Effect on Wheat Quality of Air Flow and Temperatures In Mechanical Dryers

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Due to unfavorable weather conditions during harvesting, much of the grain produced in the Canadian Prairie Region must be dried before storing. Much grain damage may result if proper drying procedures and conditions are not used. Most wheat grown in this region is processed for milling and baking; therefore, the related quality factors are important when drying wheat.

Much research has been conducted in the past on drying cereal grains, but most of this work was on corn. Limited work has been done with Hard Red Spring and Durum wheats which are grown extensively in North Dakota, usually using air flow rates below 100 CFM (cubic feet per minute) per square foot (1). With larger capacity dryers on the market today, air flow rates in the 100 to 150 CFM per square foot range are common. At the lower air flow rates, the maximum recommended temperatures were: 100°F, for seed grain, 130 to 150°F, for milling, and 160 to 180°F for animal feed (4,5). Variation in temperatures for wheat used in milling was due to different researchers' investigations, and the use of various varieties of wheat.

The importance of initial moisture content was noted from recommendations by the Malt Product Manufacturers in England. For wheat having a moisture content greater than 24 per cent, 110°F was recommended, and for wheat having a moisture content less than 24 per cent, 120°F was the recommended temperature (3). In the past, studies did not evaluate the effect on wheat quality of the air flow rate while drying, and very limited work has

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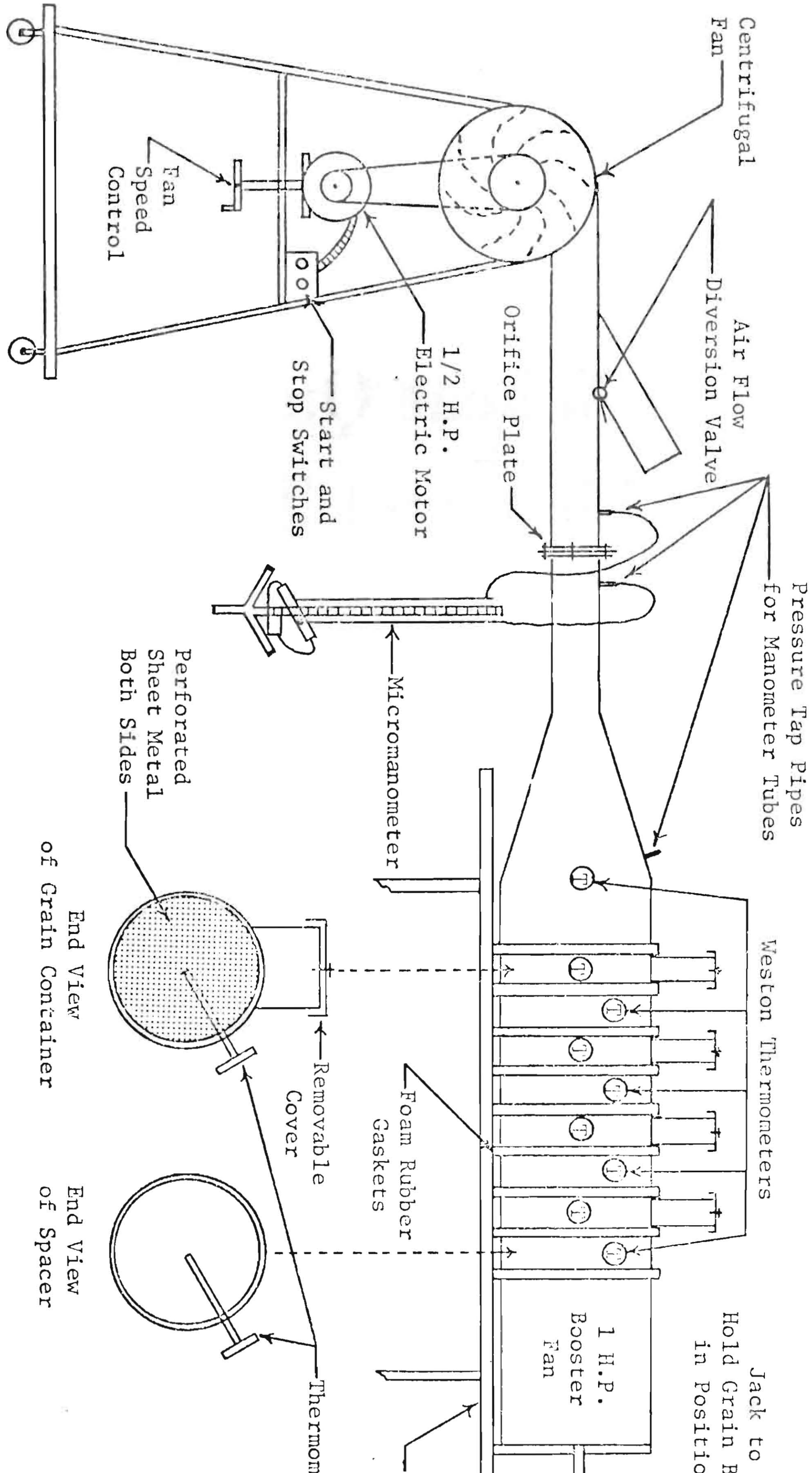

