SOME EFFECTS OF COLD, WARM AND HOT WHEAT CONDITIONING ON THE MILLING AND BAKING CHARACTERISTICS OF WHEAT

by

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INTRODUCTION

Wheat conditioning may be defined as the treatment of wheat with water and possibly heat during a period of time. Water may be added and/or removed during the treatment to bring the wheat to the required moisture for milling.

To operate at a profit the miller must extract the maximum amount of high grade flour from the wheat kernel with a minimum cost.

The primary objective of wheat conditioning is to have the moisture distributed in such a way that the bran is tough enough to resist attrition and abrasion and yet can be cleanly separated from the endosperm. The endosperm should be reduced easily to flour with a minimum consumption of power and should sift evenly and accurately.

The secondary objective of wheat conditioning is the improvement of the baking characteristics of the flour.

Adding moisture and allowing the wheat to stand for a period of time is cold conditioning or tempering. Moisture adjustment in wheat with the use of heat and time at temperatures below 46°C is warm conditioning. Using temperatures in excess of 46°C for moisture adjustment is hot conditioning. 46°C is generally considered to be the dividing point between warm and hot conditioning. At 46°C or lower there is no appreciable chemical change in the grain (23).

The four variables encountered in conditioning are moisture, time, temperature and pressure. In this study moisture and pressure were constants while time and temperature were variables.

Conditioned samples of wheat were milled and baking tests were made on the flour to determine the effects of varying conditioning temperature and time. Flour yield, flour ash, farinograms, particle size, flour sedimentation and gas production were studied.

REVIEW OF LITERATURE

A knowledge of the structure of the wheat kernel is essential in understanding some of the problems encountered in wheat conditioning. The structure has a direct influence on the absorption of moisture by the wheat kernel. Bradbury, Cull and MacMasters (6) have covered the structure of a wheat kernel in detail.

Wheat immersed in water for ten seconds or less has been found to pick up approximately 2 per cent to 4 per cent of its weight in water (18), (33), (34), (42). This is due to the bran absorbing the water in much the same way as a blotter absorbs ink. Temperature of the water seems to have no effect until after two minutes of soaking (21), (34).

Moisture enters into the interior of the wheat kernel more quickly around the germ (17), (42). Many workers (8), (17), (34), (42) have concluded that the entire bran layer will allow the passage of water to or from the endosperm though not as fast as around the germ. Jones (21) found that bran removed from a wheat kernel will pick up twice as much water as the bran on a wheat kernel. Evidently one of the six bran layers slows the passage of water from the outside of the wheat kernel to the endosperm inside. From his studies, Jones (21) concluded that the hyaline layer slows the passage of water.

Hinton (20) believes that the testa slows the passage of water.

Numerous investigators (7), (9), (17), (40), (41) have shown that the germ or germ end absorbs moisture more quickly than the rest of the kernel. The beard end absorbs moisture more slowly than the germ end in unscoured or undamaged wheat kernels. This is due in part to the air trapped by the tiny hairs of the beard (34). In scoured kernels the germ will still pick up moisture more quickly than the scoured brush end which has had many of the tiny hairs removed.

This is due in part to the attachment region of the germ which has no cuticle covering it and has many intercellular spaces in the parenchyma tissue. Water can move very quickly through this spongy tissue. Also over the lower part of the germ there are many intercellular spaces among the intermediate cells, cross cells and tube cells which would allow the rapid passage of water.

After the moisture has penetrated the germ area it travels around the endosperm through the inner bran layer towards the brush end. At the same time the water penetrates into the endosperm. A short time later water penetrates the outer bran layer and is absorbed by the endosperm.

Hinton (20) stated that the movement of moisture through endosperm is from three to six times greater than through the testa which he considers the limiting layer in the bran.

However, the amount of endosperm present is so much greater than the bran that more time is required for complete penetration of moisture into the endosperm.

The time required for complete penetration of moisture into the wheat kernel is dependent on many factors.

Fraser and Haley (14) listed time, temperature, size of kernels and variety as factors that affected the rate of water penetration in wheat kernels. Other factors studied by investigators were scouring and internal fissures.

Factors Affecting The Pickup Of Moisture By Wheat

Time And Temperature. Jones (21) stated that there are three stages of moisture absorption by an immersed kernel of wheat at 60°F.

1. A rapid initial uptake of moisture.
2. An immediately following period during which the rate of absorption is falling.
3. A long period of much slower but relatively steady absorption.

Similar results were observed by Haltmeier (17), (18), Nuret (33), and Swanson and Pence (41).

The first stage is unaffected by temperature (17), (18), (41).

However, the second and third stages are greatly affected by temperature (10), (14), (17), (18). As the temperature of the wheat and water rises, the resistance of the wheat kernel to moisture decreases rapidly.

In referring to the influence of heat on moisture penetration into the wheat kernel, Campbell and Jones (22) stated that between 20°C and 43.5°C a rise of 12°C causes a threefold increase in speed of movement of moisture to the cheek center. Table 1 illustrates the change.

Table 1. Relationship of temperature to rate of moisture penetration.

Temperature		Percentage of Final Increment		
		50	85	100
°C.	°F.	Hours	Hours	Hours
20.0	68	5	24.0	60
31.5	89	2	8.0	20
43.5	110	1	2.6	6

Campbell and Jones also found that dampened wheat held for different periods of time at an elevated temperature, 43.5°C, varied the rate of moisture penetration into the wheat kernel.

Scouring. Fraser and Haley (14) and Campbell (9) showed that scouring of wheat kernels greatly increased the amount of water absorbed during one minute's immersion in water. Campbell (9) stated that the increased rate of absorption was in the peripheral dorsal region in the scoured grain. Most of the damage, due to scouring, was at the brush and germ ends and on the dorsal side.

Internal Fissures. Fisher and Hines (12), Milner and Shellenberger (31) found that wheat which had been moistened and dried several times had fissures or cracks in the endosperm. It was found that the wheat treated in this way absorbed water more quickly than the untreated or unfissured wheat. The rapid moisture pick up was attributed to the fissures.

Kernel Size. Investigations of Nuret (33) and Fraser and Haley (14) show that small kernel samples absorb water faster than large kernel samples of equal total weight. This was attributed to the fact that small kernels have a larger absorbing surface area in relation to weight.

Kernel Texture. Herd (19) found that soft wheats absorbed moisture more slowly than hard wheats.

Nuret (33) in tests with Manitoba and a soft domestic wheat found that Manitoba picked up water more quickly than the soft wheat. However, the Manitoba was 1.27 per cent lower in moisture than the domestic before the test.

Wheat Conditioning

Conditioning of wheat involves the adjustment of the moisture content of the grain with or without the use of heat and time. This investigation was concerned with cold, warm and hot conditioning.

Cold Conditioning (Tempering). Cold conditioning requires the addition of the proper amount of water to the wheat to bring it to the proper moisture for milling and a standing period to allow the moisture to penetrate. The proper milling moisture for the different classes of wheat is determined from experience with the mill on which the wheat is to be milled. After the water has been added and mixed by a mixing screw or some other suitable device, the moistened grain is held in conditioning bins. The holding time is subject to personal opinion and experience. The average holding time in the United States is probably ten hours.

Two variables encountered in cold conditioning are moisture and time.

McCormick (30) observed with a hard red winter wheat tempered to 15 per cent moisture content that the length of tempering time, within the limits of three hours and seventy-two hours, did not affect the power consumption, amount of middlings released or ash content of the break flour.

