ADJUSTMENT OF RHEOLOGICAL PROPERTIES OF FLOURS BY FINE GRINDING AND AIR CLASSIFICATION[1]

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ABSTRACT

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Two hard red spring (HRS) wheat varieties (Era and Red River 68) were milled on our pilot mill to obtain individual flour streams. Several selected flour streams were pin milled and air-classified to give flour fractions with high, medium, and low protein contents. Protein contents, ash contents, and mixograms were obtained on the flour streams and air-classified fractions. Flour blends or "managed-flours" were made to manipulate flour-water absorption and dough rheological properties for each variety. Mixograms and farinograms were determined on each of the managed-flours. For both varieties, the blend with the highest protein content and lowest percentage extraction showed the most desirable improvement over the respective straight-grade flour blends. The data showed that rheological responses of the managed-flours from the two varieties differed. Any improvements in the flour-water absorption and dough properties were accompanied by a decrease in total flour extraction of the blends, although protein content was not necessarily lower.

Semidwarf varieties of hard red spring (HRS) wheat often exhibit better agronomic traits than conventional-height varieties. Some semidwarf varieties, however, have decreased utilization potential because of excessive rheological variability and inferior end-product quality.

Protein content and composition have a major influence on rheological and baking quality. Some evidence of the importance of those factors was reported by Nelson and Loving (1), who used flour stream selection to manipulate soft wheat flour blends for use in specific end products.

The process of air classification used to shift flour protein for various reasons has been studied by several workers, including Gracza (2) and Peplinski *et al.* (3,4). Bode *et al.* (5) used high-protein (25.2 to 26.3%) air-classified fractions of hard and soft wheat flour to fortify an experimentally milled, straight-grade flour of 10.9% protein content. The fortified blends yielded doughs with greater elasticity, absorption, and loaf volume than the unfortified flours.

Wichser (6) demonstrated differences in baking quality of various air-classified fractions removed from conventionally milled hard winter wheat bread flour. Each fraction exhibited optimum baking in either bread or layer and angel cakes.

In a pin milling and air-classification study of Kansas hard red winter wheat flours from five separate varieties, Bean *et al.* (7) added high-protein fraction

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(HPF) to three base flours (9.4 to 10.6% protein) to give blends containing 12.0% protein. Dough and bread properties of the blends were significantly influenced by the HPF, the base flour, and the method of obtaining the HPF.

Hayashi (8) recently showed rheological and baking differences for three individual air-classified fractions from pilot-milled flour streams of four spring wheat varieties. He also studied the cookie, layer cake, and bread-baking potential of these fractions after blending each fraction with either wheat starch or vital gluten to yield a specific flour protein content. The addition of starch to reduce the protein level improved cake-baking and increased the spread factor of cookies, but did not improve bread-baking characteristics. The addition of vital gluten to increase the protein level improved the quality of the bread and the baking performance.

Although considerable information is available on air classification of straight-grade flours, little has been published about the effect of air classification on the rheological properties of individual flour streams. It would be useful to investigate the air classification of only a few pilot-milled streams for recombination with the remaining pilot streams included in the straight-grade flour, rather than air-classifying the entire straight-grade flour.

The purpose of this study was to determine the rheological pattern and flour-water absorption of individual air-classified fractions from pilot-milled flour streams, and to evaluate these fractions as to their influence on the flour-water absorption and rheological properties of a manipulated flour blend (MFB) or a "managed-flour" of a specific milling extraction.

MATERIALS AND METHODS

Wheat Samples

Two varieties (Era and Red River 68) of HRS wheat grown at the North Dakota State University seed farm at Casselton were selected because they represented a range in flour-water absorption, dough properties, and baking characteristics.

Roller Milling

The two varieties of wheat were milled into 20 separate mill streams (3 feed streams and 17 flour streams) on a fifty-five hundred-weight (55-cwt) pilot mill (Buhler-Miag Co., Minneapolis, Minn.) according to established procedures (9,10). Flour streams were combined in proportions to give a straight-grade flour blend that was used as a reference for each variety. Eight flour streams were collected for each variety: three middling flour streams (1M, 2M, 4M), three break flour streams (1B, 4B, 5B), the break dust flour stream (BD), and the tailings flour stream (T). The remaining nine flour streams were blended together and used as a base "pilot mill blend" (PMB) for the MFB.

