SOME EFFECTS OF TEMPERATURE IN WHEAT CONDITIONING

by

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INTRODUCTION

The economical importance of use of heat in conditioning of wheat has been recognized since the combines were first used in harvesting the grain.

The gluten in some wheats is much weaker than in others. The physical properties of wheat are affected by heat. Therefore, the purpose of this study of heat treatment of wheat during conditioning was to determine the effect heat had on the alteration of the properties in flour as measured by physical tests, and to find a method of improving the flour and consequently the bread in countries having to use wheats of weak gluten for bread baking.

The ability of a flour to produce a satisfactory bread of high ratio of volume to weight is considered a basic requirement of its quality as a good bread flour. The low protein hard wheats and the soft red winter wheats produce flour that is not considered good bread flour. In some countries the law requires that a certain per cent of home grown wheat be used in the milling process. If it were possible to increase the ability of these flours to produce a more satisfactory bread by some physical method, it should improve the quality of the bread used in those countries. Heating of the wheat seems to alter the characteristics of the flour by changing the plasticity of the dough, the mixing, and the fermentation dough development.

After reviewing the literature on uses of heat on wheat, it was decided to use a low protein hard red winter wheat and a soft red winter wheat to determine the effects of heat and the length of time heat can be applied in order to secure improved flour for bread baking. The use of dry heat seemed to be our best method of approach to the problem with the equipment available and the adaptability to milling procedure on tempered grain.

The advantages of treating the wheat by some physical method instead of the use of chemical or physical treatment of the flour are reported by Lockwood (13), p. 210, and are summarized as follows:

1. Easier handling of wheat than of flour for the treatment.

2. Different grades of flour from a certain wheat need different amounts of heat treatment.

3. In many countries the use of chemicals in flour is prohibited.

4. Since the flours from different wheats need different treatment, separate milling of the different wheats and blending of their flours would be involved.

Separate milling of the wheats and blending of the flours after they received proper treatment would make it necessary to install adequate flour storage bins.

Although the baking test of the heat treated sample is naturally the final criterion for judging the induced change in baking quality, there are several other physical methods of wheat and flour testing which could be of significant value that were tried in this study.

Swanson and Swanson (17) conducted experiments on wheat harvested at different stages of maturity to study the effect of heat and moisture upon some favorable changes which take place slowly in threshed wheat stored under favorable conditions.

They used hot air heating system with temperatures 40, 45, 50, and 55° C for various periods of time. The baking test of the heated samples showed that certain combinations of temperature and length of time of treatment improved the volume and the texture of the bread. The best results with ripe wheat were obtained at 40° C for four days or at 50° C for two days. The unripe wheat showed higher sensitivity to heat treatment than the fully ripe wheat.

The author's conclusion was:

> Carefully controlled use of heat on new wheat may bring about an improvement in baking qualities; but if the degree of temperature is too high, or if the period of heating too long, marked damage may result, such damage being proportional to the moisture content of the wheat.

Kent-Jones (12) conducted experiments of heat treatment on Manitoba number one wheat and on flour made from that wheat. He tempered the wheat 17 to 18 per cent moisture for his experiments. The samples were then placed in tin slots one inch wide and kept in a water bath at different temperatures for various lengths of time. In this procedure he found that the flour acquired a sour smell.

Later on he modified the above procedure by heating the dry wheat and then cooled and tempered it to the usual levels of moisture for milling. An increase in the strength of the flour was produced when the wheat was given such heat treatment at 71° C for one and a half hours or 49° for 12 hours. However, longer treatment ruined the flour. Continuing the experiments on various grades of flour from the same wheat he found that the lower grade flour required more severe heat treatment than the higher grade flour. Also, he found that a small amount of very strongly (82° C - 12 hours) treated flour added to regular flour gave the same desirable results as when the whole flour was treated. He found the following principles were involved in heat treatment of the wheat or flour:

1. Inhibition of the proteolytic activity.

2. Increase of coagulation of wheat proteins, which resulted in a greater water absorption.

3. Enormous swelling of overheated flour takes place so slowly that results are not apparent until the end of the fermentation period.

Geddes (6), conducted comprehensive experiments in order to study the effect of heat treatment on the physical, chemical and biochemical properties of flour from western Canadian hard red spring wheat. His method of heating the samples consisted of enclosing them in a metallic drum which was rotated in an oil bath at temperatures between 20 and 135° C for various periods of time. The samples were rapidly cooled by submerging the drum in cold water. The flours were aged in bags for 35 days at 18° C and 70 per cent relative humidity. They were baked according to the M. J. Blish standard experimental baking method. The results and conclusions from those experiments were as follows:

1. Progressive improvement in baking quality was evident in the improved handling of dough. Decrease of underfermented characteristics and more desirable crumb texture was noticed with temperature and time extended within a certain range. No well

defined region of improvement nor significant alteration in loaf volume was observed.

2. The alterations occurred in the protein and were not due to destruction of enzymes.

3. Increase in the moisture content above a certain level in the wheat definitely decreases the safe limits of temperature beyond which the wheat is damaged; however, decreasing the moisture below certain levels does not have much influence on temperature limits.

4. Heat causes less damage on wheat than on flour.

5. Heat causes marked decrease in fermentation tolerance.

6. Heating and use of the Potassium Bromate in the same sample invariably causes damage.

7. Improvement in baking quality obtained by adding 0.001 per cent Potassium Bromate in the flour was much greater than that obtained by using heat treatment.

Geddes (7) continued his studies by examining the effect of heat on some physicochemical and biochemical properties of the flour. The samples which showed progressive change (damage or improvement) in baking quality were tested for the following: viscosity of leached, acidulated flour suspensions; rate and extent of imbibition of washed gluten; gas retension of the dough; ease of peptidation of the flour proteins by certain solutions; diastatic activity; and Hydrogen-ion concentration of flour extracts.

> The biochemical changes investigated were for the most part in a direction associated with decreased baking quality observed in certain samples when baked by the basic procedure.

The diastatic activity decreased only slightly in those flours which showed improvement in baking quality. On the contrary, the proteolytic activity was markedly decreased by the heat treatment.

In order to determine the enhancement in baking quality observed on heat treated, straight-grade flour, neither aged nor bleached, Geddes (8) experimented on 5th middlings flour which was highly refined and contained the slightest possible amount of wheat germ particles. His conclusions were:

1. The improvement of this flour by heat treatment was unsignificant.

2. The addition of germ or lecithin in such flour caused deterioration of the baking quality. However, if the germ was heated before being added to the flour, its deleterious effect was reduced.

3. The heat treatment diminishes the detrimental effect in the flour of certain reducing constituents which are associated with the germ and, under certain conditions, it compensates for the deteriorating effect of heat on gluten.

Brabender (4) maintained that the hot conditioning of wheat which is used to a great extent in European mills affects the various milling properties of the wheat and some baking properties of the flour. Reference was made to the example of Manitoba wheat which has great fermentation tolerance as used in blends with German wheats which have very low fermentation tolerance but are fast in dough development. The application of hot conditioning on Manitoba wheat produces flour with faster dough development.

The two different wheats then will make a more suitable blend for the baking conditions in Germany's short fermentation. The procedure for conditioning Manitoba wheat is:

1. Tempering to 18 per cent moisture and left to rest in the bin 12-48 hours.

2. Washing which increases the moisture content to 20-21 per cent.

3. Hot conditioning at 41° C for one hour.

4. Resting in bins three to eight hours.

5. Adding one fourth to one half per cent moisture just before milling to toughen the bran.

German wheat is tempered with cold water to the desired moisture content for milling.

In places where longer fermentation schedules are used the conditioning should be shorter and less radical. The wheat conditioning, therefore, depends not only on the wheats and their character but also on the baking practices used in certain areas.

The three factors of wheat conditioning: water, time, and temperature work toward the same direction. The increased use of any one of the three factors decreases the use of the other two, although, increase of water or of time is preferable to increase of temperature.

Annen (1) heated wheats at various temperatures between 40 and 60° C and found linear increase in the gluten swelling factor and decrease of the factor when increased temperatures were used. Optimum gluten quality was obtained at 55° C. Improvement in baking quality of soft wheat as a result of conditioning is due to hardening of gluten and not to an increase in enzymatic activity.

Berliner (2) agrees with Annen that the purpose of conditioning soft wheat is to harden the gluten. This is shown by decrease of extensibility of the gluten. Hard wheats with strong gluten should be conditioned at low temperatures since further strength is not needed. Hard wheat gluten cannot be made soft with long conditioning at high moisture content to influence the swelling rate. Dough softening should not be interpreted as gluten softening. According to Berliner the dough softening is due to excessive starch degradation and hardening of the gluten. The fact that gassing power and diastatic activity are not appreciably influenced by normal heat treatment or tempering was in agreement with Geddes. Also, Berliner supported the theory that there is no proof that proteolytic activity can be inhibited by suitable heat treatment (2).

Haltmeier (9) describes an experimental, electrical conditioner for studying the effects of heat treatment on wheat. Current of variable voltage is passed through the wheat sample and quickly increases the temperature.

Hopf (10) gives detailed procedures for conditioning hard and soft wheat and describes the effect of conditioning on different types of gluten. The explanation he gives for the disputed softening of the hard wheat gluten by conditioning is that an increase in extensibility resulting from heightened water absorption and hyperswelling of gluten actually takes place.

Lockwood (13) studied the effects of heat treatment on various domestic and imported wheats used by the mills of England. Pointing out that there is a distinction between wheat conditioning for efficient milling and heat treatment of the wheat for the purpose of changing its baking quality, he calls the latter process "gluten stabilization". In all experiments the Brabender Extensograph (see paragraph "Extensograph Test") for the detection and measurement of the changes induced in the wheat by heat treatment was used.

The heat treatment normally shortens the gluten and can only be applied to wheats of marked extensibility. The effect of the treatment in the improvement of bread making quality is an increase of resistance to extension of the dough and an increase of the area under the Extensograph curve. According to Lockwood, the object of the heat treatment should be; "to modify the gluten characteristics of weak and over extensible wheats in such a way that every individual wheat in the blend will give an extensograph curve as near as possible to the ideal" (13), p. 209. The best results with heat treatment were obtained with wheats containing large amounts of poor quality gluten. The safe limits of treatment are different in various wheats and such limits should be found by examining the extensograph curves of the wheat before and after the treatment. Table 1 shows some of these results.

Table 1. Experimental data on heat treatment of wheats*.

Variety	Maximum temperature F°	Extenso-area before treatment	Extenso-area after treatment
Uruguayan	142°	52	83
English Red Standard	168°	14	29
No. 1 Manitoba	153°	88	129
Baril Plate	170°	99	126

*From "Flour Milling" by Lockwood, p. 216.