Stark (37) observed very little difference in the milling of Kansas hard red winter wheat at a moisture of 10.5 per cent to 11 per cent held from twelve hours to fifty-four hours. However, he did not report on the middlings released, power consumption or ash content of the break flour. Swanson and Pence (41) observed little effect on moisture distribution in wheat as affected by the length of the tempering period from one hour to twenty-four hours.

Anderson (1) observed that a Turkey variety wheat tempered to 18 per cent moisture for twenty-four hours gave the best curve with the mixograph as compared to other samples held for twenty-four hours at moisture contents of 16 per cent, 20 per cent and 22 per cent.

Swanson (38), (39), moistened wheat samples up to six times at moistures between 12 per cent and 28 per cent each time drying the samples back to 10 per cent moisture. Milling tests on the samples indicated that the total flour yield and flour ash were unaffected by the number of times of wetting and the amount of moisture added. Hardness tests on the control and treated wheat showed a decrease in hardness with moisture contents from 20 to 24 per cent. With moisture contents of 26 to 28 per cent there was a slight increase in hardness. The texture tests on the control and treated wheat showed an increase in mealy kernels with an increase in the number of times wetted and amount of moisture added. Koster (26) showed that an increase in moisture caused a decrease in hardness.

Seeborg and Barmore (36) investigated the effects of various moisture levels on soft wheat. With an increase in moisture a decrease was found in flour yield, flour ash and break release.

Wichser and Shellenberger (45) studied the effects of varying wheat moisture and tempering periods on the granulation of flour. No differences were found on the granulation of flour. Also no differences were found in the ash content, protein content, farinograms or baked products.

Dedrick (11) found that the moisture of wheat should be maintained during the tempering period. A large moisture loss in tempered wheat gave less flour with lower quality than tempered wheat whose moisture content was maintained.

Vermeylen (43) showed that tempered wheat gave flour of better gluten characteristics than flour from untempered wheat. Flour from wheats that had the moisture added in several steps gave better farinograms than flour from wheats which had the moisture added in one step.

Weber (44) stated that a wheat mix of several different types milled best when each component of the mix was tempered to its optimum milling condition, using moisture and time before blending and milling.

Warm Conditioning. Warm conditioning is the heating of wheat at temperatures up to 46°C with variable holding periods. The most obvious advantage of using heating is the increased rate of penetration into the wheat berry. This can greatly reduce standing time of conditioned wheat.

Kent-Jones (23), (24), (25), heated wheat samples at varying moisture contents for varying periods of time. At temperatures of 110°F and 90°F, and heating periods up to twenty-four hours, no appreciable changes were noticed in the resulting flours as indicated by ash, soluble extract, soluble phosphorus, maltose, pH and viscosity changes.

Warm conditioning apparently doesn't eliminate the need for separate treatment of different types of wheat. Brabender and Abdon (4) held a washed mixture of Manitoba and soft Plate and

Russian wheats for eight hours and then conditioned the mixture for seventy-five minutes at 42°C. The flour streams near the tail end of the mill had Manitoba-like characteristics while the flour streams near the head end of the mill were weaker like soft Plate and Russian wheats. By cold conditioning the Manitoba wheat for forty-eight hours and the soft wheat for eight hours and then conditioning the two together at 42°C for seventy-five minutes, the higher grade streams were properly strengthened by endosperm from the Manitoba wheat. This seemed to prove that it took a longer time to mellow the endosperm of the Manitoba wheat so that it reduced easily into flour in the early stages of grinding middlings.

Vermeylen (43) observed no difference in the baking quality of wheat that had been heated for an hour to 40°C to 45°C and wheat that had been cold conditioned for twenty-four hours.

In tests conducted by Losev (29), cold conditioning at 18°C for twenty-four hours gave better baking results than warm conditioning at 27°C for twenty-four hours and hot conditioning at 85°C for thirty minutes.

Remington (35) found an increase in strength for warm conditioned wheat over unconditioned wheat using Manitoba I, Australian and English wheat.

Hot Conditioning. Hot conditioning of wheat is the application of temperatures in excess of 46°C with variable holding times. As in warm conditioning, hot conditioning greatly accelerates the penetration of moisture in wheat. High temperatures, while accelerating the penetration of moisture, can cause the denaturization of the wheat proteins (13). Therefore, the treatment must be short and closely controlled. Swanson (40) studied the effect of high temperatures during conditioning of wheat. Samples of wheat at different moisture contents were heated to 45°C, 70°C and 98°C for varying periods of time. He concluded that the baking quality of flour and the milling quality of wheat could be improved with the use of heat.

Kent-Jones (23), (24), (25), in determining the effects of heat on wheat, found that heating dampened wheat to a temperature of 110°F for twenty-four hours produced no changes in baking quality or chemical properties. No changes were observed at 135°F for two hours but for six hours slight changes were noticed. Heating at 135°F for twenty-four hours greatly increased the strength. Sour odors developed after standing for several hours. Wheat heated to 160°F for one and one-half hours to two hours before conditioning gave flour of increased strength.

Geddes (15) found that as the moisture of the wheat is increased, the critical temperature, where baking quality is impaired, is lowered.

Tests conducted by Lindberg (26) found the critical temperature for the impairment of baking quality to be 50°C at a wheat moisture of 25 per cent, 55°C at a wheat moisture of 20 per cent and 65°C for a wheat moisture of 15 per cent.

Becker and Sallans (3) found that the critical temperature dropped as the wheat moisture went up, when baking quality was the criteria.

Wild (46) showed an improvement in baking quality with hot conditioning as compared to a cold conditioned control of soft German wheat. The best improvement was found at a temperature of 50°C to 57°C for one and one-quarter hours to one and one-half hours with an added moisture of 5 per cent to 6 per cent.

Vermeylen (43) found that Manitoba II wheat held for twenty-four hours with 5 per cent moisture added and heated at 55°C for one and one-half hours gave the best improvement. Other treatment temperatures ranged from 50°C to 60°C. Also it was found that different grades and lots of wheat could vary in their response to heat treatment.

In tests with German domestic wheat, Kuhl (27) improved the gluten with heat treatment up to 62°C to 65°C for one to two hours. Ziegler (47) was able to increase the extensibility of dough after treatment in a hot air conditioner at temperatures of 48°C for Manitoba and 47°C for Swiss domestic. Gehle (16) improved the baking quality of three German domestic wheats by conditioning at 45°C and 55°C.

Becker (2) investigated the effects of hot conditioning on the gluten of wheat. Temperatures of 56°C to 60°C were used. Farinograms showed that the higher temperatures strengthened the dough.

MATERIALS AND METHODS

The wheat used in this study was a hard red winter composite composed of two varieties, Kaw and Ottawa. This wheat had 13.9 per cent protein, 12.0 per cent moisture, 1.99 per cent ash (14.0 M.B.)

Cleaning

The grain was cleaned by passing it once through a Forster laboratory scourer, after which the foreign material was removed by passing it through a Hart-Carter Dockage Tester, using the riddle, screens, feed rate and air setting on the aspirator recommended by the manufacturer for hard red winter wheat.

Addition Of Moisture

The final moisture of the wheat for milling was 15.5 per cent for each test. Moisture added to the wheat was calculated by the following formula.

$$\frac{(100-M_1)}{(100-M_2)} \times W_1 = W_1 + H$$

M_1 = per cent moisture in the untempered wheat sample.