Figure 1. Experimental Grain Dryer with Accessories

been done on drying wheats with various initial moisture content.

Objective of this study conducted by the Agricultural Engineering Department at the North Dakota Agricultural Experiment Station, Fargo was to determine the effects of air velocity and temperature while drying on the milling and baking qualities of Hard Red Spring wheat. Included in this study were the drying effects resulting at various initial moisture content levels. Effects of these drying parameters on the milling and macaroni processing qualities of Durum wheat were also investigated, but the results have not been analyzed. Milling and baking qualities investigated in the study included per cent flour extracted, mixing quality, bread loaf volume and bread crumb color. Per cent germination was also analyzed.

HARD RED SPRING WHEAT STUDY

Equipment and Procedures

For the Hard Red Spring wheat studies, tests were designed to cover the range of drying parameters commonly available on most commercial dryers. Levels of air flow studied were 50, 100 and 150 CFM per square foot, which covered the range of air flow rates of most commercial batch and continuous flow dryers presently on the market. To cover the drying temperature range which is available to the dryer operators, the following levels of temperature were studied: 120, 140, 160 and 180°F. Moisture content levels of 16, 20 and 24 per cent, wet basis, were investigated. This covered the range of moisture contents at which wheat may be harvested in North Dakota.

No specific variety of Hard Red Spring wheat was used, but a mixture of common varieties was recommended by the cereal technologists. For the results presented here, the mixture of wheat was wetted to obtain the desired moisture content. Another series of tests was conducted using grain harvested at the desired moisture contents, but the results were the same as the wetted grain (2).

Wheat samples weighing 50 pounds were dried in a small experimental heated air batch dryer shown in Figure 1. The dryer was supplied by the Hart Carter Co., Minneapolis, Minnesota. Heat was supplied by a propane burner located at the air intake of the centrifugal fan. The heated air leaving the fan passed through a four-inch pipe to the drying bed. An orifice plate was installed in the four-inch pipe. Air pressure drop across the plate was measured with a liquid manometer and used to determine and adjust the air flow rate. By changing the pitch diameter of the pulley on the fan, the speed of the centrifugal fan could be varied to adjust the air flow rate to the desired level. An axial flow fan was installed on the air outlet of the drying bed to help maintain the higher flow rate.

The grain sample being dried was split between four identical containers, which were two-inch long cylinders having a cross sectional area of one square foot. Ends of the cylinders were covered with perforated sheet metal which permitted air flow through the cylinder. The drying bed consisted of these four containers filled with wheat and four cylindrical spacers, two inches long. Containers and spacers were alternated to form the drying bed. Strips of foam rubber were placed between containers and spacers to prevent any air loss. The resultant grain depth parallel to air flow was eight inches. With this arrangement each two-inch layer could be evaluated separately. As shown in Figure 1, thermometers were placed in each container and spacer. Samples were dried to the 12 to 13 per cent moisture content range.

After the samples were dried, subsamples were taken for the germination tests, moisture content determinations and baking quality evaluations. Germination tests were conducted by the North Dakota State Seed Laboratory using their standard procedures for per cent germination evaluation. A commercial grain moisture meter was used to determine the moisture content, wet basis. The subsample used for baking quality evaluation was milled to flour and per cent flour extracted was determined. A mixograph was used to mix this flour and other ingredients for making bread dough. Mixing time was recorded and dough elasticity was determined. The dough was then baked into loaves, and loaf volume and crumb color were determined using standard methods. Baking quality determinations were made by cereal technologists at North Dakota State University.

