BAKING STUDIES ON THE PIN-MILLED AND AIR-CLASSIFIED FLOUR FROM FOUR HARD RED SPRING WHEAT VARIETIES[1]

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ABSTRACT

Three flour streams (1M, 3M, and 2B) from four hard red spring wheat varieties, Red River 68, Chris, Era, and Pitic 62, were obtained from a pilot mill. By pin-milling and air classification, the streams were fractionated into high-, intermediate-, and low-protein fractions, F-1, C-2, and F-2, respectively. Pin-milling increased starch damage in the flour, and extent of damage increased as the particle size was reduced. Red River 68 showed strong properties throughout the study and produced poor baked products. The Chris variety baked the best bread, but made poor cookies and cakes. Era had intermediate strength and produced the best cookies. Pitic 62 displayed weak characteristics, but produced acceptable cakes. Coarse particle size fractions (unfractionated and C-2 fractions) were better than fine for bread and cookies. The F-1 fractions which gave bread of good volume with poor internal characteristics made unacceptable cakes and cookies. The F-2 fractions were good for cakes but poor for bread and cookies. Addition of starch to reduce the protein level improved cakes and increased the spread factor of cookies, but did not improve the bread-baking characteristics. Addition of vital gluten increased the protein level and improved bread quality.

Wheat, the raw material of the flour miller, may be classified basically into hard and soft types which generally contain the highest and lowest percentages of protein, respectively. Bread-type products require flours of higher protein content than flour for cookies, cakes, and pastries. Hard, high-protein wheats usually are the most expensive. It is well known that any miller can make good flour from good quality wheat. However, consistently obtaining high-quality wheat can be difficult. The success of the miller has depended on his ability to judge wheats economically and to blend a grist that will satisfy the customer and return a profit. The techniques of pin-milling and air classification may help the miller produce a certain type of flour for a particular use.

For many years, the milling industry has used air and centrifugal force to make separations. Graham (1) described the basic theory of air classification.

The responses of different wheats to pin-milling or to air classification have been examined by several workers (1–5). Wichser (6) mentioned that the parent flour, high-protein fines, and endosperm chunks were suitable for bread, and the low-protein fine fractions for angel food and layer cakes. Bean *et al.* (7,8) reported that bread and dough properties of the blends were significantly

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influenced by both the high-protein fraction and base flour, and that regrinding the parent flour reduced particle size and cookie diameter. Tipples and Kilborn (9) found that pin-milling increased the starch damage and permitted the use of higher baking absorption in short-time bread-baking procedures. However, there was little advantage in pin-milling flours for use in conventional baking methods, which involve several hours of bulk fermentation. Pence *et al.* (10) found that the quality of protein in high-protein fractions appeared to be the most important factor governing farinograph characteristics and baking performance. They reported also that most low-protein fractions contained too little protein to produce good cookies and cakes.

The purpose of this study was to investigate the baking properties (bread, cakes, and cookies) of pin-milled and air-classified hard red spring (HRS) wheat varieties. The four HRS wheat varieties of diverse milling, baking, and dough characteristics selected for the study were: Red River 68, Chris, Era, and Pitic 62. The varieties were milled on a pilot mill and three flour streams were selected: second break (2B), first midds (1M), and third midds (3M).

Although information is available on the baking properties of pin-milled and air-classified flours, the studies have been concerned primarily with wheat types other than HRS. Therefore, we wanted to determine whether pin-milling and air classification of conventional height and semidwarf HRS wheats of either acceptable or unacceptable quality might be useful in producing satisfactory baked products.

MATERIALS AND METHODS

Samples

The four HRS wheats were grown at the Agronomy Seed Farm at Casselton, N. Dak., in 1971. They were Red River 68, Chris, Era, and Pitic 62. Chris was a conventional-height variety and the others were semidwarfs.

Milling and Air Classification

Samples were milled on the pilot mill (1). Three streams (1M, 3M, and 2B) from each variety were pin-milled and air-classified into three fractions. They were fine-1 (F-1) (high-protein flour), fine-2 (F-2) (low-protein flour), and coarse-2 (C-2) (intermediate-protein flour) (12).

Starch Damage Analysis

Starch damage was determined colorimetrically (13) and was expressed in Farrand Equivalent Units (F.E.U.) by the use of a regression equation.

Physical Dough Testing

The farinograph with the 50-g small bowl was used to investigate the dough properties of the flour fractions by the constant-flour method (14). Dough properties were tested of the unfractionated flour, the pin-milled and air-classified fractions, and of blends of different protein levels prepared with either vital gluten or wheat starch.

Chlorination

For cake-baking, flour fractions were adjusted to pH 4.6–4.8 with chlorine gas.