M_2 = per cent moisture in the tempered wheat sample.

W_1 = weight of untempered wheat sample.

H = weight of water to be added.

Water was added to the wheat in a rotating metal drum. Five minutes were allowed for the mixing of the water with the wheat after which time the moistened wheat sample was placed in a metal can and weighed. Knowing the weight of the empty can and the original weight of the wheat recorded, a check was made on the amount of water added.

Cold Conditioning

Cold conditioning was accomplished by moistening the sample to 15.5 per cent and allowing it to remain in the can at room temperature for twenty-four hours before milling.

Cold Soak

Cold soaking was accomplished by soaking a sample of wheat completely immersed in tap water for one hour. After soaking, all the water that would drain away in five minutes was removed by turning the can of wet wheat upside down on an 18 mesh wire screen. By weighing the can and the wet wheat, the weight of the water retained was determined and the per cent of moisture was calculated. The sample was then dried to 15.5 per cent moisture in a Miag Laboratory Wheat Conditioner by forcing air heated to 50°C through the rotating mass of wet wheat. About three hours was required for this drying process. After drying, the sample was allowed to stand for one hour before milling.

Warm And Hot Conditioning

Warm and hot conditioning was accomplished by heating a sample of wheat, moistened to 16.5 per cent, in a Miag Laboratory Wheat Conditioner for the desired length of time at the desired temperature, then cooling to room temperature. Heat was conducted to the wheat from electric heating elements in the rotating drum.

Heating Time And Holding Periods

The total elapsed time starting with the moistening of the sample, including the heating and holding operations to the start of the milling was always twelve hours. Heating periods of thirty minutes, one hour, two hours and twelve hours were tried. Holding time was twelve hours minus the heating period and varied from eleven and one half hours, eleven hours, ten hours to zero holding time. Heating temperatures of the dampened wheat were 43°C, 50°C, 60°C, 70°C or 90°C. The schedule of treatment of the wheat at one temperature is shown in Table 2.

Table 2. Treatment schedule.

Temperature	Heating Time	Holding Time
43°C	½ hr.	11½ hr.
43°C	1 hr.	11 hr.
43°C	2 hr.	10 hr.
43°C	12 hr.	0 hr.

Heating and holding periods for 50°C and 60°C were the same as for 43°C. The heating periods for 70°C were one-fourth hour and one-half hour. Corresponding holding times were eleven and three-fourths hours and eleven and one-half hours. For 90°C the sample was heated for five minutes and held for eleven hours and fifty-five minutes.

Operation Of The Miag Laboratory Wheat Conditioner

The heating chamber of the Miag Laboratory conditioner is an insulated rotating drum which has electric heating elements in the sides and ends. The desired temperature is preset with the thermostatic regulator. A twenty minute period was allowed for pre-heating the conditioner before placing the sample in it. Fifteen minutes were required to bring the sample to the desired temperature. The timing of the period was started when the wheat reached the desired temperature. This temperature was maintained throughout the heating period. Located within the interior of the drum and in a position to be completely covered by the sample is a temperature sensing device which actuates a temperature recording instrument that records the temperature of the sample on a thermograph. The temperature of the sample is known and recorded at all times.

After heating for the desired period, the sample was cooled to room temperature by a forced current of room air. At the same time, the moisture content was lowered 15.5 per cent. The rate of air flow was 13.6 cubic feet per minute. It was thought that by moistening the sample to 16.5 per cent and drying to 15.5 per cent moisture after heat treatment the cooling effect of evaporation would bring the sample to room temperature. This was found to work quite well at 43°C. However at 50°C, 60°C, 70°C, and 90°C, it was necessary to use dry ice to finish cooling the sample to room temperature after drying the wheat to 15.5 per cent moisture. By placing dry ice in with the sample in a can and continually moving the can, the wheat was brought to room temperature. After cooling, the dry ice remaining was removed and the sample was allowed to stand for the required holding time.

After several samples the proper length of time for cooling was determined. This varied for different temperatures. For high temperatures the extra one per cent of moisture was driven off more quickly. This necessitated finishing the cooling with dry ice. To check the moisture content of the cooled wheat, the sample was weighed to determine the loss in weight due to cooling. Since the weight of the sample at 16.5 per cent moisture was recorded, the final moisture could be calculated by using the formula previously mentioned.

Experimental Milling

A batch system of milling was used which was simple and gave a moderately good yield. Figure 1 shows the flowsheet followed. Ross experimental mills were used in this study while

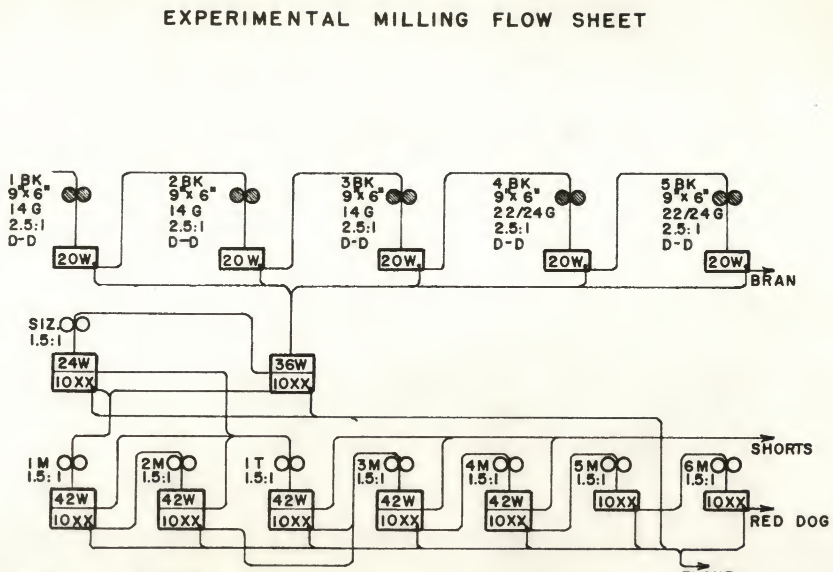

Fig. 1. Flowsheet.

sifting of the stock was done with a Smico laboratory sifter. Break roll corrugations were as follows: First, second and third breaks, 9" diameter x 6" long, 14 corrugations per inch, ¼ inch spiral, 2½:1 differential, dull to dull; fourth and fifth breaks, 24 and 22, corrugations per inch, ½ inch spiral, 2½:1 differential. Before each milling, while standing idle, the rolls were spaced as follows: first break, .022 inches; second break, .012 inches; third and fourth breaks, .008 inches; fifth break, .007 inches.

The smooth rolls were adjusted to just touch the sizing stock. First middlings stock was ground with the intent of making some flour and reducing the coarse middlings. The rest of the reductions with the exception of first tailings were ground to make as much flour as possible without flaking. First tailing was ground close enough to flatten the germ and reduce any coarse endosperm that might be present.

Sifting times were as follows: breaks and all reductions with exceptions of first middlings were sifted for one minute. First middlings was sifted for two minutes due to the large amount of stock present.

Extractions were reported on cleaned tempered wheat basis. Temperature in the mill room remained between 75°F and 80°F while the humidity was uncontrolled.

Table 3 gives the break releases and break flours which are averages of eight samples for each treatment.