Three replicates of each test were conducted to obtain an indication of experimental error. The resultant data were statistically analyzed using the "F" test to determine the effect of temperature, air flow and initial moisture content.

Results

In the following discussion, the data presented will be the average of the three replicates. In the analysis of variance, the effects of the drying variables and their interactions were analyzed to determine what significant detrimental effects were present.

Results of the germination evaluations for all test conditions are listed in Table 1. Based on the statistical analysis, the effects of the three drying parameters were significant. Observing Table 1 at

16 per cent mosture, the effects of air flow and drying temperature do not appear to affect per cent germination. For the 20 and 24 per cent moistures, the effects are apparent at the higher temperatures. A reduction in per cent germination was evident at 160°F with the initial moisture at 20 per cent and an air flow rate of 150 CFM/ft². For 180°F and 20 per cent moisture, damage to germination existed at all air flow rates. At 24 per cent moisture, reduction in germination was noted at 140°F for 150 CFM/ft², and at 160°F and 180°F for all air flow rates. Damage increased with increased air flow rate. Maximum damage occurred at the highest level for all three parameters.

Table 1. Average germination in per cent, for Hard Red Spring Wheat.

Air Flow CFM/ FT²	Drying Temperature Degrees Fahrenheit Control	120	140	160	180
	initial moisture content 16 per cent				
50	95.12	95.25	90.33	95.17	91.50
100	94.08	94.00	92.17	94.17	76.83
150	94.67	91.67	92.33	95.50	92.83
	initial moisture content 20 per cent				
50	93.17	96.33	94.67	95.83	63.67
100	93.04	95.00	96.17	93.17	43.67
150	91.12	97.00	94.50	89.83	14.33
	initial moisture content 24 per cent				
50	82.96	93.00	92.33	85.67	50.00
100	83.46	83.00	87.33	81.33	24.00
150	81.73	90.50	81.00	61.83	7.50

For the flour extraction values, per cent, listed in Table 2, no major trends or effects could be established even though the statistical analysis indicated significant effects due to initial moisture content.

Table 2. Average flour extraction, in per cent, for Hard Red Spring Wheat.

Air Flow CFM/ FT²	Initial Moisture Per Cent	Control	Drying Temperature Degrees Fahrenheit 120	140	160	180
50	16	57.97	60.52	56.07	57.67	53.97
50	20	57.75	59.00	55.13	54.93	57.53
50	24	56.00	51.70	53.13	57.53	50.50
100	16	57.30	58.43	54.63	58.30	57.93
100	20	58.53	57.60	57.80	55.63	57.10
100	24	56.83	56.40	55.90	56.43	56.85
150	16	56.90	58.07	57.03	56.23	58.53
150	20	57.32	56.97	57.40	55.57	56.30
150	24	57.68	54.40	54.37	53.37	57.45

Mixing quality scores were determined by cereal technologists, based on the following grades:

1. No change from standard control (excellent).
2. Some change from the standard control (some damage).
3. Extreme change from the standard control (severely damaged).

A mixing quality of two or three is considered to be unacceptable by commercial flour millers.

Based on the statistical analysis, the air flow rate did not significantly affect the mixing quality, but temperature and moisture content had a significant effect. Observing the results of the mixing quality scores in Table 3, no apparent damage occurred at 120°F and 140°F. At 180°F, damage occurred for all moisture levels and all air flow rates. At 160°F, no reduction in mixing quality scores resulted at the 16 per cent moisture, but damage was noted at the 20 and 24 moisture levels.

Table 3. Average mixing quality scores for Hard Red Spring Wheat.

Air Flow CFM/ FT²	Initial Moisture Per Cent	Mixing Quality Score[1] Control	Drying Temperature Degrees Fahrenheit 120	140	160	180
50	16	1.00	1.00	1.33	1.00	3.00
50	20	1.00	1.00	1.67	1.67	3.00
50	24	1.00	1.00	1.00	1.67	3.00
100	16	1.00	1.00	1.00	1.00	3.00
100	20	1.00	1.00	1.00	2.33	3.00
100	24	1.00	1.00	1.00	2.33	3.00
150	16	1.00	1.00	1.00	1.00	2.33
150	20	1.00	1.00	1.00	1.33	3.00
150	24	1.00	1.00	1.00	3.00	3.00

[1]1.00 equals Excellent, 2.00 equals Some Damage, 3.00 equals Severely Damaged.