Bread-Baking

For bread, the straight-dough baking procedure with a 3-hr fermentation was used. Bread was baked from the unfractionated, the pin-milled, and the air-classified flour fractions, and blends were also prepared using starch or vital gluten to adjust the protein level. The formula was:

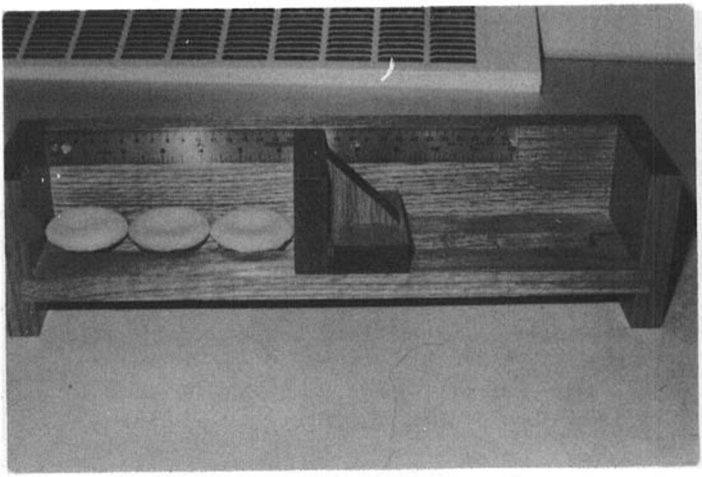

Fig. 1. Cookie-measuring device.

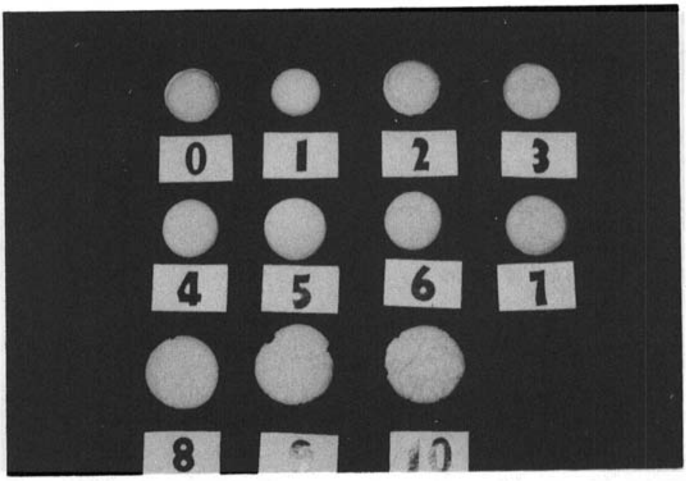

Fig. 2. Illustration of cookies used for scoring. Number 5 represents the most acceptable cookie; a higher number indicates excessive cracking, and a lower number, insufficient cracking.

Flour	100 g (14% mb)
Salt	2%
Sugar	5%
Shortening	3%
Yeast	3%
Water	Variable

Bread was judged for crust color, symmetry, break and shred, and crumb grain, texture, and color. Each factor was scored on a basis of 1 to 10 with a number 10 as the best possible score. The total bread score represented the sum of the six individual assessments.

Cake-Baking

The cake formula[4] was:

Flour (bleached)	100 g
Sugar	120%
Baking powder (double acting)	6%
Water	120%

Ingredients were mixed in a home-type Sears deluxe mixer (Sears Roebuck and Co., Chicago, Ill.) for 30 sec at low speed and 120 sec at medium speed. Batter (80 g) was placed into cake pans (3.5 in. diameter by 1 in. deep) lined with parchment paper, and baked 21 min at 375°F. Volume was measured by rapeseed displacement with the device used for measuring the volume of 100-g "pup" loaves. Cake quality was evaluated according to AACC Approved Methods (14).

Symmetry of the cake was scored on a scale from 0 to 10. A score of 5 was most acceptable; higher values indicated a peaked top, and lower values, a sunken center.

Two protein levels were used in cake-baking: the protein content of the original flour fraction, and a protein content of 8.7%, adjusted with either gluten or starch, which corresponded to commercial cake flour.

Cookie-Baking

The micro cookie-baking procedure III by Finney *et al.* (15) was used. The formula was:

Flour (unbleached)	100 g
Sugar	60%
Shortening	30%
Nonfat dry milk	3%
$NaHCO_3$	1%
NH_4HCO_3	0.75%
Salt	1%
Absorption[a]	Variable

[a]For flours without protein adjustment, absorption was equal to the farinograph absorption minus 31.5%. For flours with protein adjusted to 10.3%, absorption was 22.5%.

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Two protein levels were used in the cookie-baking experiments: the protein content of the original flour fraction and a protein content adjusted with either gluten or starch to 10.3%, which corresponded to the commercial pastry flour.