Pin Milling and Air Classification

Each stream was pin milled on an Alpine Kolloplex Laboratory Model 160Z Mill (Alpine American Corp., Natick, Mass.) at 14,000 rpm, then air-classified into three fractions on an Alpine Microplex 132 MP air-classifier. The three fractions were designated as F-1 (first cut, high-protein, fine fraction), F-2 (second cut, low-protein, fine fraction), and C-2 (second cut, intermediate-protein, coarse fraction). The air-classification flow diagram is shown in Fig. 1. In addition, some of the 1M, C-2 fraction was pin milled and air-classified to yield flour fractions F-3 (third cut, high-protein, fine fraction) and C-3 (third cut, intermediate-protein, coarse fraction). Mixogram, average particle size, protein content, and ash content were determined for each fraction.

Particle Size

The average particle size of the pin milled fractions from air classification was determined on a Fisher Sub-Sieve Sizer (Fisher Scientific Instruments, Chicago, Ill.).

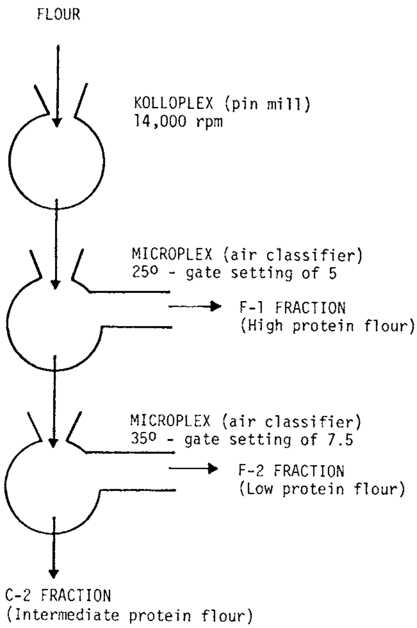

Fig. 1. Schematic flow diagram of air classification.

TABLE I
Physical and Analytical Data for Wheats

Variety	Test Weight lb/bu	1000-Kernel Weight g	Kernel Size[a] Lg. %	Med. %	Sm. %	Ash[b] %	Protein[b] %
Era	61.6	32.9	58	41	1	1.44	12.9
Red River 68	60.2	31.4	31	67	2	1.55	14.4

[a]Large kernels, over a Tyler No. 7 sieve with a 2.92-mm opening; medium kernels, over a Tyler No. 9 sieve with a 2.24-mm opening; and small kernels, over a Tyler No. 12 sieve with a 1.65-mm opening.
[b]14% Moisture basis.

Analytical Methods

Approved AACC methods (11) were used for ash content (Method 08-01), Kjeldahl protein (N × 5.7; Method 46-11), and farinogram (80 g constant dough weight; Method 54-21) determinations. Ash and protein were calculated on a 14% moisture basis.

Each mixogram, except for those of the unusually high absorption streams and fractions, was determined with 30 g of flour, 20 ml of water, and a spring setting of 10. With the high-protein fractions, more water often had to be added to keep the mixing curve on the chart recording paper. Absorptions reported were adjusted according to mixogram curve height.

RESULTS AND DISCUSSION

The data for the wheat samples are given in Table I. There was a difference of 1.5% protein between the two wheat varieties.

The analytical and physical data for the individual flour streams and the straight-grade flours are given in Table II. The data varied widely between varieties and among individual flour streams of a single variety. The wide range in results was desired to help show the influence of flour streams from different parts of the wheat kernel.

From the mass of data collected from the air-classified flour fractions, we selected data for streams 1M and 5B to show the relative extremes for protein, ash, mixing length, and flour-water absorption (Era, Table III, and Red River 68, Table IV).

