowing influence of the moisture.

Robinson (1926) states that it would be more scientific to say we are raising the moisture in No. 2 dark hard winter 3 per cent in thirty-six hours, than to say we are tempering our wheat thirty-six hours. For a long time after tempering became popular, millers thought they were tempering to toughen bran only. At the present time, it is no longer theory but a settled fact that the moisture must be allowed to penetrate the center of the wheat berry in order to produce a flour of fine uniform granulation. For example the following figures show the ash content of flour milled from five samples of No. 2 dark hard winter which was tempered to a moisture content of 15 per cent for different lengths of time. The natural moisture content of the samples before tempering was 10.5 per cent.

Length of temper hours	8	24	48	72	120
Ash in flour	.44	.44	.40	.39	.40

On baking these flours the bread showed an improvement in color, texture and volume up to seventy-two hours. To temper this wheat longer than seventy-two hours would necessitate adding a little moisture at this point to keep the bran from cutting.

Thus extending the length of temper to mellow the endosperm, improved the granulation and shortened the fermentation period, and gave rise to the possibilities of a chemical change taking place.

Bailey (1927) states that until new data are offered we are forced to conclude that ordinary tempering practice does not effect any change of consequence in the composition of the wheat.

Stark (1925) gives some very interesting figures from a series of tests on the length of tempering used in his mill. The conclusions drawn were that the location of your plant, the characteristics of the wheat such as moisture content, plumpness of berries, the degree of hardness, variation in climatic conditions, season of the year, are all factors which affect conditioning making it impossible to follow out any fixed rule.

Doherty (1926) states that if there is any change in the kilowatt hours per barrel consumed due to the temper, it is very small and if one is trying to reduce his power cost their biggest field is in keeping the mechanical condition of his plant as near perfect as possible.

Tague (1920) states that the length of time used in tempering appeared to have very little influence on either the physical or chemical composition of the flour.

RATE OF WATER PENETRATION IN WHEAT DURING TEMPERING

The question may be asked, why is it useful to know the rate that water penetrates the wheat kernel? Another question is, why do millers in the southwest vary in their time of tempering, from 3 to 72 hours. If the water gets to the center of the wheat kernel and is uniformly distributed in a short length of time, why the many hours of tempering? The object of this investigation was to get some information regarding how soon the tempering water becomes evenly distributed throughout the endosperm.

In analyzing the water penetration in wheat during tempering it is evident that absorption may take place under the following conditions: When the wheat is immersed or dipped in water, and when water is added as in tempering, that is, when a small amount of water is added to the wheat and thoroughly mixed. Water is also absorbed when the wheat is exposed to air of high humidity.

Absorption When Wheat is Immersed in Water

Last year some experiments were performed to determine the rate of absorption when the wheat was totally submerged in water for varying lengths of time. In conducting this experiment, a definite amount of wheat was immersed in the water for a given length of time. Then it was placed in specially made cups with screens on the bottoms. These cups were then placed in a centrifuge and the surface water thrown off by centrifugal force. The centrifuge used was an ordinary Babcock cream tester. It was turned at a given rate and for the same length of time in each determination. In order to eliminate error from evaporation, two cups were centrifuged at a time then weighed before starting to centrifuge the next two. A uniform lot of hard wheat was used. By this method it is believed that comparative data was obtained. In a preliminary trial, four samples were treated alike in order to determine whether comparable results could be obtained. The figures in Table II give the variation which occurred in this series of tests, and shows the limits of accuracy for the figures obtained in the trials which are reported in this paper.

Table II. Variations in the amounts of water adsorbed under similar conditions.

Time of Soaking	Grams of water absorbed by 100 gm. of wheat at room temperature.				Max. Diff.	Ave.	Max. Dev. from ave.	Prob. error	Ratio D/P.E.
10 min.	6.9	6.7	6.8	6.8	.16	6.8	.065	.667	.09
30 min.	10.4	10.2	10.2	10.4	.22	10.3	.115	.667	.17
40 min.	12.5	11.8	11.9	[illegible]	.72	12.1	.465	.667	.70
15 hrs.	46.6	46.1	46.5	46.4	.42	46.4	.265	.667	.39

The greatest difference between the maximum and minimum in these single trials was .72 gm. and the least was .16 gm., or the variation was less than 1 gm. However, one must determine if these errors are significant, or if more trials are necessary in order to obtain sufficient accuracy to find the deviation from the average and also its ratio to the probable error. The largest deviation from the average of each four trials was 0.465 gm., and for the ten minutes it was 0.065 gm., which is very small. The ratio of deviation to probable error should be less than 3 if an experiment does not need more trials for reliable information. To determine the probable error, it is first necessary to calculate the standard deviation of the point binomial using the formula $S = \sqrt{PqN}$, where S is the standard deviation of the point binomial, N is the number of trials and P is the probability of accuracy, while q is the probability of inaccuracy.

The probability of a complete set of compound events may be illustrated by tossing up a coin. The probability that heads will turn up during a number of trials will be a fifty-fifty chance or P and q will be equal to 5. The same is true with experimental work. One has a fifty-fifty chance of accuracy on each test. Now since the probable error is equal to 0.6745 times the standard deviation of the point binomial, the probable error is equal to $0.6745\sqrt{.5 \times .5}$ or $0.33725\sqrt{N}$ substituting 1/3 for 0.33725. We have the probable error equal to $1/3\sqrt{N}$. The probable error then equals $1/3\sqrt{4}$ or .667, while the largest deviation from the average is the difference between the average and the trial farthest away from the average. The ratio of deviation to probable error is found by dividing the deviation by its probable error. The ratio of the deviation from the mean to its probable error is less than one in all cases, as shown in the last column of Table II. In fact the largest ratio is .7 for the forty minutes of soaking the grain, which indicates very good experimental results. Hence, the data obtained under these experimental conditions may be considered reliable.

This data shows that in ten minutes at room temperature the wheat had taken up 6.8 per cent of its original weight in water. In thirty minutes it had gained 10.33 per cent of its original weight. This is not three times the amount absorbed in ten minutes, but is an average of .17 of one per cent per minute after the first ten minutes. We notice that in the next ten minutes it gains in a similar ratio, but as the time increases, the amount of water absorbed gradually decreases. That is the wheat becomes saturated with water and the rate of absorption diminishes. At the end of fifteen minutes it had gained 46.46 per cent of its original weight or nearly all the water possible for it to hold.

Some people believe that wheat is surrounded by an impermeable membrane, but if it were, as in the case of white clover seed, it would not absorb water. Because white clover seed does not germinate readily, it was thought by some people that the seed was poor, but the slow germination is due to the impermeable membrane which covers the grain. After scarifying the seed nearly all of it germinates quickly. Wheat does not need to be scarified to enable moisture to come into contact with the endosperm, as water can be absorbed very readily through the bran coat, germination taking place in twenty-four to forty-eight hours time if the moisture and temperature conditions are suitable.

Coating Wheat With Shellac to Determine Where the Water Enters the Berry

An experiment was conducted to find out if water enters the wheat kernel more easily at one place than another. Head samples of Kanred wheat were obtained. Each grain was picked from the head separately so that the bran coat, or any nonpermeable membrane that might surround the kernels, would not be scratched. This wheat was divided into four lots; one used as a check sample, one coated with shellac on the germ, one with shellac on the brush end, and one on the back of the grain. In each case approximately equal parts of the wheat surface was covered. After the shellac had dried, each sample was weighed and then placed between layers of muslin which had been first soaked in water, then wrung to remove excess water. The wheat was removed for weighing at the following intervals: 1, 2, 4, 6 and 24 hours. As soon as the kernels were taken from the wet muslin they were placed between blotters to remove surface water. Then they were weighed and placed again between the wet cloths. Water was added at intervals to the cloths in order to keep the moisture uniform during the experiment. Table III shows the per cent gain in these samples for the various periods of time.

Table III. Water penetration through different parts of bran coat. Per cent gain.

Sample	1 hour	2 hours	4 hours	6 hours	24 hours
Check	5.8	8.5	13.8	18.4	40.0
Shellac on brush	6.3	9.3	14.1	20.8	37.8
Shellac on back	4.3	6.9	10.6	14.1	32.0
Shellac on germ	4.1	6.2	9.3	12.6	29.7

At one hour soaking the wheat treated with shellac on brush absorbed 6.3 per cent moisture, while the check sample absorbed 5.8 per cent. The grain treated with shellac on the germ absorbed 4.1 per cent and that treated on the back gained 4.3 per cent. The fact that the absorption in the kernels whose brush ends were treated with shellac was as great as the check sample which was without shellac on any part, shows that very little if any absorption took place through the brush end. This statement will not hold for kernels which have been threshed or scoured. The kernels shellacked on germ or back absorbed less water than those shellacked on brush end. In fact very little difference is noticed in the samples shellacked on germ or back. The theory advanced by some people that water enters only through the germ does not hold in the face of these figures and it must be admitted that water enters the grain throughout the whole bran coat. The lack of absorption through the brush end in hand plucked kernels is probably due to the film of air held by the fine wheat hairs.