Of the three interdepended factors of wheat conditioning; time, moisture, and temperature, indications show that the temperature is the most important factor.

A wheat conditioner was developed in England to heat the wheat which is called the "Stabilisor". In this machine the wheat is heated to the desired temperature (maximum 66° C) in less than a minute by the use of direct steam as it travels through a screw conveyor. It is then subjected to hot binning for the desired period of time before it is cooled with cold water in a washer.

EXPERIMENTS

The wheats used in the experiment were two of the Soft Red Winter class and one of the Hard Red Winter class. They are designated as: S.R.W.-I, S.R.W.-II, and H.R.W.

Protein of	S.R.W.-I	: 12.1 per cent.
" "	S.R.W.-II	: 10.8 " "
" "	H.R.W.	: 10.5 " "

S.R.W.-I and H.R.W. were two years old. The S.R.W.-II was only one year old. The two soft wheats were obtained from a flour mill at Evansville, Indiana; the hard wheat was obtained from Manhattan, Kansas.

The work done can be divided into four parts:

1. Heat treatment of the wheat.
2. Milling of the samples.
3. Wheat tests.
4. Flour tests.

Heat Treatment of the Wheat

Heating Apparatus. The samples were heated in a "Dispatch" Air Oven, style V-15-2, which was available in the laboratories of the Milling Industry Department. It was an electrical oven with the air circulating inside and the temperature was automatically controlled to any desired degree from 45 to 350° C.

Since the specific heat of the air (0.2415 under constant pressure) and the conductivity of the wheat are low, the temperature rises slowly in the grain. The temperature of the air must be much higher than that desired in the wheat. The relative humidity of this air should be high enough to insure no loss of moisture during heating. In the oven used the rate of circulation of the hot air inside the oven can be relatively high, but there is no provision for air humidification. Consequently, in order to avoid losses and in order to secure rising of the temperature in all kernels of the sample in a short time, flat tin pans 18"x18"x1" deep were used and were covered with another similar pan. The 2500 grams of wheat used was approximately 3/4 inch deep in the pans.

Variables of the Experiment. Since there was no information from other works about the wheats used, various temperatures, moistures, and periods of time were used. Temperatures, moistures, and time needed should be within economically reasonable limits if the positive results are to be put into practical use. With the data from previous work on other wheats as a guide, the following variables were taken into consideration:

For the H.R.W. and the S.R.W.-I :

Moisture 15.5 and 16.5 per cent.

Temperature of the oven 45, 60, and 75° C.

Time of heating 30, 45, and 60° C minutes.

For the S.R.W.-II the 16.5 per cent moisture content at three temperatures and times was used, since it was already observed that the results were almost identical for the two moisture levels.

Procedure. Each sample of 2500 grams of wheat was tempered to 15.5 or 16.5 per cent moisture in metal containers for about 20 hours at room temperature. The samples enclosed in the tin pans were then heated for various periods of time in the oven at the desired temperature reached in the wheat with the air valves wide open. Temperature and samples of grain for moisture tests were taken. The wheat was spread out to cool and to dry to the suitable moisture level for milling. The most severely treated samples had to be sprayed with one half to one and one half per cent water to prevent excessive drying before they reached the room temperature. The cooled sample was placed in a container ready for milling. The temperature and the moisture content of the samples at the end of their heating period are found in Table 2.

Milling of the Samples

Two to four hours after heat treatment was completed 2000 grams of each sample were milled in the Buhler automatic experimental mill. A control sample was tempered at room temperature and left rest for 18 hours for each day's milling. The rolls were set for optimum milling of the control sample of each wheat every day of milling. The samples of the same wheat were milled at that setting. Thirty-five minutes were allowed for the milling of each sample. The three break and three reduction flours were mixed together to make a straight grade flour. The amount of flour obtained from each sample is shown in Table 3. The samples heated at the same temperature were milled the same day.

The flours were stored in metal containers for three weeks before testing, except the S.R.W.-II, which was tested after a period of one week.

Wheat Tests

Hardness Test. The hardness test was considered useful for detecting changes induced in the wheat by the heat treatment before it was converted into flour.

Table 2. Temperatures and moisture content of the heat treated wheat samples.

Heat treatment		S.R.W.-I				S.R.W.-II		H.R.W.			
		Moisture content of the wheat samples before heat treatment									
Time min.	Oven temperature C°	15.5% m.c.		16.5% m.c.		16.5% m.c.		15.5% m.c.		16.5% m.c.	
		Final temperatures and moistures									
		m.c. %	Temper. C°	m.c. %	Temper. C°	m.c. %	Temper. C°	m.c. %	Temper. C°	m.c. %	Temper. C°
	45°	15.4	35.5°	16.5	35°	16.3	37°	14.7	35°	15.3	35°
30	60°	14.7	40°	15.7	41°	16.1	46°	14.5	41.5°	15.1	38°
	75°	14.8	47°	--	47°	16.0	52°	15.0	47°	15.8	44°
	45°	15.0	39°	15.8	37°	16.2	39°	13.9	38.5°	14.8	36°
45	60°	14.5	46°	15.1	45°	16.3	47°	14.2	44°	14.8	44.5°
	75°	--	50°	--	52°	16.6	56°	14.8	52°	15.5	53°
	45°	15.2	40°	15.0	39.5°	15.8	39°	13.8	38°	14.9	39°
60	60°	14.4	49°	15.3	51°	15.9	50°	13.8	49°	14.8	49.5°
	75°	--	58°	--	58°	15.2	60°	--	59°	14.7	58°

Table 3. Grams of flour obtained from 200 grams of heat treated wheat.

Heat treatment		S.R.W. - I		S.R.W. - II	H.R.W.	
Time, min.	Temper- C°	15.5% m.c.	16.5% m.c.	16.5% m.c.	15.5% m.c.	16.5% m.c.
	45°	1300	1300	1020	1450*	1440*
30	60°	1200	1231	1020	1320	1332
	75°	1275	1265	1135	1375	1345
	45°	1375	1310	1115	1445*	1435*
45	60°	1230	1245	1090	1330	1335
	75°	1275	1315	1205	1350	1315
	45°	1360	1335	1115	1470*	1425*
60	60°	1227	1258	1165	1315	1332
	75°	1280	1255	1250	1350	1350
Untreated		1380		1090	1390*	
samples		1260		1260	1305	
Average extraction of treated samples		63.5%	64%	56.7%	68.9%	68.4%

* Setting of the rolls slightly closer than that of the other samples.

This method, introduced by Brabender (4) to control the tempering of hard wheats going to mill, consists of grinding a certain amount of the wheat in a conical buhr mill connected with an autographic dynamometer (of the Farinograph) which records the resistance of the wheat to grinding.

The Brabender's double stage tester was used for the testing of the heat treated samples. One hundred grams of wheat were reduced on the preliminary grinder into coarse particles then spouted into the second grinder which is connected with the dynamometer. Plates I and II show the curves obtained for the S.R.W.-I and the H.R.W. samples. Tables 4 and 5 show the height of the curves in Brabender units. The length of the curves measured on the base line represented minutes required for the grinding of a sample. The ratio of height to length of the curve was used to indicate hardness. The increased moisture, however, added toughness to the bran and this factor could not be separated from the hardness test.

Tests were also made using four hundred grams of Hard Red Winter wheat conditioned in various ways and ground on the single buhr tester. Table 6 shows the results of these tests.

Sifting Test of Middlings. A method to determine the effect tempering has on size of middlings produced was conducted on the Buhler mill with the sieves removed and the Rotap sifter used for the grading of stock. Wheat samples were tempered for about 16 hours at various moistures and ground on the Buhler experimental mill. The throughs from each break were collected separately. Two hundred grams of throughs of each break were sifted on the

Table 4. Hardness test measurements of the heat treated S.R.W.-I wheat.

Heat treatment		S.R.W. - I 15.5% m.c.				S.R.W. - I 16.5% m.c.			
Time min.	Temper. C°	Moisture %	Height Br.U.	Time Min.	Height / Time	Moisture %	Height Br.U.	Time Min.	Height / Time
	45°	14.6	400	13.5	29.6	15.5	340	18	18.9
30	60°	9.8	540	14.5	37.2	9.8	500	15	33.3
	75°	13.5	400	15.5	25.8	14.4	400	14	28.6
	45°	14.1	370	13.5	27.4	15.2	360	18	20
45	60°	10.1	510	15.5	32.9	10.4	510	16	31.9
	75°	--	400	13.5	29.6	14.5	385	13	29.6
	45°	13.8	380	13.5	28.1	14.7	350	17	20.6
60	60°	10.0	510	14.5	35.2	10.7	480	17.5	27.4
	75°	13.0	390	15.5	25.2	13.5	400	14	28.5
Untreated		13.5	430	12.0	35.8				
samples		9.8	570	15.5	36.8				

Table 5. Hardness test measurements of the heat treated H.R.W. wheat.

Heat treatment: Time min.	Temper. C°	H.R.W. 15.5% m.c. Moisture %	Height Br.U.	Time min.	Height/Time	H.R.W. 16.5% m.c. Moisture %	Height Br.U.	Time min.	Height/Time
	45°	13.5	420	10.5	40	14.5	420	11.5	36.5
30	60°	10.3	575	12.0	47.9	10.6	560	12.5	44.8
	75°	--	440	10.5	42	14.3	420	11	38.2
	45°	13.4	440	9.5	46.3	14.1	420	11	38.2
45	60°	10.2	560	12	46.7	10.4	560	12.5	44.8
	75°	--	450	10.5	42.8	--	430	11	39.1
	45°	13.3	460	10.5	43.8	14.0	420	10.5	40
60	60°	9.8	590	11.5	51.3	10.1	610	12	50
	75°	--	460	9.5	46	--	440	10	44
Untreated		13.8	500	8.5	58.8				
samples		10.6	590	12.5	47.2				

Table 6. Results of some hardness tests done on H.R.W.

Conditioning given		Hardness, Br.U.
Untempered wheat	11.9 % m.c.	410
Tempered 18 hours	14.7 % m.c.	427
" " "	15.2 % m.c.	420
" " "	15.7 % m.c.	407
" " "	16.0 % m.c.	397
" " "	16.2 % m.c.	390
Tempered 2 hours	15.5 % m.c.	387
" 5 "	" "	378
" 7 "	" "	365
Tempered 16 hours at 44° F and 15.3 m.c.		428
Tempered 11 hours at room temperature and then, warmed for 5 hrs to reach 107° F,		355
The above cooled to 77° F		375
The above reheated to 100° F		350

Table 7. Sifting tests.