Table 3. Average break release and break flour[1]

Treatment Temperature	Heating Time Hours	1B	2B	3B	4B	5B	Total Break Release	Break Flour
					Per Cent			
43°C	½	29.5	43.9	30.9	28.7	13.4	83.1	7.8
	1	29.0	43.7	30.1	29.1	13.0	82.9	7.8
	2	28.8	43.0	31.5	28.0	13.3	82.6	7.8
	12	29.1	43.1	30.3	27.0	12.6	82.2	7.9
50°C	½	29.5	42.0	28.4	27.5	11.8	81.3	7.4
	1	30.0	41.2	28.5	28.3	11.7	81.5	7.4
	2	28.8	42.3	30.4	26.6	11.6	81.4	7.4
	12	29.1	41.4	27.7	27.4	11.5	80.3	7.6
60°C	½	29.5	42.0	28.9	28.1	12.9	81.7	7.6
	1	29.8	41.9	29.6	27.1	12.6	82.2	7.7
	2	29.3	42.0	31.2	27.4	12.4	82.1	7.7
	12	29.7	40.0	29.8	28.0	11.9	81.4	7.9
Cold Temper 23°C	0	30.2	42.8	31.1	26.0	13.0	82.4	7.7
Cold Soak 23°C	0	31.9	40.6	28.0	25.6	10.9	80.6	7.9

1. An average of eight samples.

Analyses

The moisture, ash and protein analyses were performed according to procedures 48.3a, 9.1a and 67.1, in Cereal Laboratory Methods.

Baking tests were made on the flour resulting from the different treatments. The flour was held for about a month before baking tests. The straight dough method baking test was followed as outlined in 11.2b, Cereal Laboratory Methods, using the following bread formula: flour, 700 g.; sugar, 35 g.; salt, 14 g.; shortening, 21 g.; dry milk solids, 21 g.; malt, 3.5 g.; Arkady, 3.5 g.; yeast, 15.75 g.; water as based on farinograph absorption.

Farinograms were made according to procedure 26.4, Cereal Laboratory Methods using the 50 g. bowl and constant Flour Weight Procedure.

The flour sedimentation test was performed according to procedure 74.1, Cereal Laboratory Methods.

Gas production tests were made according to procedure 34.1, Cereal Laboratory Methods with readings taken fifteen minutes after the start and every thirty minutes thereafter until a total time of five hours had elapsed.

Flour particle size analyses were performed using the MSA-Whitby centrifuge sedimentation method (32).

RESULTS AND DISCUSSION

Heating of wheat up to temperatures of 60°C for as long as twelve hours at a constant moisture content, 16.5 per cent, seems to have no effect on the external appearance, other than swelling, of the sample. However, noticeable differences are observed in yield, ash content, water absorption, farinograms and baking tests. Tables 4-7 show the data collected on ash and yield. Each column shows the data gathered from eight trials for each treatment. The means for each set of eight trials are shown at the bottom of the columns. Figure 2 shows the mean ash value plotted against the mean yield for each treatment.

The scale for the least significant difference, (L.S.D.), is marked on each graph. By comparing the horizontal distance between two points on the graph with the horizontal L.S.D. scale it can be determined if the difference is significant.

Also by comparing the difference between two points in the vertical direction with the vertical L.S.D. scale it can be determined if the difference is significant.

Yield And Ash

A statistical analysis of the data showed a significant difference in the yield at the .05 level.

The only treatments which varied significantly in yield from the control sample were the 50°C treatments at the four

Table 4. Data collected on wheat conditioning at 23°C.

Cold Temper Control Holding Time 24 Hours			Cold Soaked		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
1	.470	64.6	9	.416	65.8
2	.448	66.3	10	.406	66.4
3	.460	65.5	11	.422	67.0
4	.457	67.4	12	.405	66.0
5	.456	67.3	13	.416	65.6
6	.462	66.3	14	.404	65.1
7	.461	66.3	15	.414	66.4
8	.450	66.4	16	.393	65.2
Means	.4580	66.26	Means	.4095	65.94

Table 5. Data collected on wheat conditioned at 43°C.

Heating Time ½ Hour			Heating Time 1 Hour		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
17	.490	67.2	25	.460	67.2
18	.456	66.3	26	.466	67.1
19	.446	67.1	27	.412	66.2
20	.443	67.6	28	.441	67.1
21	.435	65.8	29	.427	66.6
22	.435	65.4	30	.449	67.0
23	.431	66.0	31	.447	68.4
24	.449	66.3	32	.421	66.6
Means	.4481	66.46	Means	.4404	67.02
Control Means	.4580	66.26			

Heating Time 2 Hours			Heating Time 12 Hours		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
33	.432	66.6	41	.421	64.7
34	.442	66.1	42	.446	66.3
35	.441	66.8	43	.420	66.8
36	.418	65.6	44	.410	66.6
37	.438	65.6	45	.441	66.8
38	.448	67.2	46	.438	66.9
39	.445	66.9	47	.437	66.0
40	.464	67.7	48	.391	65.4
Means	.4410	66.56	Means	.4255	66.19
Control Means	.4580	66.26			

Table 6. Data collected on wheat conditioned at 50°C.

Heating Time ½ Hour			Heating Time 1 Hour		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
49	.406	65.0	57	.416	65.2
50	.415	64.7	58	.424	64.5
51	.426	66.1	59	.437	66.4
52	.424	65.1	60	.423	65.4
53	.397	64.6	61	.416	66.1
54	.395	64.7	62	.415	64.3
55	.403	65.8	63	.407	64.2
56	.407	65.0	64	.386	64.0
Means	.4091	65.12	Means	.4155	65.01
Control Means	.4580	66.26			

Heating Time 2 Hours			Heating Time 12 Hours		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
65	.424	64.2	73	.411	65.3
66	.423	64.6	74	.404	64.7
67	.435	66.4	75	.423	65.6
68	.434	65.9	76	.410	63.6
69	.434	66.3	77	.411	65.2
70	.434	65.1	78	.405	64.5
71	.415	66.4	79	.417	65.2
72	.404	64.6	80	.406	65.0
Means	.4254	65.44	Means	.4109	64.89
Control Means	.4580	66.26			

Table 7. Data collected on wheat conditioned at 60°C.

Heating Time ½ Hour			Heating Time 1 Hour		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
81	.417	66.6	89	.470	67.6
82	.424	64.6	90	.443	67.3
83	.422	65.8	91	.454	66.8
84	.403	66.2	92	.444	65.7
85	.412	66.0	93	.434	66.6
86	.413	67.0	94	.412	65.8
87	.403	65.8	95	.412	66.9
88	.443	66.8	96	.432	64.6
Means	.4171	66.10	Means	.4376	66.41
Control Means	.4580	66.26			

Heating Time 2 Hours			Heating Time 12 Hours		
Sample Number	% Ash	% Yield	Sample Number	% Ash	% Yield
97	.425	67.2	105	.434	66.1
98	.406	66.6	106	.423	67.8
99	.438	66.6	107	.411	65.8
100	.471	67.7	108	.461	66.5
101	.442	67.6	109	.453	67.4
102	.451	67.4	110	.441	65.2
103	.404	66.6	111	.460	66.4
104	.404	65.7	112	.445	65.4
Means	.4301	66.92	Means	.441	66.3
Control Means	.4580	66.26			