The cookie cutter had a diameter of 3.9 cm, the cookie sheet measured 17.8 × 12.3 × 0.7 cm, and both were made of stainless steel.

Three cookies were made for each flour sample, and diameter and thickness were measured with the device shown in Fig. 1. A top grain score of 5 represented a highly acceptable cookie; higher numbers indicated excessive cracking, and lower numbers, insufficient cracking (Fig. 2).

RESULTS AND DISCUSSION

All three flour streams (1M, 3M, and 2B) and their fractions were baked by all three procedures. The bread-baking data are presented for the 3M flour because

TABLE I
Analytical Data

Variety	Stream	Fraction	Ash[a] %	Protein[a] %	Yield %
Red River 68	3M	Unfractionated	0.35	12.9	...
		F-1	0.61	18.6	11.7
		C-2	0.32	13.9	57.7
		F-2	0.34	9.9	30.6
Pitic 62	3M	Unfractionated	0.31	8.8	...
		F-1	0.53	20.6	24.4
		C-2	0.24	6.0	48.7
		F-2	0.25	5.8	26.9

[a]14.0% moisture basis.

TABLE II
Starch Damage Analysis[a]

Stream	Fraction	Variety			
		Red River 68	Chris	Era	Pitic 62
1M	Unfractionated	26.6	22.0	35.5	4.9
	F-1	65.6	74.7	120.7	12.6
	C-2	33.7	31.6	50.5	10.2
	F-2	75.6	65.1	101.7	13.6
3M	Unfractionated	28.8	25.1	40.8	7.3
	F-1	67.2	86.5	151.8	9.7
	C-2	35.2	33.8	52.9	9.6
	F-2	80.6	75.7	121.8	14.5
2B	Unfractionated	18.3	15.4	21.9	2.9
	F-1	46.2	52.9	81.2	7.7
	C-2	21.5	22.6	28.4	7.0
	F-2	46.9	51.8	80.0	9.5

[a]Farrand Equivalent Units (F.E.U.) expressed on a dry basis.

TABLE III
Farinograph Data for Flour Stream 3M

Variety	Fraction	Protein %	Absorption %	Mixing Time min	M.T.I. BU
Red River 68	Unfractionated	12.7	60.5	15.0	10
	F-1	18.6	97.1	46.0	0
	F-1 Blend	13.5	77.1	22.0	5
	F-1 Blend	11.0	72.4	3.0	15
	C-2	13.9	66.0	16.0	5
	C-2 Blend	13.5	65.4	15.0	15
	C-2 Blend	11.0	62.8	13.0	20
	F-2	9.9	63.3	3.0	20
	F-2 Blend	15.0	68.1	20.0	10
	F-2 Blend	13.5	66.3	17.5	10
	F-2 Blend	11.0	64.6	13.0	10
Chris	Unfractionated	11.8	61.8	6.5	20
	F-1	17.9	102.7	14.0	15
	F-1 Blend	13.5	86.7	9.0	20
	F-1 Blend	11.0	79.0	5.0	20
	C-2	12.9	67.5	6.0	10
	C-2 Blend	13.5	67.0	8.0	10
	C-2 Blend	11.0	62.1	5.0	30
	F-2	8.8	65.4	1.5	45
	F-2 Blend	15.0	68.8	13.0	5
	F-2 Blend	13.5	67.4	6.0	5
	F-2 Blend	11.0	66.0	2.0	25
Era	Unfractionated	10.9	59.2	4.0	35
	F-1	16.2	92.0	10.0	20
	F-1 Blend	13.5	85.5	8.0	10
	F-1 Blend	11.0	77.9	5.5	20
	C-2	11.2	61.2	8.0	15
	C-2 Blend	15.0	65.7	15.0	5
	C-2 Blend	13.5	63.5	12.0	10
	F-2	8.3	64.1	1.5	50
	F-2 Blend	15.0	68.8	15.0	0
	F-2 Blend	13.5	66.7	10.0	5
	F-2 Blend	11.0	65.5	1.8	45
Pitic 62	Unfractionated	8.8	56.1	2.2	60
	F-1	20.6	75.7	7.5	20
	F-1 Blend	13.5	63.5	4.5	50
	F-1 Blend	11.0	59.7	3.0	55
	C-2	6.0	57.4	1.0	110
	C-2 Blend	13.5	62.1	11.0	10
	C-2 Blend	11.0	59.6	6.0	15
	F-2	5.8	57.9	0.7	165
	F-2 Blend	15.0	61.0	10.0	10
	F-2 Blend	13.5	59.7	7.0	30
	F-2 Blend	11.0	58.8	1.0	65
Standard Flour		13.5	64.0	6.5	20

