Baking Characteristics of Low-Protein Fractions from Air-Classified Kansas Hard Red Winter Wheats[1]

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ABSTRACT

Low-protein fractions from five Kansas HRW wheat flours, milled from pure-variety lots of Bison, Comanche, Pawnee, Triumph, and Wichita wheats, were tested in cookies and cakes. The wide range of baking performance observed could be attributed mainly to varietal differences in the parent flours. Suitability of the fractions for these uses differed from that found for high-protein fractions from the same parent flours in bread-baking. The Pawnee low-protein fractions were best for cookies and layer cakes, whereas the Bison and Comanche fractions were unsatisfactory even at reasonable protein levels. Triumph fractions performed similarly to Pawnee, and Wichita fractions were intermediate. Angelfood cakes made from bleached low-protein fractions collapsed on cooling. Normal performance was obtained by blending approximately 20% of a high-protein fraction with the low-protein fraction. The chlorine dosage required to bring fractions tested as cake flours to the desired pH varied with wheat variety but not with protein or ash content, the usual factors affecting chlorine bleaching requirements.

In a companion paper (1), baking results were reported for high-protein flour fractions from air-classified Kansas HRW wheats. Some of the varieties tested yielded fractions suitable for fortifying weaker, low-protein flours for use in bread products. For the most part, performance of high-protein fractions in blends with low-protein base flours correlated with the baking performance of the parent flours. Such a correlation seemed reasonable, since the parents were bread-type flours. To predict cookie or cake performance of low-protein fractions from such hard wheat parent stock would be difficult and probably not reliable. Different quality factors are important in cookies and cakes, and their evaluation might be masked in HRW parent flours. Results reported below on cookie and cake testing of several low-protein fractions from these Kansas HRW flours suggest that this is the case.

MATERIALS AND METHODS

Experimental flours and fractions are from the same lots described in the bread and dough testing studies (1). Table I gives protein contents for the fractions used in cookie and cake evaluations.

Cookies

Cookies were baked according to the AACC Approved Methods cookie test (2); parent flours and low-protein fractions having suitable protein content were used. Generally, these were intermediate fractions from the four-part fractionation and reground fractions 4 through 7 from the eight-part fractionation. For some varieties, where the protein content was reasonable, the coarse residue fraction and reground fraction 8 were tested. A premium-grade, commercial cookie flour, not treated for spread control, was used as a standard reference flour. Alkaline water retention capacity (AWRC) determinations were made by the method of Yamazaki (3).

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TABLE I. PROTEIN CONTENT OF PARENT FLOURS AND FRACTIONS USED FOR COOKIE AND CAKE TESTS[a]

	Bison %	Comanche %	Pawnee %	Triumph %	Wichita %
As-milled flour	10.8	12.9	9.2	10.6	11.0
Intermediate	5.9	9.3	6.7	5.4	6.5
Coarse residue	.....	.....	8.8	10.9	11.1
Reground flour	10.5	.....	9.0	10.4	10.9
Reground fraction 4	5.5	7.6	6.7	7.2	8.3
Reground fraction 5	4.9	6.5	5.1	5.3	6.5
Reground fraction 6	4.7	6.9	4.9	4.3	5.5
Reground fraction 7	5.9	8.5	5.9	5.3	5.9
Reground fraction 8	10.2	.....	8.7	8.8	9.8

[a] All values 14% moisture basis. Reference 7.

Cakes

Three low-protein fractions (intermediate, R-4, and R-7) from each variety were bleached with chlorine gas in a laboratory bleacher. The quantity of chlorine required to bring the flours to the desired pH range (4.8 - 5.0) was measured and expressed in terms of a "bleach factor" as suggested by Bode and co-workers (4). This factor describes the pH change which would be obtained if the flour were treated with 1 cc. chlorine gas per g. (5.08 oz./cwt.).