Rate of Water Absorption in Tempering Wheat

Water is added to wheat in tempering for two reasons to make the bran coat tougher and to mellow the endosperm. The experiments already given show that the water enters the wheat kernel rather rapidly. In tempering the water is applied in a manner altogether different from that used in the first experiment, that is, immersing the wheat in water. The fundamental principles in regard to absorption are similar, but whether it enters as rapidly in the process of tempering is a question to be answered. Also we need to determine if all that is necessary in tempering is merely distributing the water through the berry. While the amount of water is comparatively small, yet the absorption may be just as complete. Whether more of this water is absorbed by the bran than by the endosperm must also be determined, also how much of this water is lost during the tempering process. The rate of absorption in tempering for various periods may be determined by adding a definite amount of water to a weighed quantity of wheat of known moisture content, and determining the moisture in the cracked wheat, bran, and various sized middlings.

For this experiment a uniform lot of Turkey wheat, of a known moisture content was used. It was first cleaned on a small experimental separator, then scoured on a small Eureka experimental scourer. For each test 600 gm. of wheat was placed in a half gallon Mason jar. Enough water was added to bring the moisture content up to 16.75 per cent as determined by drying at 130°C., for one hour and 15 minutes, which gives approximately 1.25 per cent more moisture than by the Brown Duvel method. Hence by common methods the wheat had 15.5 per cent moisture. The periods of tempering were 1, 2, 4, 8, 16, and 24 hours and the time of tempering was so regulated that the wheat could be ground at the expiration of the period set for each sample.

This experiment was conducted during the winter months where a relatively low temperature could be maintained with a humidity of about sixty per cent. The evaporation is not as great under these conditions as it is at higher temperatures, even with higher humidities.

Five hundred grams of the tempered wheat was used for milling and the rest for moisture determination on each sample of wheat milled. The wheat was first passed through the break rolls set at .028 inches apart, which corresponds to our setting on first break and then immediately passed through rolls set at .006 inches apart, corresponding to our third break grinding. Then the sample was sifted immediately, less than five minutes elapsing from the time grinding was started until the sifting was completed. This insured only a small loss in weight due to evaporation of moisture. The following stack of sieves was used during sifting: 24 wire, 60 G.G., and 70 G.G. The stocks as well as the wheat were weighed on a balance sensitive to .1 gm.

The wheat was allowed to adjust its temperature to that of the milling room before the tempering water was added and kept at that temperature during the entire tempering period. The milling was done at a temperature which varied from 57° to 64°.

In performing experiments of this nature it is difficult to control or distinguish between the losses from evaporation and those due to the mechanical operation. The total loss during the milling and sifting operations can be obtained by adding the sum of the weights of the different stocks and then subtracting it from the original weight of wheat groun , which was 500 gm. Table IV shows an example of the experimental data obtained for each tempering period.

Table IV. A sample of the experimental data obtained for each tempering period.

Tempering time 1 hour.
Weight of wheat 600 gm.
Relative humidity .61
Temperature 60°F.

Water added 20 cc.
Weight of wheat
after tempering.
A 620 gm.
B.620 gm.
C 620 gm.

Sample Number	Weight of wheat	Over 24 W.	Over 50 G.G.	Over 70 G.G.	Through 70 G.G.	Sum	Loss
A	500	221.3	160	56.0	53.8	491.2	8.8
B	500	229.0	160	55.5	54.0	498.5	1.5
C	500	229.95	159.7	52.8	52.8	494.8	5.2
Average		226.6	159.9	54.8	53.5	494.8	5.2

Table V. Distribution of Grinding 500 gm. of Wheat.

Time of tempering hours	Temperature of room	Relative humidity	Over 24 W.	Over 50 G.G.	Over 70 G.G.	Through 70 G.G.	Sum	Loss
1	66	61	226.6	159.9	54.8	53.5	494.8	5.2
2	64	56	230.6	159.5	54.8	53.9	498.8	1.2
4	64	60	227.2	158.1	53.4	57.2	495.9	4.1
8	64	60	228.2	153.3	57.8	58.0	497.3	2.7
16	63	60	219.9	158.0	58.7	60.0	496.3	3.7
24	64	56	227.7	153.9	58.1	58.3	498.0	2.0
Average	64	59	226.7	157.1	56.3	56.8	496.9	3.1

From all the data obtained as shown in Table IV the average of the three trials were computed in each case, and Tables V and VI give the averages. The figures in Table V show the weight of the products obtained in the process of grinding these samples, the lengths of tempering period, temperature and relative humidity of the room in which the samples were ground; also the gain or loss during grinding and weighing.

The loss which is shown in the last column of Table V is very small in all cases, the mean loss was found to be 3.1 gm. or 0.62 per cent. It has been found from other experiments that the greatest amount of loss is due to evaporation and that the mechanical loss is very small.

The effect of the length of time used in tempering showed a slight effect but differences are so small that they are within the experimental error.

Table VI shows the figures for the moisture content of wheat, the overs and throughs of the seives for the different samples. These samples were taken as soon as possible after grinding and placed in air tight bottles where they were kept until the moisture tests were made. These figures are the averages from each of the three samples milled.

Table VI. Penetration of water in wheat for various periods of time.

Time of tempering hours	Temperature of room	Relative humidity	Whole wheat	Over 24 .	Over 50G.G.	Over 70G.G.	Through 70G.G.
1	66	61	16.88	17.76	16.15	16.27	16.50
2	64	56	16.91	17.53	16.13	16.11	16.07
4	64	60	16.59	17.43	16.47	16.28	16.40
8	64	60	17.09	17.50	16.39	16.51	16.63
16	63	60	17.21	17.52	16.62	16.66	16.62
24	64	56	16.74	17.17	16.39	16.52	16.51
Average	64	59	16.85	17.49	16.33	16.36	16.43

The figures show that the moisture content of the wheat samples was very uniform. They also show that in all cases the bran contained a larger per cent of moisture than the endosperm. In fact, in every case the moisture content of the bran was greater than that of the wheat. After two hours at 64°, the moisture seemed to be evenly distributed throughout the endosperm as shown by the moisture content of the sizings and coarse and fine middlings.

The following conclusions may be drawn from the experiments with the rate of water penetration of wheat.

1. The wheat kernel is not enclosed in an impermeable membrane, but absorbs water freely throughout the entire bran surface.

2. The bran coat holds a larger percentage of water than the endosperm of the wheat.

3. At 64° or room temperature the water had penetrated the wheat kernel in 2 hours and was evenly distributed throughout the endosperm.

EXPERIMENTS ON SMALL MILL

The effects of the length of tempering period on the process of milling were studied on the experimental mill from four different angles.

1. The effect of the length of tempering period on the distribution of grinding which is a measure of the per cent extraction done by each roll in the breaking process.

2. The effect of the length of tempering period on the weight of middlings produced.

3. The effect of length of tempering period on the amount of break flour produced on the different breaks.

4. The effect of length of tempering period on the ash content of the break flours.

The wheats used in the experiments consisted of three lots of hard red winter wheat, one being a lot of wheat from the 1928 crop, another a very badly shriveled lot from the

1929 crop, and the third a lot of high quality wheat from the 1929 crop.

The samples were cleaned and scoured on small cleaning machines which have the same effect on the wheat as the large cleaning machines used in commercial practice. Tempering was performed in closed stone jars to prevent as much as possible the loss of moisture due to evaporation.

The samples were ground on an Ehrsam experimental stand of break rolls equipped with a pair of 6 inch by 6 inch Dawson cut corrugated rolls. The mill was driven by an individual three horse motor which provided constant power during all tests. The differential used for grinding the samples was 2½ to 1 which is the differential used by most commercial millers on their breaks. To increase the accuracy of the roll setting a device was made which consisted of a pointer connected with each end of the movable roll and operating on the principle of the lever. By the use of these pointers the measurement of the movement of the roll in setting was magnified sixteen times which allowed for a high degree of accuracy in setting the rolls the same for each break on the various tests. The distance used between the rolls for the different settings was first break .028 inch, second break .012 inch, third break .006 inch and fourth break .008 inch. These settings were used for all the different tests run.