TABLE II
Flour Stream Analysis

					Mixograph		Farinograph	
Variety	Stream	Ext.[a] %	Ash[b] %	Protein[b] %	Peak cm	Abs.[b] %	Peak time min	Abs.[b] %
Era	1B	1.4	0.584	13.2	6.8	61.3	5.5	59.2
Era	BD	2.3	0.463	11.8	6.7	60.0	5.0	59.4
Era	4B	2.2	0.555	16.2	10.4	65.2	9.5	64.1
Era	5B	1.6	0.839	19.6	10.0	73.3	7.0	71.8
Era	1M	12.8	0.296	10.8	7.5	57.9	6.0	59.7
Era	2M	7.6	0.342	12.0	8.5	59.2	5.0	60.2
Era	4M	9.3	0.337	11.1	7.4	56.8	4.5	63.4
Era	T	3.2	0.618	11.7	7.2	59.4	3.0	64.0
Era	S.G.[c]	77.2	0.427	12.1	6.1	58.7	5.0	60.8
Red River 68	1B	1.3	0.554	14.5	13.7	63.4	13.5	61.9
Red River 68	BD	2.1	0.454	13.2	13.6	61.5	13.5	61.5
Red River 68	4B	1.8	0.513	18.5	24.2	76.2	16.0	67.3
Red River 68	5B	1.5	0.778	21.9	27.9	90.7	11.0	75.4
Red River 68	1M	13.4	0.296	12.6	15.2	59.8	14.5	62.5
Red River 68	2M	7.9	0.352	14.0	15.4	63.5	16.5	63.7
Red River 68	4M	9.8	0.356	13.6	13.7	63.9	17.0	63.8
Red River 68	T	3.1	0.537	13.8	11.6	63.6	7.5	65.8
Red River 68	S.G.[c]	77.0	0.451	14.0	11.8	64.3	14.0	62.0

[a]Percentage extraction on total products basis.
[b]14% Moisture basis.
[c]Straight-grade flour.

The fraction of smallest particle size (F-1) gave the lowest yield and average particle size, and the highest ash content, protein content, and mixograph absorption of the three fractions (F-1, F-2, C-2), regardless of flour stream or wheat variety. Comparison of 1M and 5B fractions of both varieties showed that 1M fractions had relatively less spread in protein content, ash content, mixograph peak length, and mixograph absorption among the fractions, but exhibited a somewhat larger average particle size and a greater degree of protein

TABLE III
Analytical and Physical Data of Air-Classified Flour Streams for Era

Stream	Fraction	Yield[a] %	Ash[b] %	Protein[b] %	Particle Size μ	Mixograph Peak cm	Mixograph Abs.[b] %	Protein Shift[c] %
1M	F_1	9.8	0.538	16.3	3.8	7.2	71.5	...
1M	F_2	32.0	0.292	8.5	11.9	6.0	50.2	...
1M	C_2	58.2	0.260	11.3	30.4	7.1	54.4	...
1M	Calc.[d]	100.0	0.297	10.9	...	...	...	7.3
1M	Orig.[e]	...	0.296	10.8	...	7.5	57.9	...
5B	F_1	9.2	2.165	23.3	3.8	9.6	98.2	...
5B	F_2	26.0	0.957	14.8	9.8	8.9	64.5	...
5B	C_2	64.8	0.547	20.7	25.6	15.0	84.2	...
5B	Calc.[d]	100.0	0.802	19.4	...	...	...	5.9
5B	Orig.[e]	...	0.839	19.6	...	10.0	73.3	...

[a]Percentage yield on total products basis.
[b]14% Moisture basis.
[c]Expressed as a percentage of the total protein present in the original flour.
[d]Calculated by accumulating results proportional to the individual fractions.
[e]Original flour before air classification.

TABLE IV
Analytical and Physical Data of Air-Classified Flour Streams for Red River 68

Stream	Fraction	Yield[a] %	Ash[b] %	Protein[b] %	Particle Size μ	Mixograph Peak cm	Mixograph Abs.[b] %	Protein Shift[c] %
1M	F_1	12.4	0.553	18.1	3.7	14.6	73.0	...
1M	F_2	31.7	0.308	9.4	12.6	14.4	53.9	...
1M	C_2	55.9	0.295	13.8	28.2	12.4	59.6	...
1M	Calc.[d]	100.0	0.331	12.9	...	...	...	9.4
1M	Orig.[e]	13.4	0.296	12.6	...	15.2	59.8	...
5B	F_1	13.3	1.826	24.5	3.5	14.4	101.9	...
5B	F_2	16.9	0.918	14.7	9.2	12.7	60.9	...
5B	C_2	69.8	0.596	23.2	23.0	39.8	92.9	...
5B	Calc.[d]	100.0	0.814	21.9	...	...	...	5.7
5B	Orig.[e]	1.5	0.778	21.9	...	27.9	90.7	...

[a]Percentage yield on total products basis.
[b]14% Moisture basis.
[c]Expressed as a percentage of the total protein present in the original flour.
[d]Calculated by accumulating results proportional to the individual fractions.
[e]Original flour before air classification.

shifting than the 5B fraction. Also, Red River 68 had a relatively greater protein shift than Era in the 1M fraction.