TABLE IV
Bread-Baking Data for Flour Stream 3M

Variety	Fraction	Protein %	Mixing Time min	Specific Volume cc/g	Total Bread Score
Red River 68	Unfractionated	12.9	8	6.73	59.0
	F-1	18.6	24	6.08	48.5
	F-1 Blend	13.5	16-1/2	5.44	47.0
	F-1 Blend	11.0	13-1/2	4.57	41.0
	C-2	13.9	8-1/2	6.41	52.5
	C-2 Blend	13.5	7	6.42	51.5
	C-2 Blend	11.0	6-1/2	5.82	48.0
	F-2	9.9	6-1/2	4.91	46.0
	F-2 Blend	15.0	11	5.80	52.0
	F-2 Blend	13.5	10-1/2	5.50	53.0
	F-2 Blend	11.0	9	5.09	48.0
Chris	Unfractionated	11.8	2-1/4	5.76	58.0
	F-1	17.8	9	5.94	52.5
	F-1 Blend	13.5	6	4.85	52.5
	F-1 Blend	11.0	5-1/2	4.44	50.5
	C-2	12.9	2-1/2	5.85	58.0
	C-2 Blend	13.5	2-1/4	5.69	58.5
	C-2 Blend	11.0	1-3/4	4.95	49.0
	F-2	8.8	2	4.41	46.5
	F-2 Blend	15.0	5	5.67	55.0
	F-2 Blend	13.5	4-1/4	5.50	53.0
	F-2 Blend	11.0	3	4.82	47.0
Era	Unfractionated	10.9	2-1/4	6.14	55.5
	F-1	16.2	10	5.74	51.0
	F-1 Blend	13.5	6-1/2	5.16	52.5
	F-1 Blend	11.0	6-1/2	4.52	42.0
	C-2	11.2	3	6.23	51.0
	C-2 Blend	15.0	4	6.52	52.0
	C-2 Blend	13.5	3-1/2	5.97	55.5
	F-2	8.3	3	4.82	50.0
	F-2 Blend	15.0	5-1/2	5.84	51.0
	F-2 Blend	13.5	4-1/2	5.69	52.5
	F-2 Blend	11.0	4-1/4	5.29	47.5
Pitic 62	Unfractionated	8.8	3/4	4.11	38.0
	F-1	20.6	1-1/2	4.47	37.5
	F-1 Blend	13.5	1	4.59	46.0
	F-1 Blend	11.0	3/4	4.20	45.0
	C-2	6.0	1	3.34	26.5
	C-2 Blend	13.5	3-3/4	4.77	52.5
	C-2 Blend	11.0	2-1/2	4.32	47.5
	F-2	5.8	1-1/4	3.61	26.0
	F-2 Blend	15.0	3-1/2	5.46	55.0
	F-2 Blend	13.5	3	5.25	53.0
	F-2 Blend	11.0	2-3/4	4.71	47.0
Standard Flour		13.5	2-1/2	5.82	60.0

they were more representative of bread-type flours. The cake- and cookie-baking data are represented by the 1M flours because they were more representative of cake-type flours. References are made to the other streams for comparative purposes to demonstrate characteristic differences of the streams.

Analytical data are presented for unfractionated and air-classified fractions of stream 3M for Red River 68, a hard-type wheat, and Pitic 62, a softer type (Table I). Flour was more readily separated into high- and low-protein fractions from the soft-type Pitic 62 than from the hard-type varieties. This indicates that cell structure separation can be obtained more readily for softer wheat than for the harder type wheat.

Yield by pin-milling and air classification was greatest for the C-2 fraction, composed mostly of large, unreduced endosperm chunks (Table I). Starch damage was greater in C-2 fractions than in unfractionated flours (Table II). The small particle size fractions, F-1 and F-2, had much higher contents of starch damage than C-2. The high levels of starch damage were caused by a high percentage of small starch fragments that resulted from the strong force of impact of pin-milling used to reduce particle size. Also, the differences in starch damage among the streams were directly related to the order of mill roll pressure; 3M with the greatest roll pressure had the highest starch damage. The softer wheat, Pitic 62, had the least starch damage because kernel structure was disrupted along cell walls. Also, Pitic 62 had a lower flour extraction; if milled to a higher extraction, it would have sustained more starch damage.

Farinograph

Farinograph data for 3M flour streams are shown in Table III. Red River 68 had very strong mixing characteristics, as indicated by long mixing time and low M.T.I. (mechanical tolerance index) value, even when blended to the same protein level as the other varieties. Pitic 62 had the weakest characteristics, with low absorption, short mixing time, and high M.T.I. value. Chris and Era had intermediate strength. In all varieties, addition of starch to reduce the protein level also reduced water absorption and mixing time and increased the M.T.I. value. This effect on water absorption and mixing time was more pronounced for the stronger than for the weaker flour fractions. On the other hand, the addition of vital gluten to increase the protein level increased the water absorption and mixing time and reduced the M.T.I. value.