Moisture of the tempered wheat		Through from each break	Siftings of 200 grams middlings					
			Through on 14% MB	Overs 35	Ov. 65 Thr.35	Ov.175 Thr.65	Ov.325 Thr170	Thr.325 --
	1B	268	266	54.5	80	45.5	19	1.5
14.5%	2B	669	665	36	115	34.5	15	1.5
	3B	528	524	11	108	57.0	24	2.0
		1465	1455	101.5	303	137.0	58	5.0
	1B	266	263	53.5	79.5	46.6	19	2.8
15.0%	2B	662	653	36	115	34.5	14.5	2.3
	3B	517	511	11	113	53.0	22	2.1
		1445	1427	100.5	307.5	134.0	55.5	7.2
	1B	266	261.5	55.5	79.5	46	19	1.6
15.5%	2B	662	651	36	111	34	16.5	1.5
	3B	510	501	10.5	112	55	23	1.0
		1438	1413.5	103.0	302.5	135.8	58.5	4.1
	1B	265.5	259.5	55	79.5	47	19	1
15.8%	2B	651.5	637.5	34.5	113	37	15	1
	3B	512.0	501.0	10.5	112.5	55	21.5	1
		1429.0	1398.0	100	305.0	139.5	55.5	3

Rotap sifter using the following size sieves: 35 , 65 , 175 , and 325. Table 7 shows the results of the sifting test on stock tempered to the various moistures. The method was not used in testing heat treated samples as the variation in size of the particles was insignificant.

Moisture Tests of the Wheat. All moisture tests except those done for the hardness tests, were done by the air oven method (130° C for one hour) on grain coarsely ground before testing.

The moisture test of grain for the hardness test samples was done by the Tag-Heppenstall electrical moisture meter.

Flour Tests

Farinograph Test. In order to determine the effect of heat on the plasticity of the dough the flours were tested on the Brabender Farinograph. The test was done according to the directions given by the Brabender Corporation. This consisted of mixing 50 grams of flour (14 per cent moisture base) with distilled water in a proportion so that the maximum consistency of the dough was 500 Brabender units. Plates III , IV , V , VI , and VII show the farinograms and Table 8 shows the absorptions determined by this test. Table 8 also shows the valorimeter values as measured on the farinograms according to the method described by Johnson and co-workers (11).

Mixograph Test. The effect of heat on the mixing characteristics and requirements of the flour was examined by the Mixograph test. The Mixograph, designated and described by Swanson and Working (18), was used. The curves obtained are shown in Plates VIII and IX and the mixing requirements of the samples are given in Table 9.

Extensograph Test. The Extensograph test of the flour was used in order to study the effects of heat on extensibility and on other related physical properties of the dough. The test was done according to the directions of the Brabender Corporation for the use of their Extensograph. Three hundred grams of flour

Table 8. Water absorption in percent of 14MB flour and valorimeter values obtained by farinograph test of the heat treated wheat flour.

Heat treatm.		S.R.W. - I				S.R.W. - II		H.R.W.			
Time:	Temper.:	15.5% m.c.		16.5% m.c.		16.5% m.c.		15.5% m.c.		16.5% m.c.	
min:	C°	Abspt.	Valor.	Absp.	Valor.	Absp.	Valor.	Absp.	Valor.	Absp.	Valor.
	45°	62.0	89.5	63.5	88.0	50.5	83.0	61.0	85.5	60.8	86.0
30	60°	60.2	89.0	60.5	88.0	50.0	83.0	59.5	86.0	59.8	86.0
	75°	58.0	87.0	58.0	89.5	50.0	82.5	57.0	87.0	57.5	86.0
	45°	64.0	90.0	63.5	89.0	49.5	83.0	61.5	85.0	61.0	85.0
45	60°	60.5	89.0	61.5	89.5	50.0	83.0	60.0	86.0	60.5	85.0
	75°	58.8	89.0	58.0	89.0	50.5	83.0	57.5	86.0	58.0	85.5
	45°	63.5	88.0	63.0	90.5	50.0	83.0	62.0	85.0	61.4	85.0
60	60°	61.5	89.0	60.0	89.0	50.0	84.0	59.5	86.0	60.0	86.5
	75°	57.0	88.0	59.0	90.0	51.0	84.0	57.5	87.0	58.0	86.0
Untreated		63.4	88			52.0	83.0	58.5	86.0		
samples		61.5	89			52.0	84.0	58.5	86.0		

Table 9. Mixing time in minutes required for maximum dough development, as indicated by the mixograms of the heat treated wheat flour.

Heat treatment Time min.	Temper. C°	S.R.W. - I 15.5% m.c.	S.R.W. - II 16.5% m.c.	H.R.W. 15.5% m.c.
	45°	3 ½	--	5
30	60°	3 ½	3 ¼	4 3/4
	75°	3 ¼	3 ½	5
	45°	3 3/4	3 ½	4 ½
45	60°	3 3/4	3 ½	5
	75°	4	--	5 3/4
	45°	4	--	4
60	60°	4 ¼	3 ¼	5
	75°	3 3/4	3 ½	4 ¼
Untreated		3 3/4	2 ½	5 ¼

(14 per cent moisture base), 6 grams of salt, and the amount of distilled water determined by the Farinograph test for each sample were mixed by the Farinograph for one minute. The dough was rested for five minutes, and then the mixing was continued until the minimum mobility of the dough was reached. The dough was then made into two duplicate rolls of 150 grams, prepared by twenty turns of the rounder and passing the rounded dough through the moulder of the Extensograph. They were then placed in a thermostatic cabinet at 30° C. At intervals, of 45 minutes rest,

extensograms were taken to examine the effect of heat on the behavior of the dough after various periods of relaxation. The curves at 45, 90, and 135 minute rest periods were taken for every sample. The extensibility, resistance to extension, and the area under the curve obtained after 135 minutes of rest are shown in Table 10. They are the mean values of the two duplicate curves of each sample. Plates IX, X, and XI show the three superimposed curves of each sample obtained at the end of the three rest periods.

Chemical Analysis. The protein and the ash content of the flour was determined by standard methods and the results obtained are shown in Table 11.

Baking Test. The straight dough method was used and the formula used was as follows:

Flour	100 per cent	600 grams
Salt	2 " "	
Sugar	6 " "	
Malt	.25 " "	
Arkady	.25 " "	
Shortening	3 " "	

Water, according to the absorption determined by the Farinograph.

The milk solids which are normally included in the formula were omitted in this test in order to assure the showing of the effects of heat treatment on the baking characteristics of the flour. Also, only 0.25 per cent of Arkady was added in order to secure a good yeast activity rather than for the purpose of dough conditioning.

Table 10. Extensograph test measurements ** made on curves obtained after 135 min. rest period of doughs of the heat treated wheat flour.

Heat treatment		S.R.W. - I						S.R.W. - II			H.R.W.					
Time	Temp.	15.5% m.c.			16.5% m.c.			16.5% m.c.			15.5% m.c.			16.5% m.c.		
min.	C°	Area cm²	Ext. cm	Resist B.U.*	Area cm²	Ext. cm	Resist B.U.*	Area cm²	Ext. cm	Resist B.U.*	Area cm²	Ext. cm	Resist B.U.*	Area cm²	Ext. cm	Resist B.U.*
	45°	62.0	11.0	512	67.1	9.3	617	60.9	8.5	610	66.6	8.5	735	70.0	8.2	755
30	60°	76.4	10.5	635	59.0	9.0	587	62.3	8.7	640	68.9	9.0	680	70.9	8.2	797
	75°	74.9	9.8	690	85.1	10.7	710	63.6	8.7	635	67.2	8.5	730	74.3	8.2	817
	45°	64.6	9.5	610	57.9	11.2	435	59.4	8.2	632	52.9	7.5	655	49.9	7.5	625
45	60°	75.7	10.5	660	59.7	10.0	550	71.1	9.2	720	72.8	9.2	687	64.5	8.5	680
	75°	88.9	10.7	735	74.8	9.7	670	61.2	8.2	682	67.6	8.5	730	69.6	9.3	685
	45°	70.8	10.5	560	59.7	10.5	490	62.6	7.8	725	56.2	8.7	595	79.5	10.2	765
60	60°	71.7	10.5	615	688	9.5	637	63.0	8.5	665	78.9	9.2	775	59.5	7.5	720
	75°	72.5	9.5	665	74.1	10.7	590	56.3	8.2	645	74.7	8.8	785	87.9	9.2	862
Untreated samples		65.0	10.5	555				60.8	8.7	607	106.3	11.2	855			
		67.7	9.7	597				69.2	9.0	710	89.5	9.2	887			

* 1 Brabender Unit = 1.24 gr. force.
** Mean value of two duplicate dough rolls.

Table 11. Ash* and protein* of the heat treated wheat flours.

Heat treatment		S.R.W. - I				S.R.W. - II		H.R.W.			
		15.5% m.c.		16.5% m.c.		16.5% m.c.		15.5% m.c.		16.5% m.c.	
Time min.	Temper. C°	Ash	Prot.	Ash	Prot.	Ash	Prot.	Ash	Prot.	Ash	Prot.
	45°	.56	10.7	.56	10.9	--	--	.46	9.5	.48	9.3
30	60°	.54	10.5	.48	10.5	--	--	.45	9.8	.40	9.2
	75°	.53	10.7	--	--	--	--	.43	9.4	.41	9.1
	45°	.52	10.6	.53	10.6	--	--	.49	9.5	.48	9.4
45	60°	.53	10.5	.50	10.5	--	--	.40	9.4	.39	9.3
	75°	.52	10.6	.46	10.4	.38	8.7	.43	9.3	.42	9.1
	45°	.56	10.7	.51	10.7	--	--	--	--	.53	9.7
60	60°	.49	10.5	.52	10.7	--	--	.39	9.3	.39	9.1
	75°	.50	10.4	.58	10.5	--	--	.42	9.2	.41	9.1
Untreated		.49	10.9			--	--	.47	9.8		
samples		.51	10.6			.41	8.8	--	--		

* Values on 14% MB.

The mixing time was determined by the baker with guide of the mixograms of the samples, which give approximately the mixing time required when using the Hobart A 200 mixer.

The fermentation and bake schedule was as follows:

110 minutes		after mixing; 1st punch.
50	"	after 1st punch; dividing and 2nd punch.
20	"	after 2nd punch; moulding, panning, and proofing.
55	"	proofing.
30	"	baking.

Two duplicate loaves of 16½ ounces of dough were prepared from each sample.