Bread loaves were baked and tested for the 50 and 150 CFM/ft² flow rates only. Results for the bread loaf volumes, Table 4, were varied with a slight volume increase with temperature increase at the 16 per cent moisture and a volume decrease with temperature increase at the 20 and 24 per cent levels. Volume decreases were large at the 150 CFM/ft², with the greatest reduction at 24 per cent moisture and 180°F.

Crumb color number indicated the internal cell color. A low number indicated a dull white color which was undesirable and the high number was desirable. A standard value of 100 was used for the control value. Results of the crumb color evalu-

Table 4. Average Loaf Volumes for Hard Red Spring Wheat.

Air Flow CFM/ FT²	Initial Moisture Per Cent	Loaf Volume CC Control	Drying Temperature Degrees Fahrenheit 120	140	160	180
50	16	925	900	945	980	940
50	20	925	965	990	985	950
50	24	925	965	980	1000	920
150	16	925	875	985	990	960
150	20	925	1005	1025	970	915
150	24	925	1015	1020	930	745

ation, listed in Table 5, appeared to be erratic, and no conclusions were drawn pertaining to the effects of the drying parameters.

Table 5. Average Crumb Color Values for Hard Red Spring Wheat.

Air Flow CFM/ FT²	Initial Moisture Per Cent	Crumb Color Value* Control	Drying Temperature Degrees Fahrenheit 120	140	160	180
50	16	100	100	100	100	97
50	20	100	99	98	99	98
50	24	100	104	102	101	104
150	16	100	98	97	97	99
150	20	100	100	97	96	100
150	24	100	102	101	102	101

*100 equals Excellent Crumb Color Rating

DURUM STUDY

Durum wheat that had been harvested wet and dried was processed by the Department of Cereal Chemistry and Technology. The grain was combined from the field at 18 per cent moisture and 20 per cent moisture. A third batch of grain was combined from the same field about a month later. This weathered grain was at about 17 per cent moisture when harvested.

Samples processed from each batch of grain were dried under the following conditions:

A. Drying air temperatures of 180°F, 200°F, and 220°F.

B. Air flows used (cubic feet per minute per square foot of dryer area) 50, 100 and 150.

Selected samples were processed into semolina and spaghetti at the Department of Cereal Chemistry and Technology. The data obtained is still being analyzed. Some of the findings thus far are:

1. Semolina yield appears to be higher at a given drying temperature when the dryer air flow is increased.
2. With higher drying temperatures, the percentages of specks in the processed semolina increases (increase in specks results in a lowering of semolina quality).
3. The cooking quality of the spaghetti decreases as the drying air temperature increases. The two main cooking factors are:
   a. Cooking loss (low loss desirable).
   b. Cooking firmness. This is a very important factor in the appeal and palatability of the spaghetti. Durum dried at high temperatures yield a spaghetti that is mushy and lacks firmness.
4. The data indicate that within the limits of the drying tests, some damage occurred that decreases the quality of the final product even at the lower temperatures and air flows.

Results of these tests are being analyzed further to determine the practical limits of temperatures and air flows to use in drying Durum to obtain the optimum quality.

SUMMARY OF BOTH STUDIES

Temperatures at which milling and baking damage became apparent for Hard Red Spring wheat were 160°F for 16 per cent initial moisture, 140°F for 20 per cent initial moisture, and 120°F for 24 per cent initial moisture. These values are for air flow rates of 100-150 CFM/ft². The safe drying air temperatures should be reduced 10°F to 15°F for a flow rate of 50 CFM/ft² to preserve the grain quality, because the wheat is exposed to the drying air for a longer period of time. At high moisture content, such as 24 per cent, drying time lengthened and much damage was sustained at drying temperatures above 160°F. In all cases, grain nearest the heat source was most severely damaged. For Durum wheat, damage due to temperature resulted in a reduction of semolina yield and quality. Further analysis is required before recommending specific temperatures.

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