Bread-Baking

Bread-baking data for 3M flour streams are shown in Table IV. Dough properties were very good with the C-2 and unfractionated flour fractions for all varieties except Pitic 62. The gluten of the F-1 fractions did not develop normally during mixing; doughs became quite sticky and had to be scraped from the sides of the bowl by hand. The F-1 fractions (high protein content) showed good gas production during fermentation, but produced very sticky and stiff doughs. Doughs from F-2 fractions produced a small amount of gas and were unelastic. Addition of starch to the F-1 fractions resulted in a dead, sticky, unacceptable dough. The addition of vital gluten to the F-2 fractions greatly improved the dough characteristics. The F-2 fractions with gluten added to give a 15.0% protein level produced doughs which were comparable to those of the standard, unfractionated, and C-2 flours.

Red River 68 showed the strongest dough characteristics, followed by Chris and Era, while Pitic 62 showed the weakest. It was impossible to make a cohesive dough from the C-2 and F-2 fractions of Pitic 62 because of the low protein content. Breads produced from the unfractionated flour and from fractions F-1

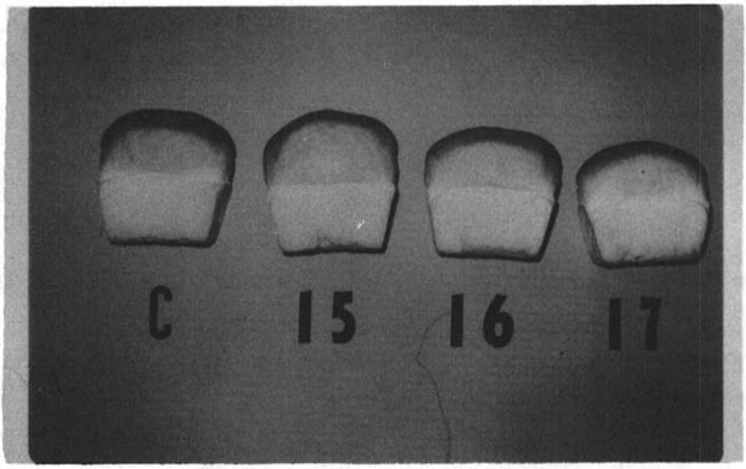

Fig. 3. Loaves of bread baked from Red River 68, flour stream 3M, fraction F-1. C = Standard bread flour; 15 = Red River 68, flour stream 3M, F-1 (18.6% protein); 16 = Red River 68, flour stream 3M (F-1-starch blend) (13.5% protein); and 17 = Red River 68, flour stream 3M (F-1-starch blend) (11.0% protein).

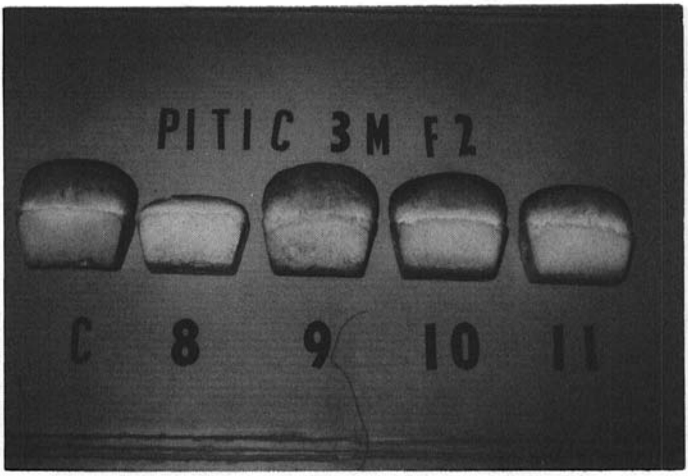

Fig. 4. Loaves of bread baked from Pitic 62; flour stream 3M, fraction F-2. C = Standard bread flour; 8 = Pitic 62, flour stream 3M, F-2 (5.8% protein); 9 = Pitic 62, flour stream 3M (F-2-gluten blend) (15.0% protein); 10 = Pitic 62, flour stream 3M (F-2-gluten blend) (13.5% protein); and 11 = Pitic 62, flour stream 3M (F-2-gluten blend) (11.0% protein).

and C-2 of each variety except Pitic 62 showed good specific volume. The F-2 fractions and all fractions from Pitic 62 showed extremely small specific volumes. Even at the high protein level (F-1), Pitic 62 showed a low specific volume. The low correlation coefficient between protein content and specific volume of 0.543 indicated that quality as well as quantity of protein is of utmost importance for bread-baking, since sufficient protein quantity was available to produce good bread. Also, volume of bread from the strongest variety, Red River 68, was largest and volume from the weakest variety, Pitic 62, was smallest. Volumes for Chris and Era were similar.