As soon as the loaves of bread were cool their volume and weight were taken. The judging of the bread was done either after a few hours or the next day by persons unfamiliar with the treatment given each sample. The scoring procedure was as follows:

Volume Score-maximum 20. It was based on the specific volume of the loaf that is the ratio volume in cubic centimeters to the weight in grams. Every two tenths of specific volume was to have the value of score one. The highest loaf volume obtained in this experiment was given the score 19. The other loaves were scored according to their specific volumes.

External Appearance-maximum 10. It included symmetry of the loaf, normality of the crust surface, and crust color.

Break and Shred-maximum 10. Normality and other characteristics of the break and shred are considered.

Grain-maximum 20. It included the fineness and uniformity of the crumb cells.

Texture-maximum 20. Smoothness, roughness, and harshness observed on the crumbs was considered.

Tables 12, 13, and 14 show the results of the baking test.

DISCUSSION OF EXPERIMENTAL RESULTS

Heat Treatment Method

Table 2 shows the temperature and moisture content of the wheat samples at the end of the heating periods. Because of the lag of heat conduction in the samples, the temperatures reached were considerably lower than the set temperatures of the oven, as it was expected (see paragraph "Heating Apparatus").

Theoretically, it can be said that the temperature of the outer layers of the wheat kernel were near the same temperature as the oven during heating, but the interior of the kernel would not be brought to this temperature unless the heating process was continued for many more hours. The temperature of the sample was taken when the mercury became constant. The temperatures in Table 2 are close to the actual mean temperature of the whole kernel; whereas, it is evident that the outer layers of the kernel were at much higher temperatures than the temperature reached at the end of the heating period.

The loss of moisture was nearly proportional to the temperature rise in each sample. The severeness of the treatment is

Table 12. Loaf volume, volume score and total score of the bread prepared from the heat treated wheat flour.

Heat treatment		S.R.W. - I						S.R.W. - II			H.R.W.					
		15.5% m.c.			16.5% m.c.			16.5% m.c.			15.5% m.c.			16.5% m.c.		
Time min.	Temp. C°	Loaf vol. cc.	Vol. sc. 20	Tot. sc. 80	Loaf vol. cc.	Vol. sc. 20.	Tot. sc. 80	Loaf vol. cc.	Vol. sc. 20	Tot. sc. 80	Loaf vol. cc.	Vol. sc. 20	Tot. sc. 80	Loaf vol. cc.	Vol. sc. 20	Tot. sc. 80
	45°	2375	16	65	2300	15	63	2325	15	49	2260	14	50	2175	13	49
30	60°	2500	17	67	2325	15	61	2230	14	46	2240	14	50	2125	12	46
	75°	2490	17	67	2475	17	68	2285	15	43	2230	14	51	2250	14	46
	45°	2350	15	62	2350	16	65	2275	15	48	2130	12	44	2175	12	42
45	60°	2435	17	65	2300	15	66	2475	17	54	2140	12	46	2100	12	46
	75°	2540	18	67	2675	19	68	2475	17	53	2110	12	45	2125	12	43
	45°	2400	16	66	2530	18	66	2390	16	48	2150	12	42	2125	12	42
60	60°	2350	15	64	2575	18	67	2450	17	52	2200	13	49	2220	14	45
	75°	2525	18	69	2630	19	68	2500	18	51	2150	12	48	1800	9	35
Untreated		2125	13	58				2385	17	61	2130	12	48			
samples		2375	15	63				2480	16	50	2040	10	44			

Table 13. Bread scores of the heat treated S.R.W.-I wheat.

Heat treatment Time min.	Temper C°	Specific vol.	Break & Shred 10	Grain 20	Texture 20	Volume 20	External appear. 10	Total score 80
				15.5% m.c.				
30	45°	6.02	7r	16	18	16	8g	65
	60°	6.20	8r	16	18	17	8g	67
	75°	6.22	8r	16	17	17	8g	67
45	45°	5.80	7r	16	17c	15	7f	62
	60°	6.15	7	16	18	17	7f	65
	75°	6.30	8r	16	17t	18	8g	67
60	45°	6.05	7r	17	18	16	8g	66
	60°	5.90	6w	18	18	15	7f	64
	75°	6.38	7r	18	18	18	8g	69
				16.5% m.c.				
30	45°	5.78	7r	16	17c	15	8g	63
	60°	5.87	6r	16o	17	15	7f	61
	75°	6.15	8r	17	18	17	8g	68
45	45°	5.90	8	16o	17c	16	8g	65
	60°	5.80	8r	17	18	15	8g	66
	75°	6.60	7r	16o	18	19	8g	68
60	45°	6.30	7r	16o	17h	18	8g	66
	60°	6.40	8	16o	17	18	8g	67
	75°	6.50	8	16o	17	19	8g	68
Untreated samples		5.33	6	17	16t	13	6	58
		5.97	7	16	17	15	8	63

g-good, f-fair, p-poor, r-rugged, w-weak, h-harsh, c-coarse, t-tough, o-open.

effected by time, temperature, and moisture. The samples having low moisture content were not affected by high temperatures as the samples containing more moisture were when heated to the same temperature. However, it should be remembered that the loss in moisture took place gradually during heating so that the variation

Table 14. Bread scores of the heat treated H.R.W. and S.R.W.-II wheats.

Heat treatment Time min.	Heat treatment Temper C°	Specific vol.	Break & Shred 10	Grain 20	Texture 20	Volume 20	External appear. 10	Total score 80
				H.R.W. 15.5% m.c.				
30	45°	5.59	5	12o	12	14	7f	50
	60°	5.50	5	12	12	14	7f	50
	75°	5.50	5	15	10	14	7f	51
45	45°	5.33	5	10	10h	12	7f	44
	60°	5.35	5	11	12	12	7f	46
	75°	5.17	5	11	10h	12	7f	45
60	45°	5.35	5	10o	8h	12	7f	42
	60°	5.45	5	13	12	13	7f	49
	75°	5.27	5	13	11	12	7f	48
				H.R.W. 16.5% m.c.				
30	45°	5.42	5	13	11	13	7f	49
	60°	5.27	5	11	11	12	7f	46
	75°	5.56	5	10	10h	14	7f	46
45	45°	5.32	3	10	11	12	6p	42
	60°	5.16	3	13	12	12	6p	46
	75°	5.26	3	11	11	12	6p	43
60	45°	5.30	3	10	11h	12	6p	42
	60°	5.50	3	11	11h	14	6p	45
	75°	4.35	3	10	8	9	5v.p.	35
Untreated samples		5.27	5	12	12t	12	7f	48
		5.04	5	10	12t	10	7f	44
				S.R.W. - II 16.5% m.c.				
30	45°	5.71	5	12	12	15	5v.p.	49
	60°	5.52	5	12	10	14	5v.p.	46
	75°	5.65	6	12	10	15	5v.p.	46
45	45°	5.60	5	12	10	15	6p	48
	60°	6.10	6	13	12	17	6p	54
	75°	6.20	6	13	11	17	6p	53
60	45°	5.95	4	13	10	16	5v.p.	48
	60°	6.09	5	13	11	17	6p	52
	75°	6.25	6	15	14	18	7f	51
Untreated samples		5.79	4	15	14	16	5v.p.	54
		6.20	6	16	15	17	7f	61

o-open, f-fair, p-poor, v.p.-very poor, h-harsh.

in treatment of the different samples was not materially changed. The losses were, in most cases, less than one per cent and never exceeded one and seven tenths per cent. The differences in the resultant moistures of the samples were not considered as factor affecting the baking quality of the wheats in the moisture levels used.

Complete recirculation and supplementary humidification of the hot air which was heating the samples at the point where it leaves the heater would eliminate the evaporation losses.

Milling of the Samples

There were certain variations in flour yields (Table 3) between millings on different days. There was no remarkable difference between samples that received various amounts of heat treatment with the millings done in the same day. In the case of the S.R.W.-I however, the untreated samples yielded a little more flour than the treated ones. In the case of the H.R.W. the opposite was observed. This result could be attributed to the fact that H.R.W. wheats have a higher optimum tempering moisture level than the S.R.W. wheats. Although the milling of the samples was done at a low moisture content it seems that the initial high moisture of tempering before heating slightly affected the yield. From the point of view of milling yield, a lower moisture content in tempering soft wheat for heat treatment might be recommended for investigation.

Wheat Testing

Hardness Test. As it is shown in Tables 4, 5, and 6 and Plates I and II the hardness test values do not show any correlation to the amount of heat treatment. The variation in moisture content was the predominant factor affecting the results. The higher the moisture content the lower the height of the curves and the ratio of height to length of time. The relationship of moisture to hardness is better illustrated in Fig. 1, which is based on the data of Table 6.

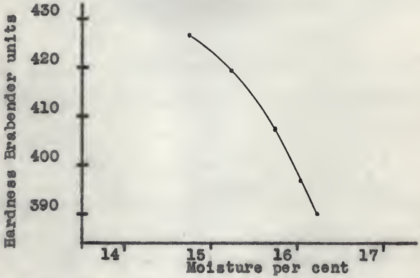

Fig. 1. Relationship of Hardness to Moisture of the Wheat.

In Table 15 the hardness test figures of the heat treated samples are arranged in the order of increasing moisture content of the samples when tested. The untreated samples which were only tempered to normal moisture levels show remarkably higher values than the treated samples of the same moisture level. This fact might be attributed to the heating, although it is more probable that the high moisture of tempering before heating was the factor that caused the decrease in hardness of the samples.

Flour Tests

Farinograph Test. Plate XII, which was prepared with the data of Table 8, illustrates the effects of the heat treatment on the water absorption of the flour. (Plates III, IV, V, VI, and VII). In both, S.R.W.-I and H.R.W. wheats it is noticed that the absorption was slightly increased with light heat treatment but more severe treatment decreased the absorption. The increase was more remarkable in the H.R.W. In the case of the S.R.W.-II wheat, the absorption dropped with heating. The highest absorption for the H.R.W. was obtained with treatment at 45° C for 60 minutes and for the S.R.W.-I at 45° C for 45 minutes.

Increase in absorption as a result of the heat treatment has been reported by Kent-Jones (12) and Lockwood (13), p. 214. In the example given by the latter the water absorption was increased one to three per cent after treatment. The increase observed in this experiment was within this range. The progressive decrease in absorption which occurred when the treatment was more severe has also been observed by Geddes (6). This was probably the result of denaturation of gluten. The variation in time of heating had no great effect on the results as shown in Table 8 and Plate VII. Also the variation in moisture content of the wheat from 15.5 to 16.5 per cent had no effect on the absorption. The main factor appeared to be the temperature.

No definite correlation of the valorimetric values of the

Table 15. Relationship of hardness test values to the moisture content of the treated samples.