The ground samples were sifted on a Rotomatic experimental sifter which is equipped with an automatic time regulator. This gave very good comparative sifting results as all samples were sifted exactly two minutes. The sifting was done on a set of sieves of the same mesh as those used in the large college experimental mill which made the sifting action resemble very closely that of a commercial mill sifter.

All weights were made on a torsion balance sensitive to .1 gm. which may be considered very accurate for samples as large as those used in this experiment.

One thousand gram samples were taken from each of the three lots of wheat used for the tests and tempered for periods of 3, 6, 12, 18, 24, 48, 72 and 96 hours. The samples were tempered in closed stone jars by adding and thoroughly mixing with the wheat the correct amount of water necessary to bring the moisture content of the wheat up to 15 per cent. After the moisture had been on the wheat for the desired periods the samples were ground through the breaks. After each grinding the samples were sifted for two minutes and the weights of the overs of the various cloths as well as the weight of break flour produced were determined. The overs of the top scalp of first break were used as the sample for second break, the overs of the top scalp of second break were used as the sample for third break, the overs of the top scalp of the third break were used as the sample for fourth break, and the overs of the top scalp of fourth break were taken as the weight of bran.

The milling of the wheat for each period of tempering was performed in triplicate for the 1928 wheat and the 1929 shrivelled wheat. The results were found to check so closely that for the 1929 plump wheat the milling was done only in duplicate. The weights of the overs and break flour for the differ nt trials were averaged and the averages taken as the weight of overs of the various tests. Composite samples of the individual break flours were taken for the different tests for each period of temper.

Results of Experiment

The data on effect of the length of tempering period on the distribution of grinding which is a measure of the per cent extraction obtained by each roll in the breaking process,are presented in Tables VII, VIII and IX.

All the calculations for the per cents extraction in this experiment were based on the original weight of the wheat sample milled. In all these tests 1000 gm. samples of tempered wheat were used. By using this weight of sample we may calculate from the weight of overs which are presented in the later tables the per cent overs of each break by multiplying each weight by 100 and dividing by 1000. Then by subtracting the per cent over of the top scalp of first break from 100 per cent we have the per cent extraction on first break. The per cent extraction for second break is found by subtracting the per cent overs of the top scalp of second break from the per cent overs of the top scalp of first break, and so on for the remaining breaks. For illustration we have 100 per cent minus 73.5 per cent or 26.5 per cent for the extraction on the first break of the three hour temper of the 1928 wheat, and 73.5 per cent minus 35.5 per cent or 38.0 per cent extraction on second break. This follows because the sum of the per cent over the top scalp on a break plus the per cent through that scalp is equal to the per cent ground on that break.

Since the percentages are all figured on the basis of the weight of wheat, the sum of the per cent extraction on each of the four breaks plus the per cent bran should equal 100 per cent which gives a very convenient method for checking the calculations. For example on the three hour temper of the 1928 wheat, first break 26.5 per cent plus second break 38 per cent plus third break 11.6 per cent plus fourth break 9.0 per cent plus bran 12.9 per cent equals 100 per cent.

In Table VII are presented the data from the 1928 wheat. The extractions on the first break were found to vary from 25.9 per cent to 27.1 per cent or a spread of 1.2 per cent for the different periods of temper used. On second break the per cent extraction was found to vary from 34.9 per cent to 39.1 per cent or a spread of 4.2 per cent. Third break has as a maximum 12.3 per cent and a minimum of 10.1 per cent or a variation of 2.2 per cent. Fourth break had a maximum of 10.6 per cent and a minimum of 8.6 per cent or a variation of 2.0 per cent. The maximum per cent bran produced was 15.8 per cent and the minimum was 14.9 per cent or a variation of .9 per cent.

In Table VIII and IX are presented similar data for the 1929 shriveled and plump wheats. Similarly small variations were obtained between the maximum and minimum extractions on each break even when in the case of the 1929 plump wheat ½, 1 and 2 hour tempers were used in addition to the periods of temper tried on the other wheats. Thus from the data in Tables VII, VIII and IX we may draw the conclusion that the period of temper has very little if any effect on the percentage extraction obtained on the different breaks or on the per cent bran.

Table VII. Per cent extraction or throughs of top scalp on each break. 1928 wheat.

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break	Bran	Total
3	26.5	38.0	11.6	9.0	14.9	100.0
6	26.5	39.0	10.1	8.6	15.8	100.0
12	25.9	38.0	10.7	9.6	15.7	99.9
18	26.5	37.9	11.2	9.0	15.4	100.0
24	26.1	39.1	10.6	8.6	15.6	100.0
48	26.3	37.7	10.9	10.1	15.0	100.0
72	26.9	35.1	12.2	10.5	15.3	100.0
96	27.1	34.9	12.3	10.6	15.1	100.0
Maximum	27.1	39.1	12.3	10.6	15.8	
Minimum	25.9	34.9	10.1	8.6	14.9	
Mean	26.5	37.4	11.2	9.5	15.3	
Variation	1.2	4.2	2.2	2.0	.9	

Table VIII. Per cent extraction or throughs of top scalp on each break. 1929 shriveled wheat.

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break	Bran	Total
3	12.5	43.9	17.5	9.0	17.5	100.4
6	12.8	43.4	16.4	9.5	17.9	100.0
12	13.3	42.9	14.2	10.7	18.9	100.0
18	13.6	43.3	13.3	11.1	18.7	100.0
24	12.7	43.5	14.3	11.1	18.4	100.0
48	11.8	43.7	15.6	10.9	18.0	100.0
72	13.0	42.6	15.5	10.9	18.0	100.0
96	14.0	42.4	15.7	9.9	18.0	100.0
Maximum	13.6	43.9	17.5	11.1	18.9	
Minimum	11.8	42.4	13.3	9.0	17.5	
Mean	12.9	43.3	15.3	10.4	18.1	
Variation	1.8	1.5	4.2	2.1	1.4	

Table IX. Per cent extraction or throughs of top scalp on each break. 1929 plump wheat.

Tempering time hours	1st. break	2nd. break	3rd break	4th. break	Bran	Total
½	20.3	39.7	16.0	9.5	14.5	100.0
1	20.8	39.7	15.3	9.6	14.6	100.0
2	21.8	40.0	14.2	9.3	14.7	100.0
3	20.0	39.0	17.5	9.0	15.5	101.0
6	22.0	38.0	14.3	12.0	13.7	100.0
12	24.5	35.5	16.3	10.2	13.5	100.0
18	22.3	36.5	16.0	11.5	13.7	100.0
24	23.8	36.0	16.2	11.2	12.8	100.0
48	22.3	39.2	14.5	11.5	12.5	100.0
72	21.8	35.0	16.5	12.5	14.2	100.0
96	22.5	33.8	17.7	11.8	14.2	100.0
Maximum	24.5	40.0	17.7	12.6	15.5	
Minimum	20.0	33.8	14.2	9.0	12.5	
Mean	22.0	37.5	15.9	10.7	13.9	
Variation	4.5	6.2	3.5	3.5	3.0	

The data on the effect of the length of tempering period on the weight of middlings produced are presented in Tables X to XXI. Tables X to XXI present the weights over the various cloths or the weight of middlings produced on the different breaks, for each period of temper, on the three lots of wheat used. In making a study of the comparison of the weights for the different lengths of temper it was found impossible on the three lots of wheat to determine any decided advantage to be obtained from the use of any particular one of the periods of temper used. For example let us take the first break stocks of the 1928 wheat. We find the maximum weight over 24 W. equal to 741.3 gm. and the minimum weight for the various periods of temper equal to 729.6 gm. or a variation of 11.7 gm. Over the 32 W. on first break we have a maximum weight of 104.5 and a minimum weight of 98.9 gm. or a spread of 5.6 gm. Over 50 G.G. we have 71.5 gm. for maximum and 69.3 for minimum or a spread of 2.2 gm. Over 70 G.G. cloth we have 39.8 gm. for maximum and 37.5 gm. for minimum or a spread of 2.3 gm. over 13XX we have a spread of 2.9 gm. with a maximum of 37.7 gm. and a minimum of 34.8 gm.

Table XI. Weight of overs and break flour from second break 1928 wheat.