TABLE V
Cake-Baking Data for Flour Stream 1M

Variety	Fraction	Protein %	Volume cc	Sym.	Total Score
Red River 68	Unfractionated	12.6	155	8.0	46.0
	Unfractionated Blend	8.7	170	4.0	88.0
	F-1	18.1	170	6.5	32.0
	F-1 Blend	8.7	170	8.0	48.0
	C-2	13.8	165	3.5	62.0
	C-2 Blend	8.7	175	6.0	90.0
	F-2	9.4	175	8.5	66.0
	F-2 Blend	8.7	175	9.0	66.0
Chris	Unfractionated	11.7	165	7.0	72.0
	Unfractionated Blend	8.7	170	8.5	86.0
	F-1	16.7	175	6.0	54.0
	F-1 Blend	8.7	190	9.0	65.0
	C-2	13.2	190	7.0	74.0
	C-2 Blend	8.7	175	8.5	90.0
	F-2	8.5	175	10.0	86.0
	F-2 Blend[a]	...	...	...	...
Era	Unfractionated	10.8	155	5.5	65.0
	Unfractionated Blend	8.7	160	6.0	72.0
	F-1	16.3	155	5.5	35.0
	F-1 Blend	8.7	160	6.0	53.0
	C-2	11.3	165	5.5	74.0
	C-2 Blend	8.7	165	7.5	88.0
	F-2	8.5	160	8.0	73.5
	F-2 Blend[a]	...	...	...	...
Pitic 62	Unfractionated	9.1	145	5.5	69.0
	Unfractionated Blend	8.7	150	6.0	60.0
	F-1	13.1	200	6.5	48.0
	F-1 Blend	8.7	160	4.5	44.0
	C-2	4.2	150	6.5	90.0
	C-2 Blend	8.7	150	5.5	80.0
	F-2	4.2	160	9.0	90.0
	F-2 Blend	8.7	160	9.5	88.0
Standard		8.7	155	8.5	77.0

[a]No blend prepared.

Addition of starch to the high-protein fraction (F-1) reduced the protein content and greatly decreased loaf volume. For example, as shown in Fig. 3, the F-1 fraction of Red River 68 with the 18.6% protein gave a specific volume of 6.08, whereas blends with protein levels of 13.5 and 11.0% gave specific volumes of 5.44 and 4.57, respectively. This effect was much less apparent for the weak variety, Pitic 62. Addition of vital gluten to the low-protein fraction increased

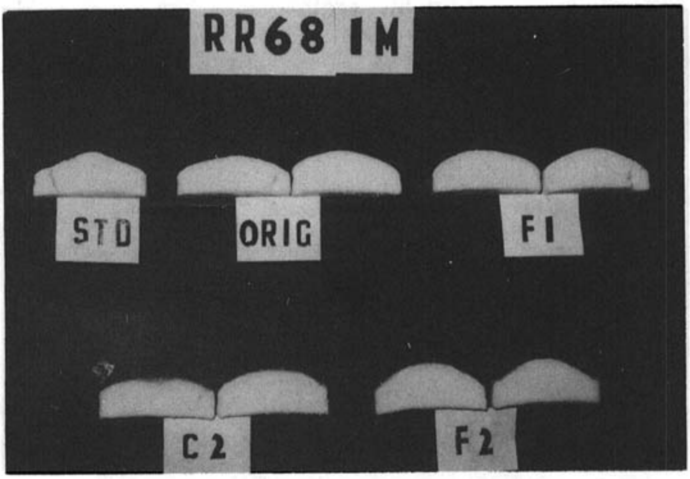

Fig. 5. Cakes from Red River 68; flour stream 1M. Std = standard cake flour. The cake on the left of each pair was made from the straight-run flour fraction, the cake on the right from a flour blend of 8.7% protein.

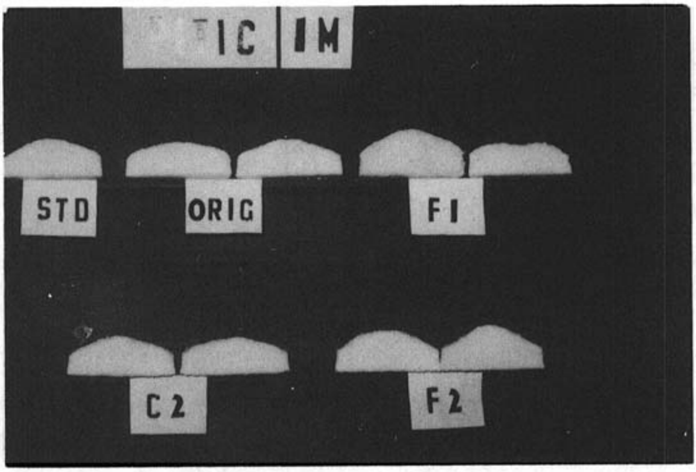

Fig. 6. Cakes from Pitic 62, flour stream 1M. Std = standard cake flour. The cake on the left of each pair was made from the straight-run flour fraction, the cake on the right from a flour blend of 8.7% protein.