S.R.W. - I				H.R.W.			
Heat tr/ment	Mois-ture	Height: Br.U.	Height/Time	Heat tr/ment	Mois-ture	Height: Br.U.	Height/Time
Untreated	9.8	570	36.8	a/60/60°	9.8	590	51.3
a/30/60°	9.8	540	37.2	b/60/60°	10.1	610	50.0
b/30/60°	9.8	500	33.3	a/45/60°	10.2	560	46.7
a/60/60°	10.0	510	35.2	a/30/60°	10.3	575	47.9
a/45/60°	10.1	510	32.9	b/45/60°	10.4	560	44.8
b/45/60°	10.4	510	31.9	b/30/60°	10.6	560	44.8
b/60/60°	10.7	480	27.4	Untreated	10.6	590	47.2
a/60/75°	13.0	390	25.2	a/60/45°	13.3	460	43.8
Untreated	13.5	430	35.8	a/45/45°	13.4	440	46.3
b/60/75°	13.5	400	28.5	a/30/45°	13.5	420	40.0
a/30/75°	13.5	400	25.8	Untreated	13.8	500	58.8
a/60/45°	13.8	380	28.1	b/60/45°	14.0	420	40.0
a/45/45°	14.1	370	27.4	b/45/45°	14.1	420	38.2
b/30/75°	14.4	400	28.6	b/30/75°	14.3	420	38.2
b/45/75°	14.5	385	29.6	b/30/45°	14.5	420	36.5
a/30/45°	14.6	400	29.6				
b/60/45°	14.7	350	20.6				
b/45/45°	15.2	360	20.0				
b/30/45°	15.5	340	18.9				

a- 15.5% m.c. before heating
b- 16.6% m.c. " "

farinograms to the differences in heat treatment of the various samples was noticed. The differences in valorimetric value between the three wheats were significant according to their bread making value. The S.R.W.-I samples had the highest values (88-90.5), the S.R.W.-II the lowest (82.5-84), and the H.R.W. was between the two (85-86.5).

The same was true with the time required for maximum dough development measured on the farinograms. The range was from three to four and a half minutes for the S.R.W.-I, from three fourths to one minute for the S.R.W.-II and from one to two minutes for the H.R.W. Actually the higher valorimeter values corresponded to the higher times of maximum dough development. This was expected, because the time of maximum dough development together with the mixing tolerance index are the main factors determining the valoremeter value (16).

In all doughs of increased water absorption a certain stickiness was observed when they were prepared for the Extensograph test. A similar phenomenon was observed by Munz and Brabender (14). They state as follows: "When flours require more than 68 per cent water (15 per cent moisture base) to yield doughs having mobility equivalent to 500 Brabender units, the resulting doughs tend to be sticky or adhesive". These authors maintain that the Farinograph in such cases is useful for indicating the limits of mixing before the dough becomes sticky.

Mixograph Test. The time required for maximum dough development, as indicated by the Mixograph for the H.R.W., remained practically unaffected. In the case of the two soft red winter wheats the time was slightly increased (see Table 9 and Plates VIIIand IX).

Extensograph Test. The trends in the S.R.W.-I with increasing temperatures of treatment showed certain increases in resistance to extension and in the area under the curve. In the case of the H.R.W. the resistance and area were remarkably lower in the treated samples than they were in the untreated samples. No significant differences were noticed between the S.R.W.-II samples. The extensibility was not changed materially in the three wheats (Plates IX, X, and XI).

In Table 16 the ratio F/E which is determined by both resistance to extension and extensibility was arranged for each wheat in the order of increasing value for the purpose of examining its relationship to the corresponding baking test values. The relationship is significant for the S.R.W.-I wheat which showed definite improvement in baking quality with a few high baking values corresponding to the lower F/E ratios. In the case of the S.R.W.-II there was no definite relationship and in the H.R.W. the relationship was slightly negative. These two wheats did not show any significant improvement as a result of the heat treatment.

Increase in extenso-area and resistance or F/E ratio due to heat treatment of the wheat or flour has been observed by Munz and Brabender (14) and by Lockwood (13). Whether or not this phenomenon can be used for predicting the baking value of any flour was not assured by the results of this experiment.

Plates XIII and XIV show the relationship between heat treatment of the wheat and the Extensograph test values.

Ash. There was certain variation in ash content of the flours but no definite trend of relationship to the treatment is shown in the samples (Table 11). The S.R.W.-I treated samples had a slightly higher ash than those untreated. The H.R.W. samples had a lower ash content than those untreated, except for those treated at 45° C and milled with a closer setting of the rolls.

Protein. The protein content of the S.R.W. samples showed almost no change. The H.R.W. samples showed a slight decrease in

Table 16. Relationship of F/E ratio# of the dough to baking values.

Heat treatment	F/E	Vol. sc.	Tot. sc.	Heat treat.	F/E	Vol. sc.	Tot. sc.	Heat treat.	F/E	Vol. sc.	Tot. sc.
b/45/45°	48.2	16	65	Untr	89	17	61	a/60/45°	85	12	42
a/30/45°	57.6	16	65	30/45°	89	15	49	b/45/75°	91	12	43
b/60/45°	58	18	66	30/75°	90.5	15	43	a/45/60°	92.5	12	46
Untreat.	65.4	13	58	30/60°	91	14	46	b/60/45°	93	12	42
a/60/45°	66	16	66	45/60°	95.5	17	54	a/30/60°	93.5	14	50
b/45/60°	68.1	15	66	45/45°	95.6	15	48	Untreat.	94.5	12	48
b/60/75°	68.3	19	68	60/60°	97	17	52	b/45/60°	100	12	46
a/60/60°	72.5	15	64	60/75°	97.5	18	51	b/45/45°	103	12	42
a/30/60°	75	17	67	Untrea	98	16	50	a/60/60°	104	13	49
Untreat.	76	15	63	45/74°	103	17	63	a/45/75°	106	12	45
a/45/60°	78	17	65	60/45°	115	16	48	a/30/75°	106	14	51
a/45/45°	79.5	15	68					a/30/45°	107	14	50
b/30/60°	81	15	61					a/45/45°	108	12	44
b/30/45°	82	15	63					a/60/75°	110	12	48
b/30/75°	82.2	17	68					b/30/45°	114	13	49
b/60/60°	83	18	67					b/60/75°	116	9	35
a/45/75°	85	18	67					b/60/60°	119	14	45
b/45/75°	85.6	19	68					Untreat.	120	10	44
a/60/75°	87	18	69					b/30/45°	120	12	46
a/30/75°	87.2	17	67					b/30/75°	123	14	46

a-15.5 per cent moisture before treatment.
b-16.5 " " " " "

$F/E = \frac{R \times 1.24}{E}$

R = Resistance to extension in Brabender units.
1.24 = Grams of force per Brabender unit.
E = Extensibility of dough which is approximately the ratio of the final length of the extended dough to the original one. (Munz and Brabender, 14)

protein when compared with treated samples.

Baking Test. Tables 12, 13, 14, and 15 show the results of the baking test. In Plate XV the relationship of the heat treatment to the loaf volume is shown.

S.R.W.-I. Several samples showed a remarkable improvement in loaf volume, grain, and texture. Those heated at 60 and 75° C and for the longer periods had the highest scores. The maximum difference in volume between treated and untreated samples was 550 cubic centimeters.

S.R.W.-II. No differences were observed between treated and untreated samples. In general, the volume of the bread was relatively good but, if other characteristics and the low absorption of the flour are taken into consideration (Table 8), its value as a bread flour is questionable.

H.R.W. The treated samples showed deterioration of the baking quality as indicated by their low total scores with the exception of the samples treated for only 30 minutes. The loaf volume in the lightly treated samples showed some increase. The rest were almost the same as the untreated samples. In general, the bread making quality of this wheat was not satisfactory. The fact that the light treatment of 30 minutes somewhat improved the quality of the bread and increased the absorption of the flour two or three per cent (Table 8) indicates that warm conditioning of this wheat would be helpful for a higher baking value.

SUMMARY AND CONCLUSIONS

Two S.R.W. wheats and one H.R.W. wheat were heat treated at 45, 60, and 75° C; at 15.5 and 16.5 per cent moisture content for 30, 45, and 60 minutes in a hot air "Dispatch" oven to study the effects of the heat treatment on the properties of the wheats and the flours. The effects studied are as follows:

a. Hardness of the wheat.

b. Water absorption.

c. Mixing characteristics.

d. Extensibility and related physical characteristics of dough.

e. Ash and protein content of the flour.

f. General baking value of the flour for bread.

The conclusions reached in this investigation are:

1. The moisture content variation in the heat treated samples was the predominant factor affecting the results of the hardness test. If the heat treatment has any effect on the hardness of the wheat this could not be detected.

2. The slight heat treatment increased the water absorption in the S.R.W.-I and the H.R.W. wheat flours from one to three per cent. More severe treatment decreased the absorption progressively. The absorption of the S.R.W.-II wheat flours was decreased.

3. The Valorimeter value and the time required for maximum dough development measured on the farinograms showed enough difference in bread making value of the three wheats but did not show the changes in value between the treated samples of the same wheat.

4. The extensibility of the dough was not changed remarkably in any of the treated samples. There was no adequate positive correlation between Estensograph test values and the corresponding baking test values. This was especially true in the H.R.W. and the S.R.W.-II wheats.

5. No trend of relationship was found between the amount of

the heat treatment and the ash and the protein content of the flour.

6. The heat treatment was particularly beneficial to the baking quality of the S.R.W.-I wheat. Increase in volume and improvement in grain and texture was noticed in the more severely treated samples of the series. A more severe treatment might bring about a greater improvement in bread quality but it is very probable that the water absorption of the flour would be more decreased.

7. The slightly treated samples of the H.R.W. wheat showed some improvement in the bread making quality. The more severely treated samples were harmed.

8. The S.R.W.-II wheat did not show any change in bread quality. Since its low water absorption was even more decreased by the treatment, it should be concluded that the treatment was harmful to this wheat.

9. If the improvement in quality of bread with an increasing amount of treatment is accompanied by progressive decrease in absorption as in the case of the S.R.W.-I wheat, it is questionable whether or not heat treatment should be used extensively to improve the quality.