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	12 XX	Break flour
3	355.6	80.2	158.1	61.7	42.1	27.5
6	345.3	81.6	159.3	63.6	47.4	24.0
12	360.0	86.2	156.5	61.8	45.5	25.4
18	356.6	86.2	152.6	62.2	45.7	23.0
24	348.3	83.0	159.2	64.6	47.5	26.3
48	360.0	84.2	150.2	58.3	42.4	25.2
72	380.0	84.3	136.7	56.4	43.1	22.3
96	380.6	89.6	135.7	54.8	43.2	21.3
Maximum	380.6	89.6	159.3	64.6	47.5	27.5
Minimum	345.3	80.2	135.7	54.8	42.1	21.3
Mean	360.8	84.4	151.0	60.4	44.6	24.1
Variation	35.3	9.4	13.6	9.8	5.4	6.2

Table XII. Weight of ovem and break flour of third break 1928 wheat.

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	12 XX	Break flour
3	239.0	14.2	29.6	27.6	27.9	14.6
6	244.0	15.4	28.0	22.1	22.1	9.0
12	253.0	14.3	30.2	23.5	22.2	11.6
18	244.3	13.2	28.0	24.2	24.9	11.6
24	242.3	13.8	28.8	22.8	22.9	9.9
48	251.0	13.8	30.5	24.8	24.4	12.3
72	258.3	16.2	34.2	26.0	25.5	12.5
96	257.0	18.1	36.1	26.8	25.2	11.8
Maximum	258.3	18.1	36.1	27.6	27.9	14.6
Minimum	239.0	13.2	28.0	22.1	22.1	9.0
Mean	246.6	14.6	30.7	24.7	24.3	11.6
Variation	19.3	4.9	8.1	5.5	5.8	5.6

Table XIII. Weight of overs and break flour from fourth break. 1928 wheat.

Tempering time hours	18 W.	26 W.	44 W.	70 G.G.	13 XX	Break flour
3	149.1	34.5	15.6	13.6	14.8	6.6
6	158.0	31.6	12.7	15.4	18.0	5.3
12	157.9	32.6	13.6	17.1	19.0	7.2
18	154.2	31.9	12.6	14.0	17.0	5.6
24	156.2	32.1	12.8	15.5	18.6	6.3
48	150.2	32.0	13.2	15.3	18.8	6.0
72	153.7	35.0	14.3	17.4	18.4	6.9
96	151.9	36.3	15.3	19.5	19.6	8.2
Maximum	158.0	36.3	15.6	19.5	19.6	8.2
Minimum	149.1	31.6	13.2	13.6	14.8	5.3
Mean	153.9	33.2	13.7	15.9	18.0	6.5
Variation	8.9	4.7	2.4	5.9	8.8	2.9

Table XIV. Weight of overs and break flour from first break
1929 shriveled wheat

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	13 XX	Break flour
3	875.0	44.7	35.7	20.0	17.3	4.0
6	872.6	45.9	36.0	26.3	19.6	4.8
12	867.3	48.5	39.8	22.8	21.5	4.8
18	864.0	47.2	38.0	21.3	20.6	4.5
24	873.3	45.4	37.2	21.3	20.0	4.6
48	882.3	47.5	38.2	22.0	19.6	4.8
72	870.0	48.0	38.6	22.1	20.8	5.3
96	860.0	51.2	38.7	22.0	20.3	6.3
Maximum	882.3	51.2	39.8	26.3	21.5	6.3
Minimum	860.0	44.7	35.7	20.0	17.3	4.0
Mean	870.5	47.3	37.7	22.2	19.9	4.9
Variation	22.3	6.5	4.1	6.3	4.2	2.3

Table XV. Weight of overs and break flour from second break 1929 shriveled wheat

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	12 XX	Break flour
3	436.6	120.6	176.3	20.0	17.3	4.0
6	438.0	121.3	170.0	26.3	19.6	4.8
12	438.6	102.2	170.0	22.8	21.5	4.8
18	431.3	103.8	174.8	21.3	20.6	4.5
24	438.6	108.1	167.8	21.3	20.0	4.6
48	445.0	112.8	169.8	22.0	19.6	4.8
72	444.6	115.3	165.6	22.1	20.8	5.3
96	436.6	120.6	161.4	22.0	20.3	6.3
Maximum	445.0	121.3	176.3	26.3	21.5	6.3
Minimum	431.3	103.8	161.4	20.0	17.3	4.0
Mean	438.6	113.1	169.3	22.2	19.9	4.8
Variation	13.7	17.5	4.9	6.3	2.2	2.3

Table XVI. Weight of overs and break flour of third break 1929 shriveled wheat

Tempering time hours	24 W.	36 G.G.	54 G.G.	72 G.G.	12 XX	Break flour
3	265.0	22.5	49.5	44.9	36.5	13.2
6	274.6	23.6	49.7	38.3	35.3	15.6
12	296.3	22.2	44.7	33.3	39.6	11.8
18	298.0	22.5	45.8	33.5	28.6	9.8
24	295.0	22.5	48.3	36.0	33.3	12.6
48	289.0	23.8	49.1	35.6	31.6	11.5
72	289.0	25.2	49.5	36.0	29.7	11.3
96	279.0	24.6	49.0	29.2	24.8	11.7
Maximum	298.0	25.2	49.7	44.9	36.5	15.6
Minimum	265.0	22.2	44.7	29.2	24.8	11.3
Mean	285.7	23.5	48.2	35.9	31.1	12.2
Variation	33.0	3.0	5.0	15.7	11.7	4.3

Table XVII. Weight of overs and break flour from fourth break 1929 shriveled wheat.

Tempering time hour	18 W.	26 W.	44 W.	70 G.G.	13 XX	Break flour
3	175.0	27.0	11.2	18.5	19.0	6.0
6	179.0	27.3	12.6	21.1	21.3	7.6
12	189.6	28.2	13.6	25.6	26.3	7.0
18	187.3	30.2	15.4	25.6	29.3	8.6
24	184.0	29.2	14.0	22.5	24.0	7.0
48	180.6	30.3	11.2	25.5	26.2	8.6
72	180.0	29.7	15.1	27.7	27.6	8.3
96	180.0	26.0	11.6	24.6	22.6	8.0
Maximum	189.6	30.3	15.4	27.7	29.3	8.6
Minimum	175.0	26.0	11.1	18.5	19.0	6.0
Mean	181.9	28.5	13.0	23.8	24.5	7.6
Variation	14.6	4.3	4.3	9.2	10.3	2.6

Table XVIII. Weight of overs and break flour from first break 1929 plump wheat.

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	13 XX	Break flour
½	797.5	81.5	56.0	30.5	25.0	5.0
1	792.5	86.5	61.0	33.5	30.0	7.5
2	782.5	85.5	62.5	35.0	30.5	7.0
3	800.0	74.5	54.5	30.0	26.5	6.0
6	780.0	86.5	60.0	32.0	28.0	7.5
12	755.0	97.5	68.0	37.0	31.5	10.0
18	777.5	87.5	62.0	33.5	29.0	9.5
24	762.5	94.5	66.5	35.5	31.0	11.0
48	777.5	88.0	62.0	32.5	28.0	8.5
72	782.5	86.5	60.0	33.0	28.0	9.5
96	775.0	86.5	62.5	34.5	31.0	7.0
Maximum	800.0	97.5	68.0	37.0	31.[illegible]	11.0
Minimum	755.0	74.5	54.5	30.0	25.0	5.0
Mean	780.2	86.8	61.3	33.3	28.9	8.0
Variation	45.0	23.0	13.5	7.0	6.5	6.0

Table XIX. Weight of overs and break flour from second break 1929 plump wheat.

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	12 XX	Break flour
½	400.0	106.0	170.0	58.0	43.0	18.0
1	396.0	88.5	169.0	63.0	45.0	19.5
2	382.5	78.0	168.5	67.5	47.0	22.0
3	410.0	91.0	165.0	59.5	46.5	19.0
6	400.0	98.0	154.5	59.0	43.5	20.0
12	400.0	97.5	147.5	54.5	40.0	18.0
18	412.5	102.5	144.5	54.0	41.0	16.5
24	402.5	97.5	143.5	53.5	39.0	19.0
48	385.0	95.0	158.0	62.5	45.0	22.0
72	432.5	105.0	133.0	49.0	37.5	15.0
96	437.5	103.0	131.5	46.0	37.0	13.5
Maximum	437.5	106.0	170.0	67.5	47.0	22.0
Minimum	382.5	78.0	131.5	46.0	37.0	13.5
Mean	405.2	94.7	153.2	56.9	42.2	18.4
Variation	55.0	28.0	38.5	21.5	10.0	8.5

Table XX. Weight of overs and break flour from third break
1929 plump wheat

Tempering time hours	24 W.	36 W.	54 G.G.	72 G.G.	12 XX	Break flour
½	240.0	20.5	47.0	39.5	33.0	13.0
1	242.5	17.5	37.5	37.5	35.0	13.5
2	240.0	18.5	34.0	36.0	34.0	14.5
3	245.0	18.5	47.5	39.0	34.0	12.0
6	257.5	21.0	44.5	31.5	27.0	12.0
12	237.5	22.5	46.5	38.0	34.5	14.0
18	252.5	23.0	49.5	38.5	34.5	15.0
24	240.0	21.0	46.0	38.5	34.5	16.0
48	240.0	19.0	41.0	34.5	30.0	12.0
72	267.5	26.0	55.5	38.0	33.0	14.0
96	260.0	24.0	58.5	40.0	34.0	14.0
Maximum	257.5	26.0	58.5	40.0	35.0	16.0
Minimum	237.5	17.5	34.0	31.5	27.0	12.0
Mean	247.4	21.4	46.1	37.3	33.4	13.6
Variation	20.0	8.5	24.5	8.5	8.0	4.0

Table XXI. Weight of overs and break flour from fourth break 1929 plump wheat.