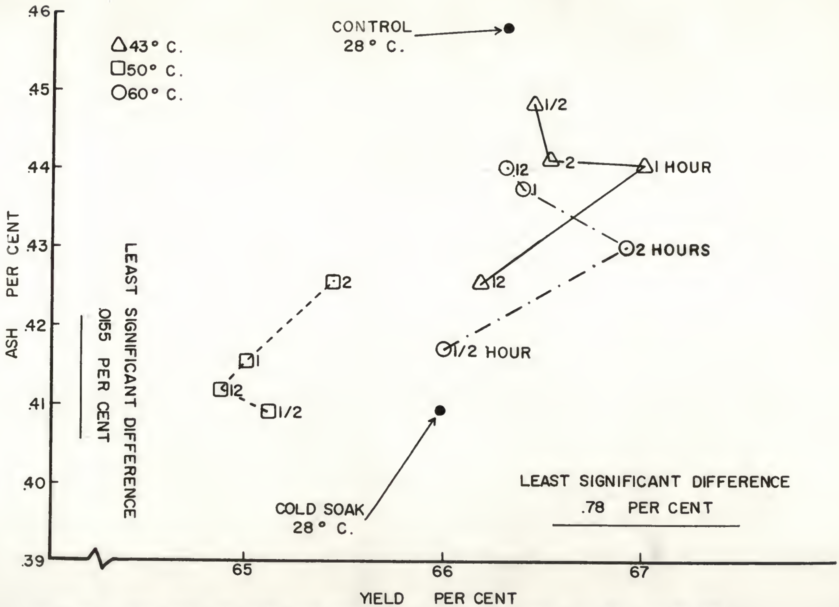

Fig. 2. Mean ash per cent versus mean yield per cent for each treatment.

different heating periods. In this case the yields were significantly lower. Although the other treatments did not vary significantly from the control they were significantly different within themselves. At 43°C, the treatments for one hour and twelve hours were significantly different. The one hour treatment gave the highest yield. However, the one hour and twelve treatments at 43°C did not vary significantly from the one-half hour and two hour treatments. This indicates that heating for longer periods of time, twelve hours, at 43°C will tend to lower yield as compared to heating for moderate periods of time, one hour at 43°C. The twelve hour heating period may make it difficult to separate the bran from the endosperm.

Heating at 50°C produced no significant differences in yield within the four different heating periods. This may be partly due to a poor separation of bran from endosperm.

The four treatments at 60°C did not significantly affect the yield as compared with the control. Within the four treatments the two hour heating was significantly higher in yield than the one-half hour treatment. This shows that at 60°C, heating for two hours may give an easier separation of bran from endosperm as compared to the one-half hour treatment.

The yield from the cold soak sample did not vary significantly from the control.

The only treatments giving significantly higher yields than the cold soak treatment were at 43°C for one hour and 60°C for twelve hours. Treatments at 50°C for one-half hour, one hour, and twelve hours gave significantly lower yields than the cold soak treatments.

The effects of temperature and holding time on yield were analyzed. It was found that the effect of temperature was significant at the .05 level while the effect of holding time was not significant. Also the interaction of temperature and holding time was not significant. Therefore, in this study temperature and length of heating time seemed to be the only factors that influenced yield. This influence was not linear. The yields resulting from the treatments at 43°C and 60°C were significantly different from the yield resulting from the 50°C treatment. But the yields resulting from the 43°C and 60°C treatments were not significantly different from each other. This is shown in Fig. 3.

Statistical analysis of the ash data shows that temperature is significant at the .05 level. The ash differences were large and nonlinear interaction is significant. This means that holding time and temperature were not additive in effect.

The control sample gave the highest ash, .458 per cent. All of the treatments except 43°C gave ash values which were significantly lower than the control. The 50°C treatment for one-half hour and the cold soak treatment gave the lowest ash values, .409 per cent. However, the yield for 50°C for one-half hour was significantly lower than the yields for the cold soak and control. The 43°C twelve hour treatment gave a significantly lower ash than 43°C for one-half hour, one hour and two hours.

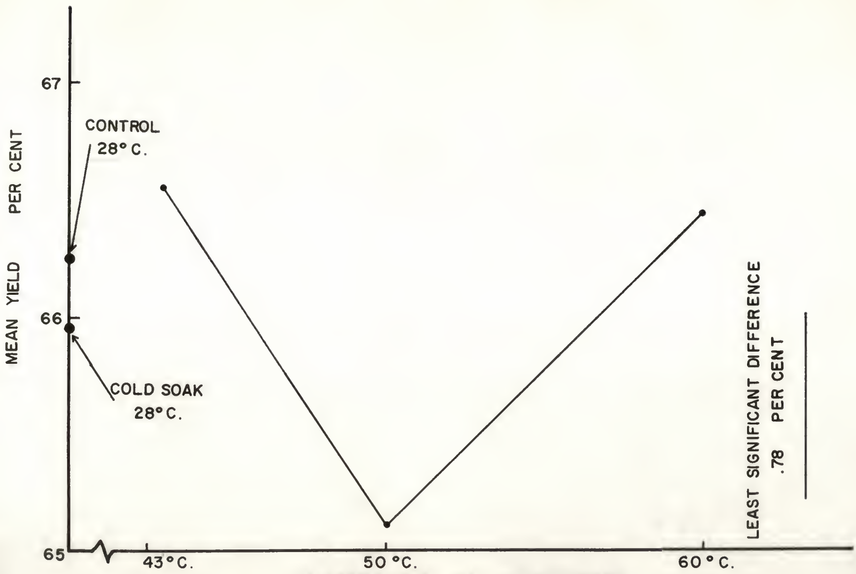

Fig. 3. Mean yield versus temperature of conditioning for each temperature.

At 60°C the one-half hour treatment gave an ash which was significantly lower than the twelve hour treatment and the one hour treatment. The one-half hour treatment was not significantly lower than the two hour treatment. Comparing the 60°C one-half hour treatment with the 43°C twelve hour treatment it appears that the higher temperature had the same effect as the lower temperature, in a much shorter time. 43°C for one hour gave a significantly higher yield without a significant change in ash as compared with 43°C for twelve hours.

60°C for one-half hour was significantly lower in yield but not in ash as compared with 60°C for two hours.

The 50°C treatment for the four different heating periods gave low ash values. 50°C for one-half hour, one hour and twelve hours gave ash values quite close together. The 50°C treatment for one-half hour was significantly lower than the 50°C two hour treatment. Neither the 50°C one-half hour treatment nor the 50°C two hour treatment was significantly different from the other two 50°C treatments. While the 50°C treatment seemed to give the best ash value for all heat treatments the yield was low.

Figure 4 shows the mean ash values for each treatment. The treatment giving the lowest ash value without having the yield significantly affected was the cold soak treatment.