ACKNOWLEDGMENTS

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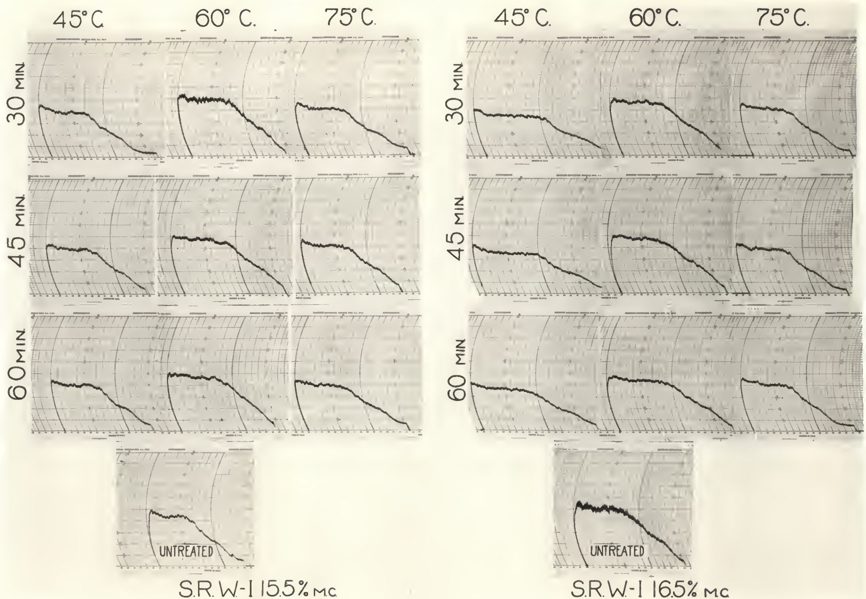
EXPLANATION OF PLATE I.

Hardness test curves of the S.R.W.-I wheat samples; samples of the same column were treated at the same temperature; samples of the same horizontal line were treated for the same period of time.

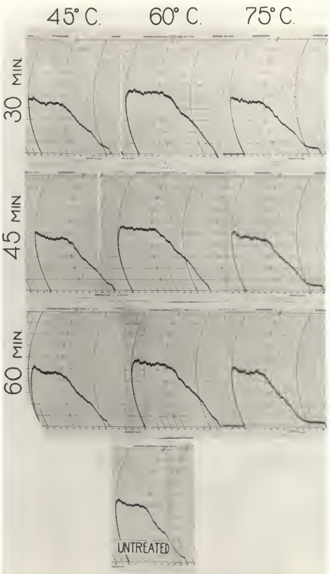
PLATE I


45°C.
60° C.
75°C.
30 MIN.
45 MIN.
60 MIN.
UNTREATED
S.R.W.-I 15.5% MC
45°C.
60°C.
75°C.
30 MIN
45 MIN
60 MIN
UNTREATED
S.R.W.-I 16.5% MC

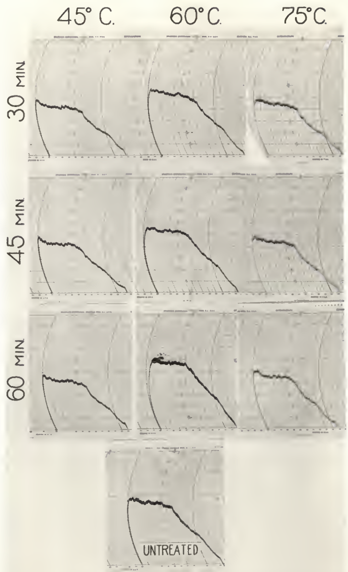
EXPLANATION OF PLATE II.

Hardness test curves of the H.R.W. wheat; samples of the same column were treated at the same temperature; samples of the same horizontal line were treated for the same period of time.

PLATE II



H.R.W. 15.5% M.C.

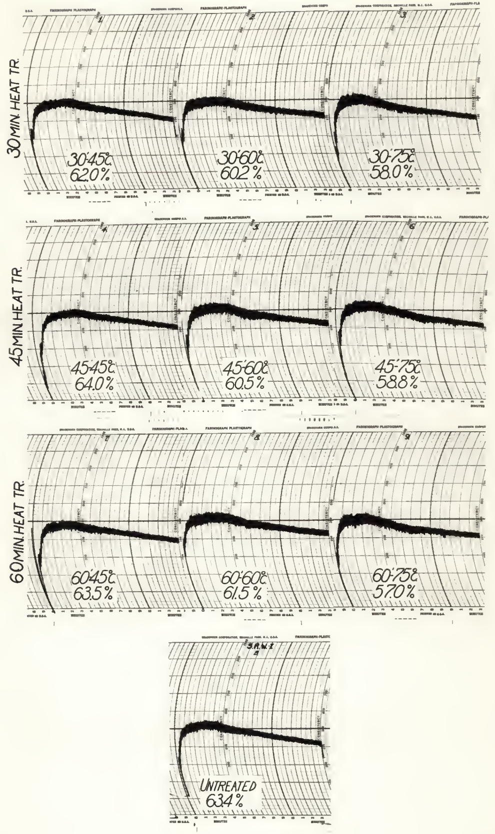


H.R.W. 16.5% M.C.

EXPLANATION OF PLATE III.

Farinograph curves of the S.R.W.-I wheat. Heat treatment at 15.5% m.c. The time, temperature, and water absorption are given on the curves.

PLATE III

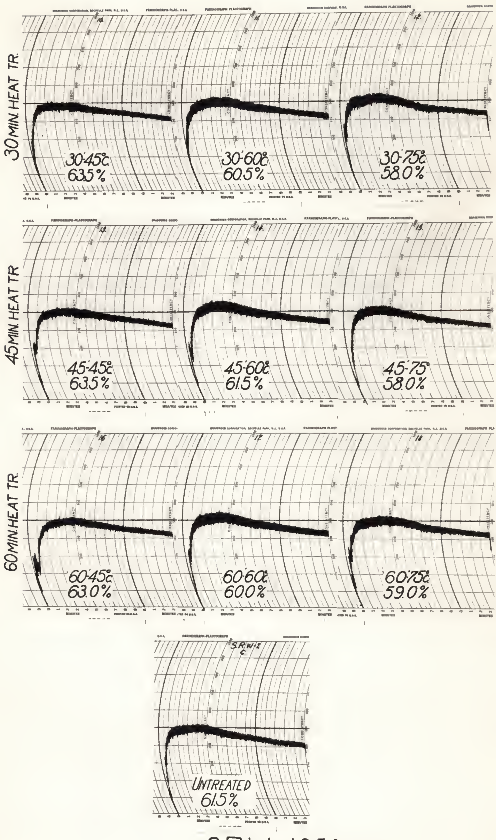


S.R.W.-I 15.5% M.C.

EXPLANATION OF PLATE IV.

Farinograph curves of the S.R.W.-I wheat. Heat treatment at 16.5% m.c. The time, temperature, and water absorption are given on the curves.

PLATE IV

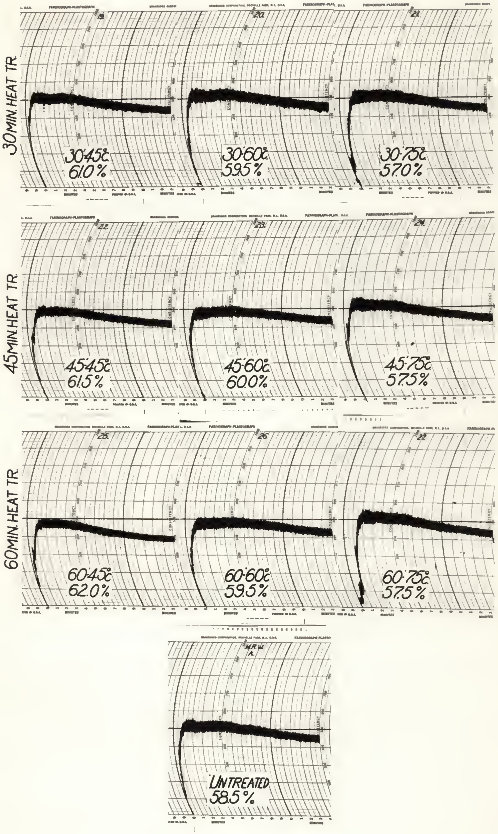


S.R.W.-I 16.5% M.C.

EXPLANATION OF PLATE V.

Farinograph curves of the H.R.W. wheat. Heat treatment at 15.5% m.c. The time, temperature, and water absorption are given on the curves.

PLATE V

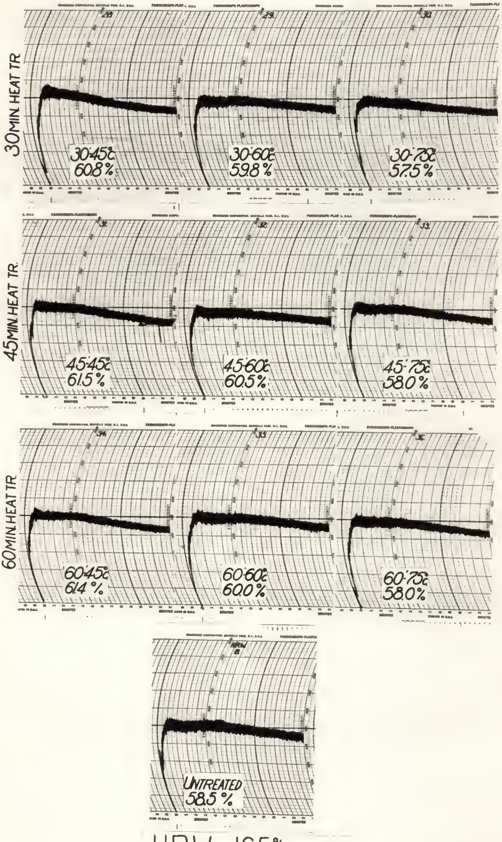


H.R.W. 15.5 % M.C.

EXPLANATION OF PLATE VI.

Farinograph curves of the H.R.W. wheat. Heat treatment at 16.5% m.c. The time, temperature, and absorption are given on the curves.

PLATE VI

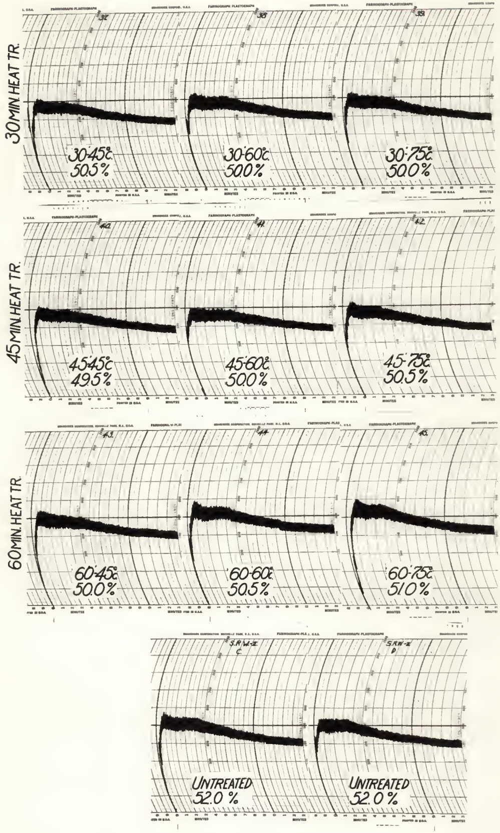


H.R.W. 16.5% M.C.