Tempering time hours	18 W.	26 W.	44 W.	70 G.G.	13 XX	Break flour
½	145.0	32.5	14.5	17.5	17.0	5.0
1	146.5	31.5	14.5	15.0	15.0	3.0
2	147.5	30.5	15.5	14.5	15.0	4.5
3	155.0	32.0	15.5	19.0	23.5	7.5
6	137.5	34.5	17.5	24.0	24.0	10.0
12	135.0	36.0	17.0	21.0	22.0	7.5
18	137.5	36.5	18.0	23.0	24.0	8.0
24	128.5	37.0	18.5	19.5	21.5	8.5
48	125.0	38.0	20.0	20.5	21.5	9.0
72	142.5	36.0	20.0	25.5	28.5	10.0
96	142.5	31.0	17.5	25.5	28.0	10.5
Maximum	155.0	38.0	20.0	25.5	28.5	10.5
Minimum	125.0	30.5	14.5	14.5	15.0	3.0
Mean	140.2	34.1	17.1	20.4	21.8	7.6
Variation	30.0	7.5	5.5	11.0	13.5	7.5

Likewise we find in Tables X to XXI no advantage of the short tempers over the long or vice versa as far as the weight of break flour is concerned. For illustration let us use the break flours from the 1928 wheat. On first break we have a maximum weight of 15.4 gm. and a minimum weight of 12.5 gm. or a variation of 2.9 gm. On second break we have the maximum weight of break flour equal to 27.5 gm. and the minimum weight equal to 21.3 gm. or a variation of 6.2 gm. On third break the maximum weight of break flour is equal to 14.6 gm. and the minimum equal to 9.0 for a variation of 5.6 gm. On fourth break the variation was found to be 2.9 gm. with a maximum of 8.2 and a minimum of 5.3 gm. Similar variations were found on break flours for the other tests.

In Tables XXII to XXIV we have presented the ash content on the break flours for the different lots of wheat used. On the 1929 plump wheat in which the periods of temper range from ½ hour to 96 hours we have a maximum ash content on first break of .781 per cent, and a minimum of .690 per cent or a variation of .091 per cent. On second br ak we have a maximum ash content of .636 per cent and a minimum of .570 per cent or a variation of .066 per cent. On third break we find the maximum per cent equal to .628 and the minimum equal to .445 or a variation of .183 per cent. On fourth break the variation was .188 per cent with a maximum

Table X. Weight of overs and break flour first break 1928 wheat.

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	13 XX	Break flour
3	735.3	100.0	71.5	39.0	34.9	15.4
6	735.0	103.0	70.6	38.0	36.1	12.9
12	741.3	99.0	69.3	37.9	34.9	15.1
18	735.3	104.0	71.2	38.4	35.5	12.7
24	739.0	100.0	69.3	37.5	35.3	13.6
48	737.3	98.9	70.7	36.8	37.5	13.5
72	731.3	102.5	71.3	39.8	37.5	13.5
96	729.6	104.5	71.5	39.2	37.7	15.0
Maximum	741.3	104.5	71.5	39.8	37.7	15.4
Minimum	729.6	98.9	69.3	37.5	34.8	12.5
Mean	735.4	101.5	70.7	38.3	35.8	13.8
Variation	11.7	5.6	2.2	2.3	2.9	2.9

Table XXII. Ash on break flours
1929 plump wheat.

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break
½	.764	.636	.628	.828
1	.700	.570	.560	.796
2	.690	.570	.592	.790
3	.715	.595	.540	.642
6	.781	.607	.598	.691
12	.733	.596	.541	.650
18	.744	.600	.538	.641
24	.771	.605	.445	.670
48	.753	.604	.578	.678
72	.752	.602	.598	.660
96	.746	.636	.563	.640
Maximum	.781	.636	.628	.828
Minimum	.690	.570	.445	.640
Mean	.741	.602	.562	.699
Variation	.091	.066	.183	.188

Table XXIII. Ash on break flours
1929 shriveled wheat.

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break
3	.713	.587	.546	.627
6	.706	.557	.545	.620
12	.523	.518	.538	.605
18	.607	.635	.628	.695
24	.620	.622	.628	.595
48	.647	.506	.513	.589
72	.645	.510	.517	.596
96	.673	.564	.548	.603
Maximum	.713	.587	.628	.695
Minimum	.523	.518	.513	.589
Mean	.642	.562	.558	.616
Variation	.190	.069	.105	.106

Table XXIV. Ash on break flours
1928 wheat.

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break
3	.640	.550	.602	.772
6	.664	.529	.575	.712
12	.633	.537	.602	.678
18	.656	.574	.604	.720
24	.649	.558	.582	.673
48	.646	.584	.610	.682
72	.685	.584	.468	.682
Maximum	.688	.584	.604	.772
Minimum	.633	.529	.468	.673
Mean	.657	.560	.576	.707
Variation	.055	.055	.136	.099

of .828 per cent and a minimum of .640 per cent. Similar ash contents were obtained on the other lots of wheat. Thus from the data obtained there seems to be no significant advantage either for or against the shorter or longer tempers as far as ash content of the break flour is concerned.

The conclusions to be drawn from the above experiment are that under like conditions making the only variable the tempering period, the length of tempering period has no significant effect upon the per cent extractions obtained on the different breaks, the weight of middlings produced, the weight of break flour produced, or the ash content of the break flours.

LARGE MILL EXPERIMENT

In order to check the results obtained on the small experimental mill for the effects of the length of tempering period on the breaking process, additional experiments were conducted on the large experimental mill using ten bushel samples for each period of temper, to determine any further effect of the tempering period on the milling process. Ten bushel samples were used because we had no satisfactory way to dispose of the flour from larger samples.

The wheat used for the large mill experiment consisted of a lot of 1929 high quality hard red winter wheat. Eight lots of ten bushels each were used in performing the experiment, seven for the different periods of temper used, and one as a check sample to warm the mill up and make sure that the mill was operating properly. The same system of cleaning and conditioning was used on all samples, receiving separator, milling separator, horizontal scourer, temper, and scour again just before wheat goes to the roll. The different samples were tempered 3, 6, 12, 24, 48, 72 and 96 hours respectively. The check sample was tempered 24 hours. The humidity control was allowed to run all night the night before in order to obtain constant humidity and temperature conditions. To maintain these conditions all doors and windows were kept closed throughout the experiments.

The break and reduction rolls were set during the period of grinding the check samples and not changed during the grinding of the seven remaining samples unless absolutely necessary due to a roll heating.

Data Obtained for Measuring Length of Tempering Period Effects

The method used to determine the effect of tempering period on breaking consisted of catching samples of break stock for each test. These samples were placed in cans and sifted on a Rotomatic sifter. From the weight of overs found the percentage extraction was calculated.

The power used for grinding each sample was determined by use of a wattmeter which was connected to the 25 H.P. motor which drove the rolls. Readings were taken at the time the wheat first hit the first break roll and at the time the last portion of the sample had just passed through the first break roll. The difference in readings was then calculated and used as the power consumption.

Samples of flour were caught for 10 minutes from each reduction and the weights determined. From these samples small portions were taken for ash and moisture determinations. The samples were placed in air tight bottles and the moisture tests made as soon as possible the same day the samples were ground to prevent any great loss of moisture due to evaporation. Samples of flour were also taken from the patent and clear streams for ash and moisture determinations and for baking and diastatic activity tests.