Differences for protein content, mixograph peak length, and mixograph absorption of the air-classified fractions were relative to those of the original streams (1M, 5B) within a variety, with the exception of the 5B, F-2 fraction where Era yielded essentially the same protein content and 3.6% higher mixograph absorption than Red River 68.

Individual mill streams and air-classified fractions were evaluated for absorption, rheological properties, and protein content relative to the values obtained for the original straight-grade flour. Based on these comparisons with the straight-grade flour, selected mill streams and air-classified fractions were blended with the PMB. In selecting the flour streams and fractions, emphasis was placed on manipulation of absorption and mixing peak length of the MFB without particular regard to the amount of each stream or fraction obtained originally. Contents of MFBs are given in Table V.

For Era, the purpose was to increase the flour-water absorption and maintain or slightly increase the mixing length. Conversely, the goal for Red River 68 was to maintain or increase the flour-water absorption and decrease the mixing length.

After MFBs were made, values were calculated for mixograph peak length and mixograph absorption by accumulating results proportional to the percentage extraction of PMB, individual flour streams, and air-classified fractions within each of the eight MFBs. In addition, actual analyses were made for ash content, protein content, mixograms, and farinograms. The data for the calculated and actual values are given in Table VI.

Although the calculated values for the MFBs did not always appear to be an improvement over the values for the straight-grade flours, we hoped that the actual performance of each blend would show the desired improvement.

The data show varietal differences between calculated and actual mixing length and absorption (Table VI). Both mixing length and flour-water absorption showed desirable responses in all blends of Era, except blends No. 1 and No. 2, for which mixograph absorptions were less than for the straight-grade flour. However, the absorptions were greater for these two blends than for the straight-grade flour when comparisons were made on the farinograph, which is a better controlled instrument than the mixograph. The increase in farinograph absorption of the blends compared to the straight-grade flour for Era ranged from 0.8% for blend No. 3 to 2.2% for blend No. 4.

Red River 68 was not nearly as responsive to manipulation as Era. In all cases but one (mixograph peak length of blend No. 4), the actual blends did not give the anticipated responses. This lack of response was no doubt due to the abnormal, strong gluten characteristics of the wheat. The farinograph data showed the desired reduction of peak time in three of the four blends, and increased absorption in one of these three blends, but the improvement was not nearly as large as we had hoped. Although the relation between calculated and actual absorptions was somewhat parallel, the calculated value was always much higher than the actual absorption of the Red River 68 blends.

For both varieties, the blend with the highest protein content and the lowest percentage extraction showed the most desirable improvement over the respective straight-grade flour blends; this response was not unexpected. It was

TABLE V
Contents of Manipulated Flour Blends

Stream	Fraction	Era Extraction[a] %	Era Blend No. 1	Era Blend No. 2	Era Blend No. 3	Era Blend No. 4	Red River 68 Extraction[a] %	Red River 68 Blend No. 1	Red River 68 Blend No. 2	Red River 68 Blend No. 3	Red River 68 Blend No. 4
1B	Unfractionated	1.4	...	...	X	...	1.3	X	X	X	...
	F-1	0.2	X	X	...	X	0.2	...	...	...	X
	F-2	0.4	...	...	...	...	0.4	...	...	...	X
	C-2	0.8	X	X	...	X	0.7	...	...	...	...
BD	Unfractionated	2.3	...	...	X	...	2.1	X	X	X	X
	F-1	0.2	X	X	...	X	0.2	...	...	...	...
	F-2	0.7	...	...	...	...	0.7	...	...	...	...
	C-2	1.4	X	X	...	X	1.2	...	...	...	...
4B	Unfractionated	2.2	...	X	X	X	1.8	X	...	X	...
	F-1	0.2	X	...	...	...	0.2	...	X	...	...
	F-2	0.6	...	...	...	...	0.5	...	X	...	X
	C-2	1.4	X	...	...	...	1.1	...	...	...	...
5B	Unfractionated	1.6	...	X	X	X	1.5	X	...	X	...
	F-1	0.2	X	...	...	...	0.2	...	...	...	...
	F-2	0.4	...	...	...	...	0.3	...	X	...	X
	C-2	1.0	X	...	...	...	1.0	...	...	...	...
1M	Unfractionated	12.8	...	...	...	...	13.4	...	...	...	...
	F-1	1.3	X	X	X	X	1.6	X	...	X	...
	F-2	4.1	...	...	...	...	4.3	...	X	X	X[b]
	C-2	7.4	X	X	...	...	7.5	...	X	...	...
	F-3[c]	0.7	...	...	...	X	0.5	...	...	...	...
	C-3[c]	6.7	...	...	...	...	7.0	...	...	...	X
2M	Unfractionated	7.6	...	...	X	...	7.9	X	...	X	...
	F-1	0.8	X	X	...	X	1.1	...	...	...	...
	F-2	2.3	...	...	...	...	2.5	...	X	...	X
	C-2	4.5	X	X	...	X	4.3	...	X	...	X
4M	Unfractionated	9.3	...	...	X	...	9.8	X	...	X	...
	F-1	1.0	X	X	...	X	1.4	...	...	...	...
	F-2	2.9	...	...	...	...	3.0	...	X	...	X
	C-2	5.4	X	X	...	X	5.4	...	X	...	X