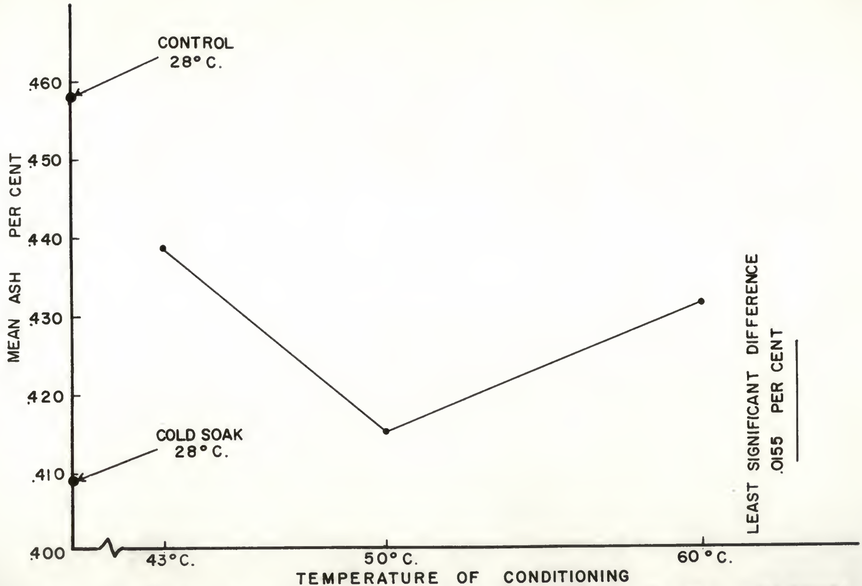

Fig. 4. Mean ash per cent versus temperature of conditioning for each temperature.

Baking Characteristics

Figure 5 illustrates the changes in the farinograms which indicate the damage produced by heating at high temperatures. There was very little change in the farinograms for the control, cold soak, 43°C treatment, and 50°C treatments. The 60°C treatments produced little change except for the twelve hour treatment. Heating for twelve hours at 60°C had a decided detrimental effect on the farinogram of the flour. This was the first indication of heat damage. Heating to 70°C for fifteen minutes and thirty minutes and 90°C for five minutes also produced heat damage as shown by the farinogram.

Table 8 gives the farinograph absorption, dough development time and mixing tolerance index. It is interesting to note that the absorption of the flour decreased with increased treatment temperature. Figure 6 is a graph of the corrected water absorption of the flour plotted against the treatment temperature.

Results of the baking tests are given in Table 9 and shown in Figs. 7-11. Baking scores ranged from 18 to 94. The 90°C treatment ruined the wheat for baking purposes. 70°C for fifteen minutes and thirty minutes did not completely ruin the wheat but it had a detrimental effect on the final loaf of bread. The cold soak treatment gave the best loaf of bread.

The flour from the 60°C twelve hour treatment, 70°C fifteen minute and thirty minute treatments were difficult to handle during baking. The 90°C treatment was the worst, being very sticky

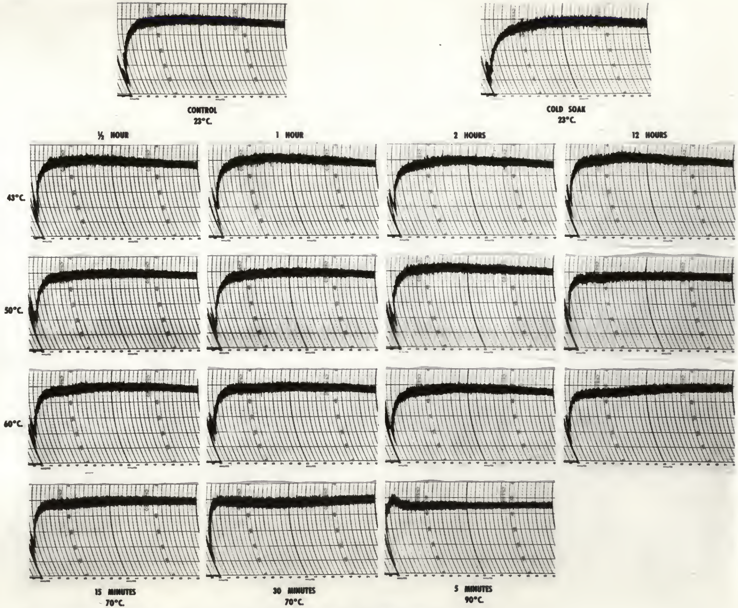

Fig. 5. Farinograms of flour from each treatment.

Table 8. Data taken from farinograph curves.

Treatment	Farinograph Absorption %	Corrected Absorption	Dough Development	Mixing Tolerance Index
Control 23°C	65.0	65.0	8	10
Cold Soak 23°C	68.0	67.4	10	10
43°C ½ hour	66.0	66.0	7	20
43°C 1 hour	68.0	68.6	7	15
43°C 2 hour	67.6	67.6	9	15
43°C 12 hour	65.0	65.3	7	10
50°C ½ hour	65.0	65.0	10	10
50°C 1 hour	65.0	65.0	10	5
50°C 2 hour	65.0	65.6	7.5	10
50°C 12 hour	65.0	64.4	10.5	5
60°C ½ hour	65.0	65.0	10	5
60°C 1 hour	65.0	64.7	9.5	5
60°C 2 hour	65.0	64.4	8.5	10
60°C 12 hour	63.4	63.1	15	15
70°C 15 minutes	63.0	63.0	10	5
70°C 30 minutes	62.6	62.0	2	--
90°C 5 minutes	60.2	59.9	1.5	40

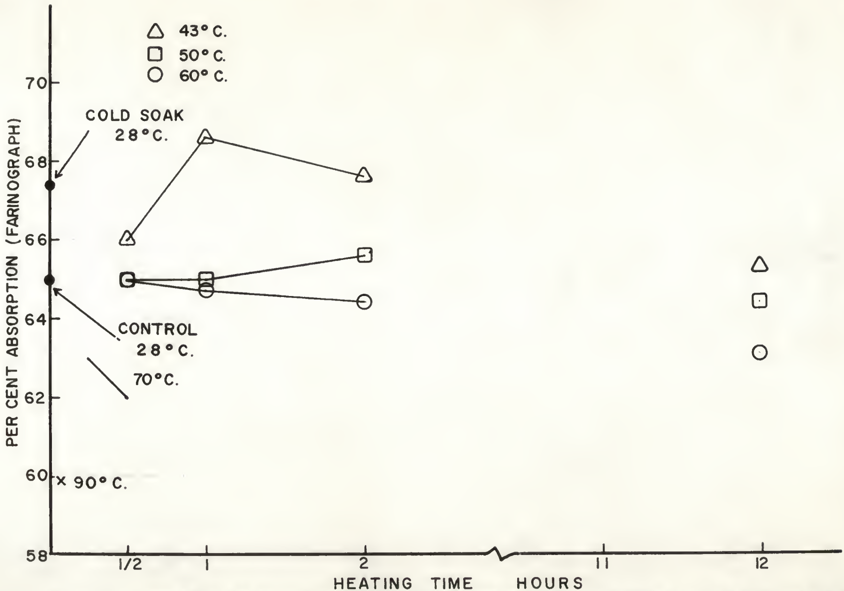

Fig. 6. Corrected absorption (Farinograph) versus heating time for each treatment.

Table 9. Baking scores.