protein content and volume (Fig. 4). The F-2 fraction from the 3M flour streams of Pitic 62 with 5.8% protein gave a specific volume of 3.61, but with 15.0, 13.5, and 11.0% protein, volumes were 5.45, 5.25, and 4.71, respectively. When protein contents of F-2 fractions of Red River 68, Chris, and Era were increased to 15.0%, volumes were comparable to volume from the standard bread flour.

Breads from unfractionated and C-2 fractions of each variety, except Pitic 62, were comparable to bread from the standard flour (Table IV). Most of the C-2 fractions showed whiter and brighter crumb color than the standard.

Bread from the F-1 fraction, for all varieties except Pitic 62, had a dark,

TABLE VI
Cookie-Baking Data for Flour Stream 1M

Variety	Fraction	Protein %	Spread Factor[a]	Top Grain Score
Red River 68	Unfractionated	12.0	76.6	3.5
	Unfractionated Blend	10.3	94.0	5.5
	F-1	18.1	39.1	0.5
	F-1 Blend	10.3	56.0	0.5
	C-2	13.8	59.2	2.5
	C-2 Blend	10.3	84.1	5.5
	F-2	9.4	68.2	3.0
	F-2 Blend	10.3	54.5	2.0
Chris	Unfractionated	11.7	70.2	3.5
	Unfractionated Blend	10.3	88.3	4.0
	F-1	16.7	33.1	1.0
	F-1 Blend	10.3	59.5	1.5
	C-2	13.2	61.8	3.0
	C-2 Blend	10.3	74.5	4.0
	F-2	8.5	51.3	3.0
	F-2 Blend	10.3	68.4	1.5
Era	Unfractionated	10.8	94.6	5.0
	Unfractionated Blend	10.3	87.4	5.5
	F-1	16.3	32.8	0.5
	F-1 Blend	10.3	60.8	1.0
	C-2	11.3	78.3	4.5
	C-2 Blend	10.3	73.4	4.0
	F-2	8.5	65.0	2.5
	F-2 Blend	10.3	53.3	2.0
Pitic 62	Unfractionated	7.1	124.0	8.0
	Unfractionated Blend	10.3	120.4	8.0
	F-1	19.1	43.8	1.0
	F-1 Blend	10.3	72.7	1.0
	C-2	4.2	105.9	8.0
	C-2 Blend	10.3	144.4	8.5
	F-2	4.2	111.8	10.0
	F-2 Blend	10.3	119.1	9.0
Standard		10.3	100.0	4.5

[a]Spread factor = D/T of sample/D/T of standard × 100
where D = diameter and T = thickness.

reddish crust, dull, grayish crumb, open grain, and soggy texture. The loaves had good external but poor internal characteristics. Bread from F-1 of Pitic 62 was poor both internally and externally.

Because of low protein contents, F-2 fractions of all varieties made very poor breads. Besides low loaf volumes, they gave very pale crust color, rough break and shred, close grain, and soggy texture, but acceptable crumb color.

Addition of starch to the high-protein fraction reduced colors of crust and crumb, and generally decreased external and increased internal score. The bread score was not affected greatly by the addition of starch. On the basis of the large reduction in loaf volume, the addition of starch to the high-protein fractions affected bread negatively.

The addition of vital gluten to the low-protein fractions improved the bread characteristics for all varieties. It enriched the pale crust color as well as all other bread characteristics except crumb color, which tended to be grayish.

Among the varieties, Chris yielded the best bread, followed by Red River 68 and Era. Pitic 62 was too weak to make an acceptable loaf of bread.

Results were similar for the 2B flour streams from the other varieties.

Cake-Baking

Cake-baking data for 1M flour stream are shown in Table V. The strongest variety, Red River 68, produced very poor cakes, even from the low-protein F-2 fractions. Cell walls were slightly thick, and the texture was gummy and slightly firm. Cakes from the unfractionated and C-2 fractions had uneven and slightly open cells; grains were harsh, and textures were slightly dry, tough, and firm. The F-1 fractions gave cakes with uneven, open, and thick cells and gummy, tough, and firm textures, similar to corn bread. Adjustment of protein content to 8.7% with starch greatly improved the cake characteristics of all fractions except F-2. After blending, the cakes from the unfractionated and C-2 fractions, in particular, were almost perfect. The dilution of protein with starch gave cakes with increased volumes and peaked contours.