TABLE V, *Continued*
Contents of Manipulated Flour Blends

Stream	Fraction	Era Extraction[a] %	Era Blend No. 1	Era Blend No. 2	Era Blend No. 3	Era Blend No. 4	Red River 68 Extraction[a] %	Red River 68 Blend No. 1	Red River 68 Blend No. 2	Red River 68 Blend No. 3	Red River 68 Blend No. 4
T	Unfractionated	3.2	...	...	X	...	3.1	X	X	X	X
	F-1	0.3	X	X	...	X	0.3	...	...	...	...
	F-2	0.8	...	...	...	...	0.7	...	...	...	...
	C-2	2.1	X	X	...	X	2.1	...	...	...	...
PMB[d]	Unfractionated	36.8	X	X	X	X	36.1	X	X	X	X
Total extraction, %		77.2	65.0	66.0	65.7	59.3	77.0	65.2	70.6	69.5	65.2

[a]Percentage yield on total products basis.
[b]To obtain a flour extraction equal to Red River 68 No. 1 blend, only part of this fraction was used.
[c]Since the F-3 and C-3 fractions were obtained from the C-2 fraction, they were not considered part of the total extraction when the C-2 fraction was included in a flour blend.
[d]A "pilot mill blend" was comprised of the pilot-milled flour streams which were not to be investigated as individual streams.

TABLE VI
Analytical and Physical Data of Manipulated Flour Blends

Flour Blend	Ext.[a] %	Ash[b] %	Protein[b] %	Mixograph Absorption[b] Calc.[c] %	Mixograph Absorption[b] Act.[d] %	Mixograph Peak length Calc.[c] cm	Mixograph Peak length Act.[d] cm	Farinograph Absorption[b] %	Farinograph Peak length min
Era No. 1	65.0	0.433	12.5	59.7	58.4	6.1	7.0	62.2	5.0
Era No. 2	66.0	0.443	12.6	59.5	58.0	6.3	6.8	61.9	6.0
Era No. 3	65.7	0.464	12.4	59.3	59.4	6.3	6.5	61.6	5.0
Era No. 4	59.3	0.454	12.9	60.5	59.5	6.1	7.2	63.0	6.0
Era S.G.[e]	77.2	0.427	12.1	...	58.7	...	6.1	60.8	5.0
Red River 68 No. 1	65.2	0.484	14.4	66.3	62.7	12.4	12.7	62.5	12.0
Red River 68 No. 2	70.6	0.426	13.5	63.2	60.9	11.5	12.4	61.1	12.5
Red River 68 No. 3	69.5	0.463	14.1	65.5	62.0	12.4	12.4	62.1	14.5
Red River 68 No. 4	65.2	0.435	13.7	64.9	60.4	10.5	11.7	61.7	12.5
Red River 68 S.G.[e]	77.0	0.451	14.0	...	64.4	...	11.8	62.1	14.0

[a]Percentage extraction on total products basis.
[b]14% Moisture basis.
[c]Calculated value obtained by accumulating results proportional to the percentage extraction of PMB, individual flour streams, and air-classified fractions which made up a given blend.
[d]Actual value obtained for each flour blend.
[e]Straight-grade flour.

surprising, however, that the Red River 68 blend (No. 1) with the highest protein content gave the lowest farinograph peak time.

This study showed that the rheological responses of the managed-flours from the two varieties differed. The correlation was highly significant between calculated mixograph absorption and actual farinograph absorption (Era, 0.995 and Red River 68, 0.991), but the slopes were different (Era, 1.14 and Red River 68, 0.45). Any improvements in the flour-water absorption and dough properties were accompanied by a decrease in total flour extraction of the blends, although protein content was not correspondingly lower.

Acknowledgments

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