Maximum Points	Volume 20	Crust Color 10	Symetry 10	Break and Shred 10	Grain 20	Crust Color 10	Texture 20	Total Score 100
Wheat Treatment								
Control 23°C	19	8	9	9	15	8	16	84
Cold Soak 23°C	20	10	10	9	17	10	18	94
43°C ½ hour	20	8	8	6	18	8	17	85
43°C 1 hour	19	8	8	8	15	8	15	81
43°C 2 hour	19	8	9	8	17	8	17	86
43°C 12 hour	20	8	8	8	16	8	16	84
50°C ½ hour	19	7	7	7	16	8	16	80
50°C 1 hour	20	8	7	8	17	8	17	87
50°C 2 hour	20	9	8	7	16	8	17	84
50°C 12 hour	20	9	8	7	16	8	16	90
60°C ½ hour	19	8	7	7	15	8	16	80
60°C 1 hour	18	8	7	6	15	8	16	78
60°C 2 hour	20	8	8	7	16	8	17	84
60°C 12 hour	18	8	8	8	15	8	15	80
70°C 15 minutes	18	8	7	7	15	8	15	78
70°C 30 minutes	16	7	7	6	16	7	15	74
90°C 5 minutes	10	4	0	0	0	4	0	18

Fig. 7. Loaves baked from wheat heated to 43°C, 9 - Control, 1 - 43°C - ½ hour, 2 - 43°C - 1 hour, 3 - 43°C - 2 hours, 4 - 43°C - 12 hours.

Fig. 8. Loaves baked from wheat heated to 50°C,
9 - control, 14 - 50°C - ½ hour, 15 - 50°C - 1 hour,
16 - 50°C - 2 hours, 17 - 50°C - 12 hours.

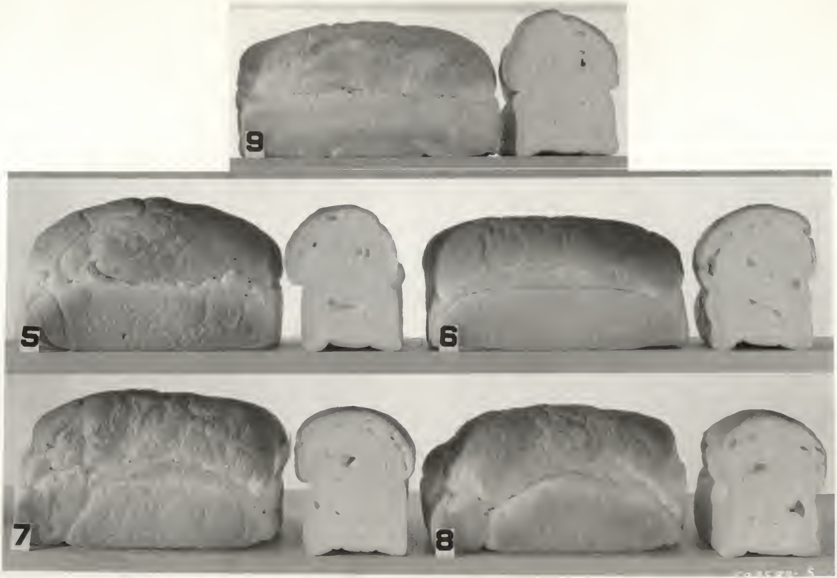

Fig. 9. Loaves baked from wheat heated to 60°C, 9 - control, 5 - 60°C - ½ hour, 60°C - 1 hour, 7 - 60°C - 2 hours, 8 - 60°C - 12 hours.

Fig. 10. Loaves baked from wheat heated to 70°C and 90°C, 9 - control, 10 - 70°C - 15 minutes, 12 - 70°C - ½ hour, 13 - 90°C - 5 minutes.

Fig. 11. Loaf baked from wheat cold soaked in water.

and difficult to manage.

Evaluation of the treatments, cold soak, 43°C, 50°C and 60°C, through consideration of the yield, ash and baking score was done with the following formula:

Y.A.B.=(yield-per cent) (1-ash per cent) (baking score ÷ 100). The results are shown in Fig. 12. Cold soak gave the best score followed by 50°C for twelve hours. 60°C for one hour had the lowest score. The control sample was third from the lowest score.

Flour Particle Size Analysis

The particle size was determined by the M.S.A. Whitby sedimentation test. The results, Table 10, showed very little difference in granulation of the flours from the various treatments.

Flour Sedimentation Test

The results of the flour sedimentation test, Table 11, were not consistent. The 90°C treatment for five minutes gave the lowest sedimentation value. 50°C heating for one, two and twelve hours gave the highest value. The cold soak treatment gave the same value as the control. The sedimentation values did not correlate with loaf volumes very well. It may be possible that heat treatments have a detrimental effect on the sedimentation value.

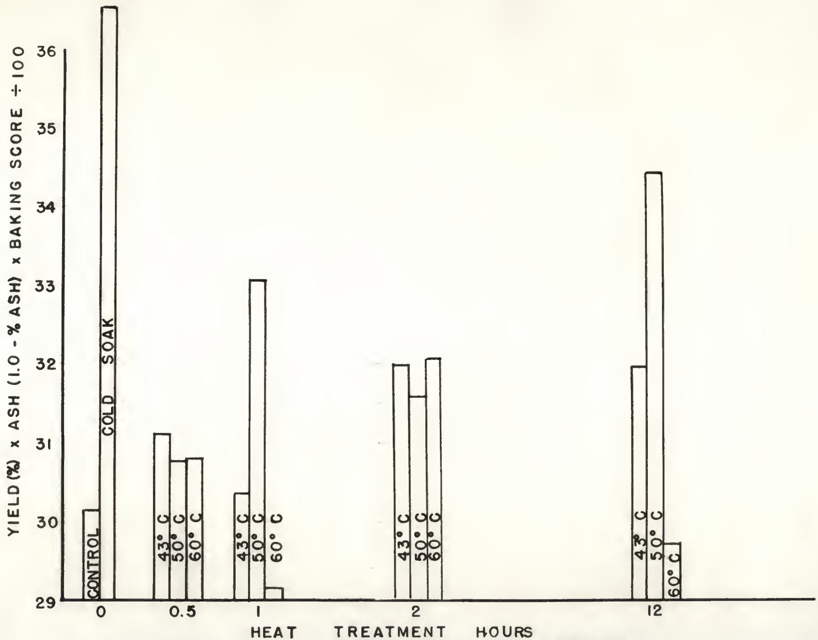

Fig. 12. Yield, ash, baking scores versus time of treatment.

Table 10. Particle size analysis[1]/

Treatment Temperature	Heating Time Hours	Diameter Microns 100	80	60	40	30	20	10	5
		Per Cent Diameter							
43°C	½	99.6	93.0	59.6	29.1	18.8	11.0	.1	.1
	1	99.3	92.9	64.4	36.7	24.3	12.6	.2	.1
	2	97.4	85.1	60.7	34.5	22.5	12.4	1.7	.1
	12	99.3	88.8	66.3	39.3	24.2	12.6	.7	.1
50°C	½	99.7	93.9	59.0	32.3	20.8	10.5	.2	.1
	1	99.4	92.1	65.1	33.4	22.9	13.4	.3	.1
	2	99.7	95.0	68.2	38.0	24.8	13.5	1.2	.1
	12	99.7	95.9	70.2	41.5	26.7	14.7	.3	.1
60°C	½	99.4	93.9	64.1	32.6	21.6	11.9	.1	.4
	1	99.6	92.7	64.1	39.1	27.5	14.8	.8	.1
	2	99.6	95.0	77.3	43.1	28.0	15.9	.4	.1
	12	99.4	91.6	67.6	34.8	22.1	11.7	.1	.3
70°C	½	97.1	93.8	66.0	35.9	20.6	12.0	.4	.2
	½	97.6	93.5	64.7	30.4	18.8	9.6	.1	.3
90°C	1/12	99.7	94.8	72.7	44.5	29.5	13.5	.5	.1
Cold Soak 23°C	0	99.4	92.0	61.1	38.9	22.2	11.6	.5	.1
Control 23°C	0	99.6	94.4	73.1	41.2	27.2	16.4	1.8	.1

1. MSA - Whitby Centrifuge Sedimentation Method.

Table 11. Flour sedimentation compared with loaf volume.