EXPLANATION OF PLATE VII.

Farinograph curves of the S.R.W.-II wheat. The time, temperature, and absorption are given on the curves.

PLATE VII

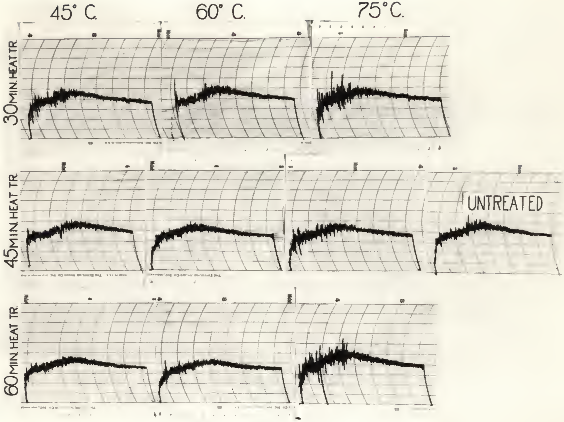


S.R.W-II 16.5% M.C.

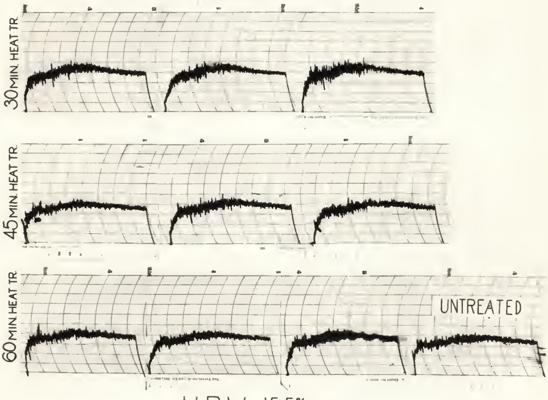
EXPLANATION OF PLATE VIII.

Mixograph curves of the S.R.W.-I and the H.R.W. wheats. The samples of the same column were treated at the same temperature. The samples of the same horizontal line were treated for the same period of time.

PLATE VIII



S.R.W-I 155% MC.



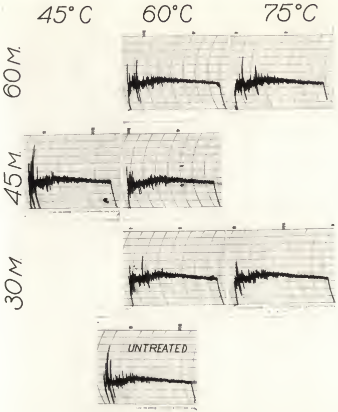
H. R. W. 15.5% M.C.

EXPLANATION OF PLATE IX

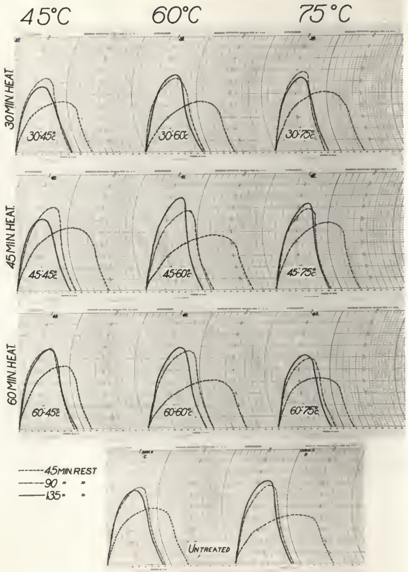
1. Left. Mixograph curves of the S.R.W.-II wheat.
2. Right. Extensograph curves of the S.R.W.-II wheat.

The samples of the same column were treated at the same temperature. The samples of the same horizontal line were treated for the same period of time.

PLATE IX



S.R.W-II 16.5% M.C.

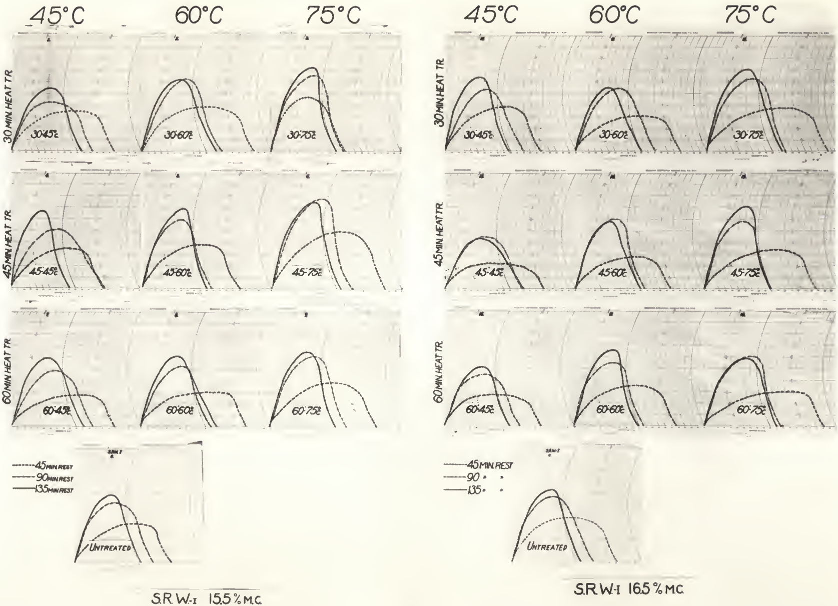


S.R.W-II 16.5% M.C.

EXPLANATION OF PLATE X.

Extensograph curves of the S.R.W.-I wheat. The samples of the same column were treated at the same temperature. The samples of the same horizontal line were treated for the same period of time.

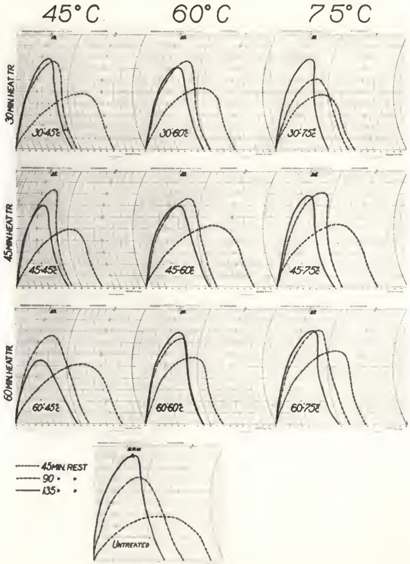
PLATE X


45°C
60°C
75°C
45°C
60°C
75°C
30 MIN HEAT TR.
45 MIN HEAT TR.
60 MIN HEAT TR.
30·45°C
30·60°C
30·75°C
45·45°C
45·60°C
45·75°C
60·45°C
60·60°C
60·75°C
45 MIN REST
90 MIN REST
135 MIN REST
UNTREATED
S.R.W.-I 15.5 % M.C.
45 MIN REST
90 " "
135 " "
UNTREATED
S.R.W.-I 16.5 % M.C.

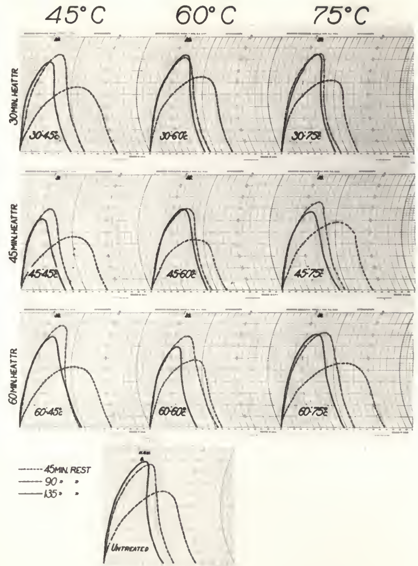
EXPLANATION OF PLATE XI.

Extensograph curves of the H.R.W. wheat. The samples of the same column were treated at the same temperature. The samples of the same horizontal line were treated for the same period of time.

PLATE XI



H.R.W. 15.5% M.C.

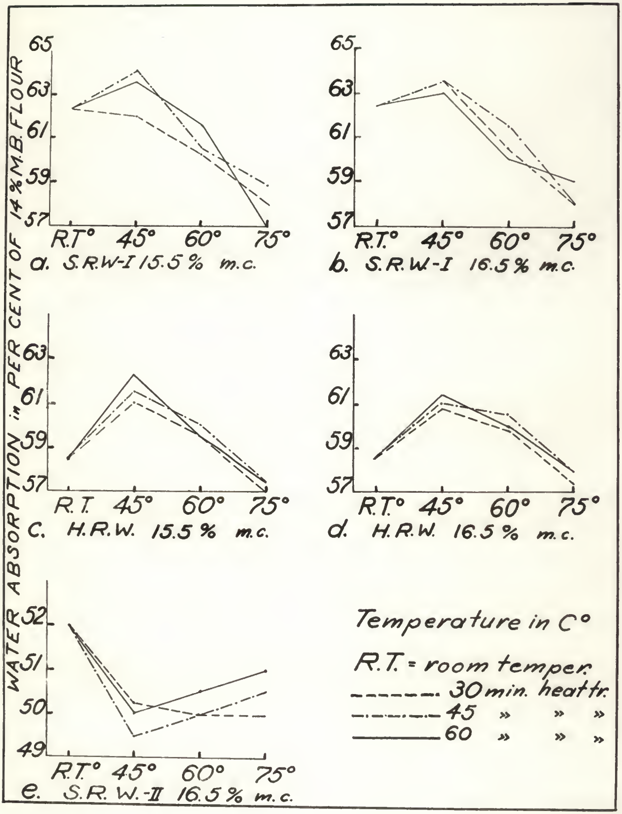


H.R.W. 16.5% M.C.

EXPLANATION OF PLATE XII.

Relationship of the heat treatment of the wheat to the water absorption of the flour.