Chris gave higher quality cakes than Red River 68. Cakes baked with the F-2 fractions from the 1M and 2B flours were better than, and cakes from the unfractionated flours were equal to, cake from standard flour. Although still unacceptable, cakes from the F-1 fractions of Chris were better than those from Red River 68, but had uneven, open, and thick cells, similar to corn bread, with a gummy, tough texture and a creamy color. The cakes from the C-2 fractions were much like those from the unfractionated flours. The addition of starch to each of the flours to adjust the protein content to that of the commercial cake flour control improved the cake-baking characteristics. The cakes from F-2 fractions and from flours blended with starch (except F-1) had whiter color than cakes from the standard flour. The addition of starch increased cake volume and produced a peaked contour.

Era showed the poorest cake-baking characteristics, producing cakes with poor cell structure and texture. Only cakes from the C-2 fractions blended with starch were acceptable.

The weakest variety, Pitic 62, gave the best cake-baking performance, and cakes from the C-2 and F-2 fractions were very acceptable. The cakes from F-1 fractions were similar to those from F-1 of the other wheats. Adjustment of protein to 8.7% reduced cake score; crumb color was dull and grain was harsh.

Addition of starch to the F-1 fractions did not improve quality, and decreased volume. This loss in volume, not shown by the other wheats, was attributed to the weak gluten of Pitic 62.

The cakes from the 1M flour stream of Red River 68 and Pitic 62 are shown in Figs. 5 and 6, respectively, For all varieties, the C-2 and F-2 fractions gave better cakes than other fractions. Overall, addition of starch to dilute the protein content improved the cake quality.

Cake results with 3M and 2B flour streams differed slightly, but in general followed the same type of pattern.

Cookie-Baking

The cookie-baking data for flour stream 1M are shown in Table VI. From each variety, unfractionated flour showed the largest spread factors, followed in order by C-2, F-2, and F-1. Cookie diameter decreased after the particle size of flour was reduced by pin-milling. This was partially attributed to the higher water-holding capacity of smaller particle size flour and/or to the surface area. Also, the very small cookie spread factor for the F-1 fractions could be related to their high protein content. The F-2 fractions had the lowest protein content, but had low spread due to small particle size.

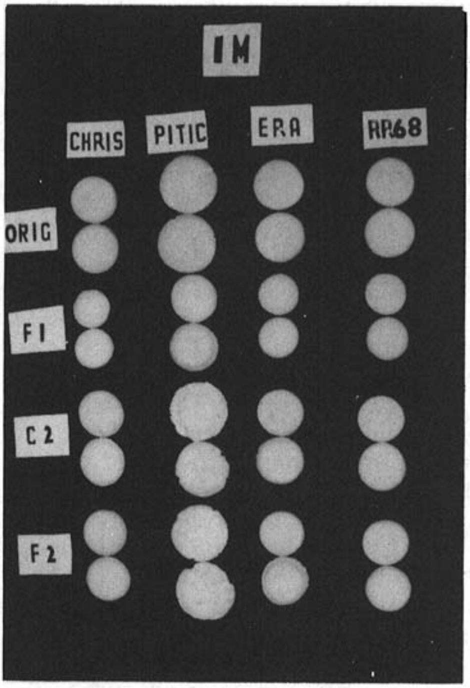

Fig. 7. Cookies from flour stream 1M from four different flour varieties. Orig = unfractionated flour. The upper cookie for each pair was made from the straight-run flour fraction, and the bottom cookie from a flour blend of 10.3% protein.

Of all varieties tested, the soft-type variety, Pitic 62, showed the largest spread factor. This weak variety was able to hold the dough shape and spread during baking, but had severe cracking, as reflected by the high top grain scores. On the other hand, the stronger varieties, Red River 68 and Chris, yielded small spread factors. Their strong protein had a binding effect on the dough and did not allow much spread, so that these cookies had less cracking and low top grain scores.

The unfractionated and C-2 fraction flours gave good cookie-baking results, except the Era 2B flour, which was the intermediate strong variety.

When compared to the corresponding individual parent flour fractions, the addition of starch to the higher protein fractions to reduce their strength increased the spread factor, which was directly related to higher top grain scores. The cookies from unfractionated flours and C-2 fractions of Red River 68 and Chris with added starch were significantly improved. The addition of starch to the F-1 fractions also improved quality, but cookies were still unacceptable. The addition of vital gluten to increase the protein level did not improve the cookie-baking performance of Pitic 62, as shown in Fig. 7, for the 1M flour stream of all varieties tested.

This study showed that the reduction of particle size has a negative effect on cookie quality. The best cookies were obtained from the larger particle size fractions of the intermediate strong variety, Era. The addition of starch to the larger particle size fractions of the stronger varieties, Red River 68 and Chris, improved their cookie quality. The addition of vital gluten to the lower protein fractions did not improve cookie quality.

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