Treatment Temperature	Heating Time-Hours	Sedimentation Value	Loaf Volume c.c.
Control 23°C	0	46.3	2938
Cold Soak 23°C	0	46.9	3025
43°C	½	44.7	3000
43°C	1	44.8	2913
43°C	2	43.9	2987
43°C	12	44.2	3000
50°C	½	41.6	2975
50°C	1	49.0	3000
50°C	2	49.5	3000
50°C	12	48.5	3000
60°C	½	48.1	2950
60°C	1	46.7	2837
60°C	2	45.1	3000
60°C	12	48.3	2800
70°C	¼	46.7	2850
70°C	½	47.1	2612
90°C	1/12	36.9	1000

Gas Production Tests

The gas production tests, Table 12, show little variation. The treatments used in this study appeared to have little effect on the gassing power of the flour.

SUMMARY AND CONCLUSIONS

Treatments at 43°C, 50°C, 60°C and cold soaking proved to be beneficial in lowering the ash content of the resulting flour. However, treatments at 50°C had a detrimental effect on yield; cold soaking gave the lowest ash without affecting yield.

Baking tests conducted on the flour indicated that the cold soak treatment gave the best loaf of bread. Treatments at 60°C for twelve hours, 70°C for fifteen minutes and one-half hour, and 90°C for five minutes produced doughs that were difficult to handle.

Farinograms also indicated damage for these four treatments at 60°C, 70°C and 90°C.

Gas production tests failed to show any differences in the treatments. However, sedimentation tests on the flour showed that at 90°C the flour proteins had been altered in some manner. Particle size analysis did not show any change in granulation.

It can be concluded that:

1. Warm conditioning, hot conditioning and cold soaking can be beneficial in relation to the ash content of the flour.

Table 12. Gas production results - centimeters mercury

Treatment Temperature									
Time Hours	43°C Treatment				50°C Time - Hours				Control
	½	1	2	12	½	1	2	12	24
¼	2.3	2.0	2.5	1.8	1.8	2.3	1.5	2.1	2.2
½	6.7	6.5	6.4	5.9	5.7	6.5	5.7	6.3	6.0
1	11.2	11.1	11.3	10.0	9.7	10.4	9.6	10.2	10.7
1½	17.4	17.4	16.8	15.7	15.3	16.8	15.6	16.4	16.4
2	20.4	20.5	19.2	19.8	20.8	19.8	19.7	18.7	18.6
2½	21.3	21.5	20.2	20.9	22.9	20.8	21.5	19.5	19.2
3	21.8	22.2	20.7	21.6	23.7	21.4	22.2	20.0	19.7
3½	22.4	22.7	21.1	22.2	24.3	21.8	22.7	20.3	20.1
4	23.0	23.0	21.6	22.7	24.9	22.4	23.2	20.6	20.4
4½	23.4	23.5	22.0	23.1	25.4	22.8	23.7	20.9	20.7
5	23.7	24.1	22.5	23.6	25.8	23.2	24.1	21.1	20.9

Treatment Temperature									
Time Hours	60°C Treatment				70°C Time - Hours		90°C	Cold Soak	Control
	½	1	2	12	¼	½	1/12	5	24
¼	1.6	2.3	1.6	2.4	2.6	2.0	1.2	1.3	2.2
½	5.6	6.3	5.6	6.2	6.4	5.7	5.2	4.9	6.0
1	9.5	11.4	9.5	11.2	11.9	10.8	8.7	8.8	10.7
1½	15.1	17.1	15.2	16.6	16.0	16.2	13.6	13.7	16.4
2	19.0	19.8	19.1	18.3	17.4	18.0	16.8	18.5	18.6
2½	20.1	20.6	20.1	19.0	18.1	18.9	17.9	19.5	19.2
3	20.7	21.2	20.7	19.4	18.5	19.5	18.2	20.2	19.7
3½	21.2	21.8	21.2	19.8	19.1	19.9	18.5	20.7	20.1
4	21.5	22.3	21.8	20.6	19.4	20.1	19.0	21.2	20.4
4½	22.0	22.6	22.1	20.4	19.8	20.5	19.3	21.6	20.7
5	22.3	23.0	22.6	20.6	20.2	21.0	19.7	22.0	20.9

2. The yield may be unaffected except in the case of the 50°C treatment.
3. Prolonged heating of wheat at 60°C and shorter heating at 70°C and 90°C at a moisture content of 16.5 per cent can damage the wheat proteins.
4. Cold soaking is the safest way to improve the ash and baking characteristics without adversely affecting the yield.

SUGGESTIONS FOR FUTURE WORK

Cold soaking of wheat showed the most promise in the improvement of baking and milling characteristics. Further work should establish how short the soaking period can be and possibly the highest temperature that can be used to remove the excess moisture.

More work can be done to study the effect of higher temperatures on the milling results as indicated by ash and yield and on the baking qualities of the flour.

Steam could be studied as a means of conditioning wheat and how it effects the milling and baking qualities of the flour.

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SOME EFFECTS OF COLD, WARM AND HOT WHEAT
CONDITIONING ON THE MILLING AND BAKING
CHARACTERISTICS OF WHEAT

by

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The primary objective of wheat conditioning is to change the physical condition of the wheat kernel into the proper condition for milling through the use of moisture, time and with or without the use of added temperature or pressure. The moisture should be distributed in such a way in the wheat kernel that the endosperm separates cleanly from the bran with a minimum of attrition and abrasion and with the endosperm reducing easily into products that can be sifted readily.

The secondary objective of wheat conditioning is to improve the baking characteristics of the flour.

In this study moisture and pressure were constants while time and temperature were variables.

Samples of hard red winter wheat were moistened to 16.5 per cent moisture and heated to 43°C, 50°C and 60°C for varying periods of time, then dried to 15.5 per cent moisture to study the effects of different temperatures and heating periods on the milling and baking characteristics. Several samples moistened to 16.5 per cent moisture were heated to 70°C and 90°C and dried to 15.5 per cent moisture to determine the effects of heat on baking characteristics.

Other samples were soaked under water for one hour and dried to 15.5 per cent moisture before milling to determine what effect cold soaking has on milling and baking characteristics.

Control conditioning was the addition of water to increase the wheat moisture to 15.5 per cent and allowing it to stand for twenty-four hours.

Factors studied included baking tests, flour yield, flour ash, farinograms, particle size analysis, flour sedimentation and gas production.

Flour yield was significantly lower for the 50°C treatment for one-half hour, one hour and twelve hours. Treatments at 43°C, 50°C for two hours, 60°C and cold soaking gave yields that were not significantly different from the control.

Except for the 43°C one-half hour treatment, all the other treatments at 43°C, 50°C, 60°C and cold soak gave significantly lower ash values than the control.

Cold soaking and 50°C for one-half hour both had mean ash values of .409 per cent compared with control which had an ash of .458 per cent.

The baking tests and farinograms showed heat damage for samples heated to 60°C for twelve hours, 70°C for fifteen minutes or one-half hour, and 90°C for five minutes. Cold soaking treatments gave the best loaf of bread.

Considering the baking tests, flour yield and flour ash the cold soak treatment resulted in the most improvement.