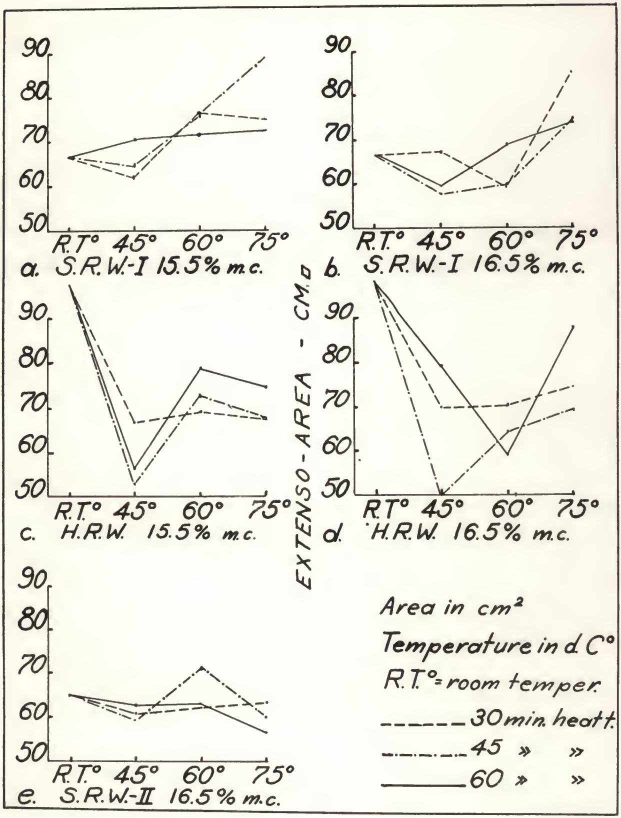
PLATE XII


WATER ABSORPTION in PER CENT OF 14% M.B. FLOUR
65
63
61
59
57
R.T° 45° 60° 75°
a. S.R.W-I 15.5% m.c.
b. S.R.W.-I 16.5% m.c.
63
61
59
57
R.T. 45° 60° 75°
c. H.R.W. 15.5% m.c.
d. H.R.W. 16.5% m.c.
52
51
50
49
R.T° 45° 60° 75°
e. S.R.W.-II 16.5% m.c.
Temperature in C°
R.T. = room temper.
30 min. heat tr.
45 » » »
60 » » »

EXPLANATION OF PLATE XIII.

Relationship of the heat treatment of the wheat to the area under extensograph curves.

PLATE XIII

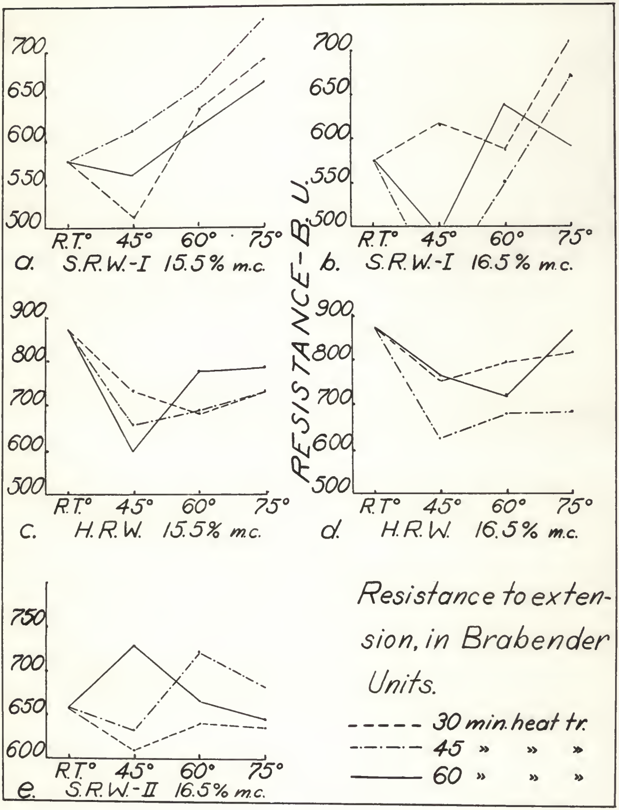


90
80
70
60
50
R.T° 45° 60° 75°
a. S.R.W.-I 15.5% m.c.
b. S.R.W.-I 16.5% m.c.
c. H.R.W. 15.5% m.c.
d. H.R.W. 16.5% m.c.
e. S.R.W.-II 16.5% m.c.
EXTENSO - AREA - CM.□
Area in cm²
Temperature in d. C°
R.T°= room temper.
30 min. heatt.
45 » »
60 » »

EXPLANATION OF PLATE XIV.

Relationship of the heat treatment of the wheat to the resistance to extension of the dough as measured by the Extensograph.

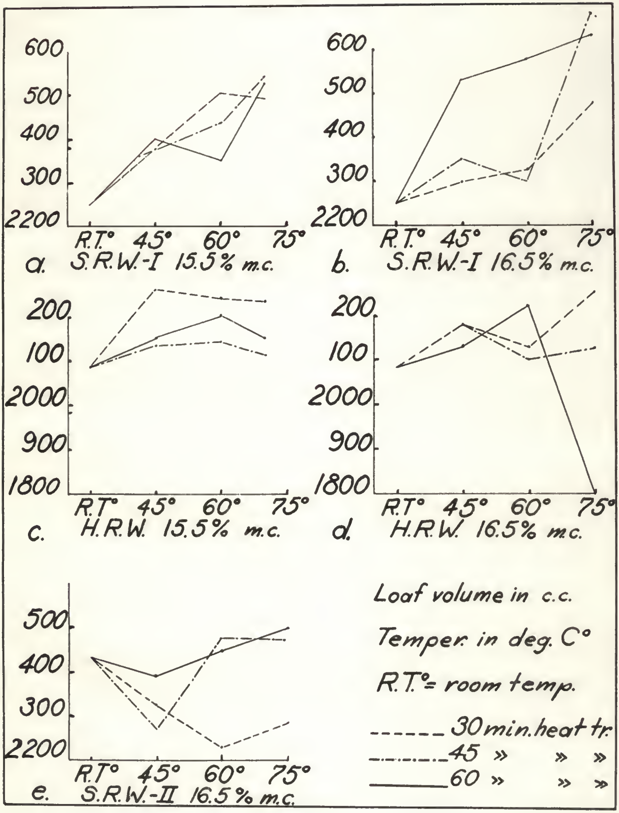
PLATE XIV


700
650
600
550
500
R.T.° 45° 60° 75°
a. S.R.W.-I 15.5% m.c.
700
650
600
550
500
R.T.° 45° 60° 75°
b. S.R.W.-I 16.5% m.c.
RESISTANCE-B.U.
900
800
700
600
500
R.T.° 45° 60° 75°
c. H.R.W. 15.5% m.c.
900
800
700
600
500
R.T.° 45° 60° 75°
d. H.R.W. 16.5% m.c.
750
700
650
600
R.T.° 45° 60° 75°
e. S.R.W.-II 16.5% m.c.
Resistance to extension, in Brabender Units.
30 min. heat tr.
45 " " "
60 " " "

EXPLANATION OF PLATE XV.

Relationship of the heat treatment of the wheat to the loaf volume.

PLATE XV


600
500
400
300
2200
R.T.° 45° 60° 75°
a. S.R.W.-I 15.5% m.c.
600
500
400
300
2200
R.T.° 45° 60° 75°
b. S.R.W.-I 16.5% m.c.
200
100
2000
900
1800
R.T° 45° 60° 75°
c. H.R.W. 15.5% m.c.
200
100
2000
900
1800
R.T° 45° 60° 75°
d. H.R.W. 16.5% m.c.
500
400
300
2200
R.T° 45° 60° 75°
e. S.R.W.-II 16.5% m.c.
Loaf volume in c.c.
Temper. in deg. C°
R.T.°= room temp.
30 min. heat tr.
45 » » »
60 » » »

SOME EFFECTS OF TEMPERATURE IN WHEAT CONDITIONING

by

JOHN GEORGE MENTZOS

B. S., Agricultural College of Athens, Greece, 1948

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Flour and Feed Milling Industries

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1954

ABSTRACT

Experimental work in various countries has shown that heat applied on wheat during the conditioning process of milling or on flour causes some changes in the physicochemical properties of the flour. These changes can be detected by physical dough tests and by baking tests.

The possibility of using this effect of heat on wheat and flour to obtain improved baking quality of the flour is of economical importance in countries producing and having to use for bread making, wheats characterized as too weak for this use.

Several investigators have reported changes induced by heating wheat or flour, on properties of the flour such as: increase or decrease of the water absorption; decrease of dough extensibility; increase of resistance to extension of the dough; decrease of fermentation tolerance; inhibition of proteolytic activity; increase of the loaf volume of bread; and improvement in the quality of bread.

An investigation of applying dry heat during conditioning to three weak bread wheats, common in this country, was made.

The wheats were:

Soft Red Winter	12.1 per cent protein
Soft Red Winter	10.8 " " "
Hard Red Winter	10.5 " " "

The wheat samples were tempered to 15.5 and 16.5 per cent moisture content and then they were heated at 45, 60, and 75° C for 30, 45, and 60 minutes in a hot air oven. They were then spread

out to cool and dry before milling on Buhler experimental mill. Each heat treated sample of wheat was tested for hardness with a Brabender hardness tester. Also, the flours from these wheats were tested for the following properties:

1. Water absorption.
2. Mixing characteristics.
3. Extensibility and related physical properties of dough.
4. Ash and protein content of the flour.
5. General baking value of the flour for bread.

The moisture content variation in the heat treated samples was the predominant factor affecting the results of the hardness test. If the heat treatment has any effect on the hardness of the wheat this could not be detected.

The slight heat treatment increased the water absorption in the high protein soft red winter and the hard red winter wheat flours from one to three per cent. More severe treatment decreased the absorption progressively. The absorption of the low protein soft red winter wheat flours was decreased.

The Valorimeter value and the time required for maximum dough development measured on the farinograms showed enough difference in bread making value of the three wheats but did not show the changes in value between the treated samples of the same wheat.

The extensibility of the dough was not changed remarkably in any of the treated samples. There was no adequate positive correlation between Extensograph test values and the corresponding baking test values. This was especially true in the hard red winter and the low protein soft red winter wheats.

No trend of relationship was found between the amount of the heat treatment and the ash and the protein content of the flour.

The heat treatment particularly was beneficial to the baking quality of the high protein soft red winter wheat. Increase in volume and improvement in grain and texture was noticed in the more severely treated samples of the series. A more severe treatment might bring about a greater improvement in bread quality, but it is very probable that the water absorption of the flour would be more decreased.

The slightly treated samples of the hard red winter wheat showed some improvement in the bread making quality. The more severely treated samples were harmed.

The low protein soft red winter wheat did not show any change in bread quality. Since its low water absorption was even more decreased by the treatment, it should be concluded that the treatment was harmful to this wheat.

If the improvement in quality of bread with an increasing amount of treatment is accompanied by progressive decreases in absorption as in the case of the high protein soft red winter wheat, it is questionable whether or not heat treatment should be used extensively to improve the quality.