Results of Large Mill Experiments

The samples taken under the break rolls for determining the per cent of extraction on each break were caught by moving the sampling pan under the roll from one end to the other while it was filling, as this method gave a sample representative to a very close degree of the work being done by the entire roll. The sampling pan was not allowed to run over as this will result in retaining too much fine material in the sample. The samples were weighed on a torsion balance sensitive to .1 gm. They were then sifted over a set of sieves which was chosen to represent the sifting done in the larger experimental mill. Two minutes was used as the sifting time in order to be sure of the proper separation. This is longer than the time used in the common mill sifter, but since the results were desired for comparative purposes, two minutes seemed to be the most advisable length of time to use. After each sifting the weights of the overs as well as the break flour were determined to the nearest .1 gm.

The sets of sieves used for each break stock were as follows:

1st. break	2nd. break	3rd. break	4th. break
20 W.	20 W.	24 W.	26 W.
32 W.	32 W.	36 W.	44 W.
50 G.G.	50 G.G.	54 G.G.	
70 G.G.	70 G.G.	72 G.G.	70 G.G.
13 XX	12 XX	12 XX	13 XX

The same sets of sieves were used in sifting the samples from all tests so that the results obtained would be comparative for different tests.

In Table XXV are presented the data and calculations for the 3 hour temper, 15 minute samples. Column 1 contains a list of the cloths used for the different break stocks as shown above. Column 2 contains the weights of overs of the various sieves and the break flour. Column 3 contains the calculated weight of sample or the weight of wheat necessary to produce the weight of break stock caught. Column 4 contains the per cent overs from the various sieves and the per cent of break flours. These figures are based on the calculated weights found in Column 3. Column 5 gives the per cent throughs of the top scalp or the per cent extraction of the various breaks. This column of figures shows the distribution of grinding on the different breaks and together with the per cent of bran should add up to 100 per cent.

The method used in calculating the per cents for this experiment is based on the weight of wheat as it goes to first break roll, not only for the first break, but also for the subsequent breaks. The per cent overs on the first break is calculated by multiplying the weight over each sieve by 100 and dividing by the weight of sample caught for

Table XXV. Data and calculations for three hour tempering period.

1	2 Weight	3 Calculated weight of sample	4 Per cent overs	5 Per cent extraction
1st. Break				
Wt. of sample	351	351		
18 W.	250		71.2	28.8
32 W.	33		9.4	
54 G.G.	33		9.4	
70 G.G.	15		4.2	
13 XX	15		4.2	
Flour	2		.57	
2nd. Break				
Wt. of sample	312	438		
20 W.	170		38.8	32.4
32 W.	26		5.9	
54 G.G.	64		14.7	
70 G.G.	25		5.7	
12 XX	19		4.3	
Flour	8		1.8	
3rd. Break				
Wt. of sample	232	597		
24 W.	139		23.2	15.6
36 W.	12		2.0	
60 G.G.	34		5.7	
72 G.G.	15		2.5	
12 XX	19		3.2	
Flour	9		1.5	
4th Break				
Wt. of sample	228	982		
26 W.	135		13.7	
44 W.	20		2.0	
70 G.G.	33		3.3	
13 XX	30		3.0	
Flour	6		.61	

first break. That is in the case of 3 hour temper the per cent overs on 20 [illegible]. $= \frac{250 \times 100}{351} = 71.2$ per cent. On the second break, however, it is necessary first to find the relation of the sample caught to the weight of wheat going to the first break roll. Since it is the overs of the top scalp of the first break sifting which goes to the second break, and furthermore since it is already known what per cent this is of the wheat, having already made the calculations for the first break stock, it is a simple matter then to find the relation of the sample caught to the weight of wheat. For example in Table XXV the per cent overs of the top scalp of first break was 71.2 per cent. Therefore, 71.2 per cent of the material from the original wheat is going to second break. The weight of the sample caught under second break was 312 gm., and since this is 71.2 per cent of the original wheat, then the amount of wheat required to produce 312 gm. of second break stock is found thus $\frac{312 \times 100}{71.2} = 438$ gm. The weights of overs of the second break are then divided by 438 gm. or the weight of wheat necessary to produce 312 gm. of second break stock in order to obtain the per cents over the various sieves. For illustration let us use again Table XXV: The per cent over 20 [illegible]. on second break $= \frac{170}{438}$ or 38.8 per cent, and so on for the other overs and the break flour. This method will hold true for the subsequent breaks as the per cent overs on the top scalp is equal to the weight of sample caught under the next break, and the weight of wheat necessary to produce that weight of sample may be calculated readily.

The per cent overs and the per cent break flour for the four breaks, for each period of temper used are presented in Tables XXVI to XXIX. This data is presented both for the samples caught 15 minutes and for those caught 45 minutes after the tests are started.

It is found in making a study of the maximum and minimum percentages over the various cloths that there seems to be little or no trend toward an advantage for either the longer or shorter tempers on the coarser middlings. But in the case of the break flour there seems to be a trend toward the production of a higher per cent of break flour on the 48 and 72 hour temper due probably to a mellowing effect of the endosperm. The shorter tempers seem to be very consistent in producing for all four breaks the smallest per cent of break flour. Likewise the extra long 96 hour temper produced a smaller per cent of break flour than did the 48 and 72 hour tempers due probably to a drying out of the endosperm.

Table XXVI. Per cent overs and per cent break flour of first break.

15 Minute Samples

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	13 XX	Flour
3	71.2	9.4	9.4	4.2	4.2	.57
6	72.0	9.3	9.3	4.3	4.3	.58
12	71.5	8.6	9.5	4.0	4.0	.87
24	72.5	8.8	8.8	4.1	3.8	.88
48	70.0	8.7	9.9	4.6	4.6	1.10
72	70.5	9.3	9.6	4.1	4.1	1.50
96	70.0	8.9	10.0	4.8	4.8	.51
Maximum	72.5	9.4	10.0	4.8	4.8	1.50
Minimum	70.0	8.6	8.8	4.0	3.8	.51
Variation	2.5	.8	1.2	.8	1.0	.99

45 Minute Samples

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	13 XX	Flour
3	71.5	9.1	9.4	3.9	4.4	.60
6	72.0	8.8	9.1	4.1	4.1	.58
12	71.5	8.6	9.5	4.3	4.3	.57
24	72.0	8.4	9.5	4.2	4.2	.53
48	73.0	8.0	8.8	4.0	4.0	.86
72	72.4	8.9	9.5	4.3	4.3	1.10
96	68.0	9.2	11.0	4.9	5.1	.6
Maximum	73.0	9.2	11.0	4.9	5.1	.86
Minimum	68.0	8.0	9.1	3.9	4.0	.53
Variation	5.0	1.2	1.9	1.1	1.1	.33

Table XVII. Per cent overs and per cent break flour of second break.

15 Minute Samples

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	12 XX	Flour
3	38.8	5.9	14.7	5.7	4.3	1.0
6	37.6	5.6	15.0	5.9	4.5	2.1
12	39.8	6.0	13.9	5.0	4.1	1.6
24	38.2	6.1	15.4	6.1	4.4	2.0
48	33.5	5.1	15.6	7.5	5.1	2.7
72	40.6	7.5	12.9	3.2	3.7	2.0
96	36.8	5.2	14.0	6.6	5.0	2.0
Maximum	40.6	7.5	15.6	7.5	5.1	2.7
Minimum	33.5	5.1	12.9	3.2	3.7	1.8
Variation	7.1	2.4	2.7	4.3	2.4	.9

45 Minute Samples

Tempering time hours	20 W.	32 W.	50 G.G.	70 G.G.	12 XX	Flour
3	39.1	6.0	14.1	5.3	3.9	1.8
6	39.3	6.2	14.7	5.7	4.3	1.9
12	39.2	5.6	14.4	5.4	4.0	1.8
24	38.2	5.9	14.8	5.5	4.2	2.2
48	35.6	5.5	15.9	7.8	5.8	2.5
72	42.8	7.4	13.0	3.2	3.9	1.7
96	34.6	5.1	14.3	6.9	4.6	2.3
Maximum	42.8	7.4	15.9	7.8	5.8	2.5
Minimum	34.6	5.1	14.1	3.2	3.9	1.7
Variation	8.2	2.3	1.8	4.6	1.9	.8

Table XXVIII. Per cent overs and per cent break flour of third break.

15 Minute Samples

Tempering time hours	24 W.	36 W.	54 G.G.	72 G.G.	12 XX	Flour
3	23.2	2.0	5.7	2.5	3.2	1.5
6	24.0	1.7	5.5	2.2	2.7	1.1
12	23.0	2.2	5.5	2.9	3.7	1.3
24	22.7	2.0	5.5	2.4	3.1	1.7
48	21.6	1.8	3.3	2.0	2.5	1.2
72	23.0	2.1	5.9	2.9	3.7	2.1
96	22.5	2.3	4.2	2.5	3.5	1.5
Maximum	24.0	2.3	5.9	2.9	3.7	2.1
Minimum	21.6	1.7	4.2	2.0	2.7	1.1
Variation	2.4	.6	1.7	.9	1.0	1.0

45 Minute Samples

Tempering time hours	24 W.	36 W.	54 G.G.	72 G.G.	12 XX	Flour
3	24.4	1.8	5.0	2.5	3.4	1.5
6	24.3	2.1	5.7	2.4	2.9	1.2
12	23.0	2.1	5.4	2.8	3.6	1.6
24	24.9	1.8	5.3	1.9	2.5	1.2
48	22.0	2.0	4.1	2.4	3.4	1.5
72	24.4	2.3	6.2	3.1	3.9	2.1
96	21.5	2.1	4.1	2.3	3.2	1.3
Maximum	24.9	2.3	5.7	3.1	3.9	2.1
Minimum	21.5	1.8	4.1	1.9	2.5	1.2
Variation	3.4	.5	1.6	1.2	1.4	.9

Table XXIX. Per cent overs and per cent break flour of fourth break.

15 Minute Samples

Tempering time hours	26 W.	44 W.	70 G.G.	13 XX	Flour
3	13.7	2.0	3.3	3.0	.61
6	14.9	1.9	3.3	3.0	.60
12	14.1	2.2	3.1	2.6	.54
24	13.7	2.3	3.2	2.8	.53
48	14.2	1.9	2.5	2.3	.56
72	13.5	2.3	3.5	2.7	.62
96	14.3	2.4	2.4	2.4	.45
Maximum	14.9	2.4	3.5	3.0	.62
Minimum	13.5	1.9	2.4	2.3	.45
Variation	1.4	.5	1.1	.7	.17

45 Minute Samples

Tempering time hours	26 W.	44 W.	70 G.G.	13 XX	Flour
3	15.8	1.9	3.0	2.4	.58
6	15.1	1.9	3.3	3.0	.60
12	13.7	2.4	3.2	2.9	.55
24	15.5	2.1	3.3	2.9	.65
48	14.0	2.5	2.3	2.3	.58
72	15.6	2.2	3.0	2.5	.75
96	13.8	2.5	2.3	2.2	.42
Maximum	15.8	2.5	3.3	3.0	.75
Minimum	13.7	1.9	2.3	2.2	.42
Variation	2.1	.6	1.0	.8	.33

The percentage extraction on the breaks for each period of temper was calculated by a method similar to that used in the report of the small experimental mill work, for calculating the per cent extraction and per cent bran. The per cents extraction for the different breaks for the different periods of temper are presented in Table XXX for both the 15 minute and 45 minute samples. It is found in comparing the extractions for the 15 minute and 45 minute samples that they check very closely showing that the grinding during the test was very uniform over the entire period of grinding. The variations in the per cent extraction for the different periods of temper were very small and as in the small mill work the temper period had very little effect on the per cent extraction. The small variations that are found can be easily accounted for by the experimental error and the error in weighing.

In Table XXXI are presented the weights of flour from the different reductions for the various periods of temper. The samples were caught for a ten minute period and the weights of the sample determined. This test failed to show any trend or advantage for the shorter or longer tempers. The errors due to the short periods of time during which the samples were caught were much greater than any differences which might occur due to a variation in the length of the tempering period. Thus it would seem advisable in

Table XXX. Per cent extraction on breaks.

15 Minute Samples

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break	Bran	Total
3	28.8	32.4	15.6	8.5	13.7	99.0
6	28.0	33.4	13.6	9.1	14.9	99.0
12	28.5	31.7	16.8	8.9	14.1	100.0
24	27.5	34.3	15.5	9.0	13.7	100.0
48	30.0	36.5	11.9	7.4	14.2	100.0
72	29.5	29.9	17.6	9.5	13.5	100.0
96	30.0	33.2	14.3	8.2	14.3	100.0
Maximum	30.0	36.5	17.6	9.5	14.9	
Minimum	27.5	29.9	11.9	7.4	13.5	
Variation	2.5	6.6	5.7	2.2	1.4	

45 Minute Samples

Tempering time hours	1st. break	2nd. break	3rd. break	4th. break	Bran	Total
3	28.5	32.4	14.7	9.6	15.8	101.0
6	28.0	32.7	15.0	9.2	15.1	100.0
12	28.5	32.3	16.2	9.3	13.7	100.0
24	28.0	33.8	13.3	9.4	15.5	100.0
48	27.0	37.4	13.6	8.0	14.0	100.0
72	27.6	29.6	18.4	8.8	15.6	100.0
96	32.0	33.4	13.1	7.7	13.8	100.0
Maximum	32.0	37.4	18.4	9.6	15.8	
Minimum	27.0	29.6	13.1	7.7	13.7	
Variation	5.0	7.8	5.3	1.9	2.1	

further work of this nature to take the samples for a longer period of time in order to get a better representation for the test.

In Table XXXII and XXXIII are presented the ash and moisture determinations for the different reductions for the different periods of temper. We find in the data in these two tables no trend of an advantage for either the shorter or longer tempers as far as moisture or ash of the flour streams are concerned.

Thus we may conclude from this data that under like conditions the tempering period has very little if any effect on the moisture and ash content of the flour streams produced.

In Table XXXIV are presented the percentage yields of the different products for the different periods of temper. Considerable variation appears in the total per cent of flour produced for the different tests, but considerable error enters into this postion of the experiment due to the small samples used.

Diastatic activity determinations were made on the flours and wheat from the 3, 24, 48 and 72 hour periods of temper. The determinations were made by measuring the sugar content of the samples at room temperature, 25°C. and at 63°C.

Table XXXI. Weights of flour streams for a ten minute period.

Flour Streams	Tempering period						
	3 hours	6 hours	12 hours	24 hours	48 hours	72 hours	96 hours
1st. Break	470	450	480	495	475	505	480
2nd. Break	585	690	200	795	655	630	675
3rd. Break	575	595	770	670	560	630	645
4th. Break	495	805	275	665	790	510	620
Sizings	1105	1250	1120	1385	1160	1150	1445
1st. Midds.	3105	3245	4025	3015	3860	1925	4070
2nd. Midds.	2360	3120	3210	2565	3180	4485	3345
3rd. Midds.	4315	5465	4335	4265	5430	4385	5260
4th. Midds.	3945	4550	3920	3510	4425	3540	4255
5th. Midds.	1865	2295	1955	1460	2235	1920	2290
1st. Tail.	1275	1595	1110	1580	1395	1410	1595
2nd. Tail.	1730	1965	1595	1430	1910	2295	1760
Reel	2100	2220	2320	1835	2565	2545	3105
Total	23925	28235	25815	2[illegible]720	28660	25930	29545

Table XXXII. Ash on flour stream.

Flour Streams	Tempering period 3 hours	6 hours	12 hours	24 hours	48 hours	72 hours	96 hours
1st. Break	.43	.43	.45	.46	.41	.45	.40
2nd. Break	.45	.42	.48	.46	.44	.45	.44
3rd. Break	.46	.49	.52	.53	.48	.50	.49
4th. Break	.64	.62	.49	.65	.56	.69	.69
Sizings	.36	.38	.39	.38	.38	.39	.40
1st. Midds.	.37	.39	.37	.38	.37	.40	.39
2nd. Midds.	.37	.37	.37	.38	.38	.37	.38
3rd. Midds.	.34	.33	.34	.35	.34	.36	.35
4th. Midds.	.36	.36	.40	.37	.38	.40	.39
5th. Midds.	.41	.39	.44	.43	.42	.43	.43
1st. Tail.	.42	.41	.47	.42	.43	.42	.43
2nd. Tail.	.47	.46	.52	.48	.48	.44	.52
Reel	.60	.61	.66	.63	.63	.61	.61
Clear	.54	.54	.69	.56	.55	.62	.53
Patent	.37	.38	.40	.41	.37	.40	.39

Table XXXIII. Moisture on flour streams.

Flour Streams	Tempering period 3 hours	6 hours	12 hours	24 hours	48 hours	72 hours	96 hours
1st. Break	10.5	15.5	15.6	15.1	15.5	15.8	15.4
2nd. Break	15.5	15.2	14.5	14.4	15.0	15.5	15.3
3rd. Break	15.2	14.9	15.4	14.6	14.9	15.2	15.1
4th. Break	14.9	14.9	13.7	14.5	14.7	14.3	14.7
Sizings	14.8	14.9	14.9	14.6	14.9	15.3	14.9
1st. Midds.	15.0	14.5	15.2	14.5	14.8	15.1	14.4
2nd. Midds.	14.5	14.3	14.4	14.1	14.3	14.8	13.9
3rd. Midds.	14.2	14.3	14.5	14.0	14.1	14.4	14.1
4th. Midds.	13.5	13.6	13.4	13.1	13.2	13.5	13.3
5th. Midds.	12.6	12.8	12.5	12.2	14.2	12.7	12.4
1st. Tail.	13.7	14.1	13.8	13.7	13.9	14.4	13.8
2nd. Tail.	13.0	13.3	12.4	12.8	13.1	13.8	12.9
Reel	13.2	13.2	12.0	12.6	13.1	12.9	12.8
Clear	13.1	12.9	11.7	12.6	12.3	12.5	12.8
Patent	13.5	13.3	12.6	12.1	12.9	12.5	13.7

The latter temperature is the optimum temperature for action of the diastatic enzyme. The diastatic activity was then taken to be the difference between the sugar contents at these two temperatures. A decided trend was found in both the wheat and flour as is shown in Table XXXV.

Table XXXV. Diastatic Activity.

Period	Flour	Wheat
3 hour	52.1	33.5
24 hour	32.9	18.6
48 hour	38.9	16.6
72 hour	26.8	12.1

The explanation for the slightly higher diastatic activity on the shorter tempers is that it is probably due partly to a respiratory action which is increased by the longer periods of temper. It is generally thought among chemists that the enzyme action due to the addition of moisture to wheat would increase with the time of tempering. The writer was unable to find any satisfactory explanation for the trend found unless some respiratory action in addition to the diastatic action was measured.

Table XXXIV. Per cent yields of products produced.

Tempering time hours	Wheat weight	Patent Weight	Patent Per cent	Clear Weight	Clear Per cent	Total flour	Bran Weight	Bran Per cent	Shorts Weight	Shorts Per cent
3	568	281	49.5	73	12.8	62.3	108	19.0	63	11.1
6	586	284	48.5	73	12.4	60.9	110	18.7	65	11.1
12	550	268	48.6	51	9.3	57.9	90	16.4	51	9.3
24	556	255	45.8	102	18.3	64.1	94	16.9	63	11.3
48	610	307	50.3	86	14.1	64.4	103	16.9	68	11.1
72	486	235	48.3	61	12.5	60.8	85	17.5	58	11.9
96	602	313	52.0	83	13.8	65.8	99	16.4	61	10.3

Baking tests were run on the patent flour samples for the various periods using a standard baking formula but lengthening the fermentation period and using no sugar. This was to magnify any differences in the amount of sugar produced by the diastatic enzymes which had been developed due to the different periods of temper. The results obtained showed practically no difference in volume, color and texture.

Power determinations for the different periods of temper are presented in Table XXXVI.

Table XXXVI. Power required per bushel for each period of temper.

Tempering period hours	Weight of wheat pounds	Power K.W. hour	Power per bushel
3	568	12.5	1.32
6	586	11.5	1.18
12	550	11.8	1.28
24	556	12.0	1.29
48	610	12.3	1.21
72	486	11.0	1.35
96	602	12.3	1.22

This shows no decided advantage as far as power consumption is concerned for the different periods of temper. The three hour sample used a little more power due to the toughness of the bran, while the six hour sample used the smallest amount of power, but no general trend is shown.

Conclusions

1. Within the limits of 3 hours and 72 hours the length of the tempering period has practically no effect upon the weight of middlings produced, the ash content of the flour streams, the moisture content of the flour streams, the baking quality of the flour, or the power consumed in grinding the samples.

2. The weight of break flour produced showed a trend toward being slightly larger for the longer tempers.

3. The diastatic activity of the flour and wheat was slightly higher for the shorter tempers, apparently showing a decreasing trend as the period of temper was lengthened.

SUMMARY AND CONCLUSIONS

To obtain information on the length of the tempering period used by hard wheat millers in various sections of the country, questionnaires were sent in the spring of 1929 to 140 mill superintendents. In the replies of the mills using hard wheat very striking differences were found in the lengths of the tempering period being used. The periods of temper varied from 7 to 74 hours with about as many millers using the longer tempers as the shorter ones showing a wide difference of opinion upon the correct length of tempering period to use.

In a review of the milling press for the past five years very little scientific information could be obtained as most papers published on the subject of length of temper discussed this only in general terms, and did not give specific data to prove their statements, but relied mostly on the author's personal opinion.

Thus on account of the wide variation in current practice and small amount of available data on the subject, there is a need for a study of the effects of the length of the tempering period upon the process of milling.

The problem of tempering period was studied from three angles, the rate and place of water penetration, experimental tests on the small mill and experimental tests on the large mill. Experiments were performed to determine the place of water absorption by coating the germ, back, brush, and crease of the kernels with shellac to prevent the penetration of water through those portions. The kernels were then placed between wet cloths and the percentage gain in weight due to the absorption of water through different parts of the kernel was determined for different periods.

The data obtained showed that the wheat kernel is not enclosed in an impermeable membrane, but absorbs water freely throughout the entire surface. Moisture determinations on the different middlings stocks produced from some milling tests using different periods of temper showed that the bran coat has a greater affinity for water than did the endosperm of the wheat. These determinations also showed that at 64°F or room temperature the water had penetrated the wheat kernel in two hours, and was evenly distributed throughout the endosperm.

Experiments were conducted on the experimental mill to determine the effect of the length of tempering period on the percentage extraction of the different breaks, the weight of middlings produced, the amount of break flour produced, and the ash content of the break flours. Three lots of wheat were used, one plump wheat from the crop of 1929, one plump wheat from the crop of 1928, and one shriveled wheat from the 1929 crop. The 1928 wheat had suffered partial damage and would represent quite old wheat. Thus extremes in wheat were represented. The results of these tests using tempering periods of 3, 6, 12, 18, 24, 48, 72 and 96 hours, showed that under like conditions the period of temper has very little effect upon the above factors in the milling process.

Experiments were conducted on the large mill to verify the findings of the work on the small mill, since it was possible to make several added tests. The tempering periods used were 3, 6, 12, 24, 48, 72, and 96 hours. The samples used consisted of 10 bushel lots of hard red winter wheat, and were milled the same in every way except for the periods of temper.

The per cent extraction on the break rolls was determined by taking samples of the break stock under the rolls and sifting them for extraction. The percentage extraction was then calculated on the basis of weight of wheat going to first roll so that an accurate check upon the distribution of grinding could be determined. The results of the data obtained showed that the tempering period had little or no effect upon the percentage extraction of the different breaks.

The per cents of middlings and weight of break flour produced on each break were determined from the siftings of the break extractions. The results obtained showed no trend in favor of the short or long tempers as far as the per cent of middlings produced was concerned, but the data did show a trend toward the production of a higher per cent of break flour on the longer tempers than on the shorter tempers.

The results from the ash and moisture determinations showed as in the case of the work of the experimental mill that the variation in results for the different periods of temper was very small and that the variation did not follow any certain trend showing any advantage for either the long or short tempers as far as these two factors are concerned.

Baking tests were made on the patent flours produced for the different periods of temper. The baking formula was altered by omitting suger and extending the fermentation period. This was done to measure if possible the effects of any diastatic activity which had resulted from the longer periods of temper. The results obtained showed that there was no variation occurring which could be measured by volume, texture, or color.

Diastatic activity determinations were made by measuring the sugar content at room temperature and at 63°C. the difference between the two results being taken as the diastatic activity. The results of these tests showed a slightly higher diastatic activity for the shorter tempers which is contrary to theory, and the only explanation which can be offered is that in the short temper there is obtained a measure of a respiratory action in addition to the diastatic activity.

Power determinations were made on the large mill samples by the use of two meters, one a recording wattmeter, and the other an integrating wattmeter. The results of these determinations showed that the length of tempering period has very little effect on the power requirements for milling.

Due to the nature of the results obtained it was impossible to plot curves or apply statistical methods to the data as there were in most cases no trends either in favor of the short or long temper. The results of the experiments on the big mill were accurate and comparative. It would have been possible to have obtained much better information had the test been made on larger samples of wheat and more tests made using the same period of temper. In milling small samples there are certain variations due to mechanical operations. These would be averaged or smoothed out by running a longer time or by making more determinations. The reason this could not be done was because of a lack of a market for the products produced.

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