The bleached fractions were tested in a high-sugar-ratio cake and in a two-egg white angelfood cake formula. The high-sugar-ratio cakes used the formula under study by the AACC Cake Flour Testing Committee. It had the following composition:

Flour	200 g.
Sugar	280
Shortening	100
Nonfat dry milk	24
Dried egg white	18
Baking powder	12
Salt	6
Water	variable

A Hobart C-100 mixer with 3-qt. bowl and flat beater attachment, was used in a three-stage mixing procedure. Batter was scaled 425 g. per 8-in. round pan and baked at 375°F. for 27 min. in a Despatch rotary-hearth oven. A water absorption series was performed on each experimental sample, then fractions and varieties were compared at optimum absorption. Volume (measured by seed displacement), contour, crust, and crumb characteristics were evaluated for each cake.

The angel cake procedure followed one used successfully for evaluating egg-white products (5). For flour tests, either commercially frozen egg whites were used or a uniform batch of egg whites was prepared by blending together freshly broken-out whites at low speed in a Waring-type blender. Initially, a series of bakes was made from a control flour to determine optimum whip time for the experimental flours. Because of the type of results obtained in the angel cake test, volume measurements were not made.

RESULTS AND DISCUSSION

Cookies

Table II gives average cookie diameters obtained from duplicate bakes of the samples and also average particle size for flours and fractions. (The size of fractions 5 and 6 is assumed to be between 18 and 23 μ.) Regrinding the parent flours to reduce particle size, preliminary to the eight-part fractionation, had a negative effect on cookie performance, as measured by size of cookie. For example, regrinding Triumph as-milled flour reduced average particle size from 50 to 20 μ and cookie diameter from 8.1 to 7.4 cm. The smallest decrease (0.1 cm.) was obtained with cookies made from the Wichita flour. Regrinding the coarse residue fraction also reduced cookie size. Starch damage has been shown to decrease cookie spread (6) and must have been the main factor in the decreases noted here, since no compositional change occurred in the flours at this stage. Higher maltose values (7) and higher AWRC values (Table III) were obtained with the reground samples. Both of these indicate starch damage when regrinding is the only treatment. Of particular note were the very small changes in maltose value (127 to 154) and the lack of

TABLE II. AVERAGE PARTICLE SIZE AND AVERAGE COOKIE DIAMETERS FOR FLOURS AND LOW-PROTEIN FRACTIONS

Flour or Fraction	MMD[b]	Cookie Diameter				
		Bison	Comanche	Pawnee	Triumph	Wichita
	μ	cm.	cm.	cm.	cm.	cm.
As-milled flour	50	7.8	7.5	8.0	8.1	7.8
Intermediate	20	7.7	7.1	7.9	8.2	7.7
Coarse residue (C.R.)	74	...	...	8.1	8.2	8.0
Reground C.R.	20	...	...	7.8	7.6	7.5
Reground flour	20	7.3	...	7.6	7.4	7.7
Fraction 4	18	7.4	7.3	7.6	7.8	7.9
Fraction 5	...	7.6	7.1	7.9	8.3	7.7
Fraction 6	...	7.9	7.5	8.2	8.4	8.0
Fraction 7	23	7.9	7.5	8.1	8.3	7.9
Fraction 8	39	7.4	...	7.9	7.6	7.6

[a] Commercial control: cookie diameter, 8.2 cm.

[b] Reference 7.

TABLE III. ALKALINE WATER RETENTION CAPACITY FOR FLOURS AND LOW-PROTEIN FRACTIONS (Commercial control: 55% AWRC)

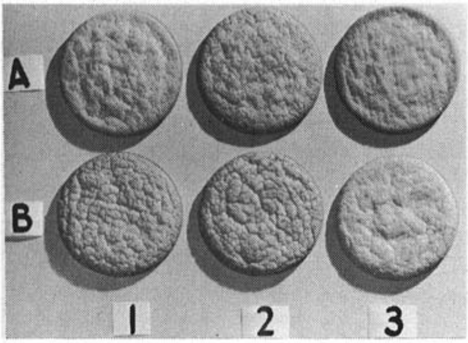
Flour or Fraction	Bison	Comanche	Pawnee	Triumph	Wichita
	%	%	%	%	%
As-milled flour	68	67	59	63	71
Intermediate	70	70	67	68	70
Coarse residue	...	...	49	58	58
Reground C.R.	...	...	67	71	74
Reground flour	82	78	72	73	71
Fraction 4	72	80	78	76	70
Fraction 5	72	74	74	72	72
Fraction 6	67	71	67	68	66
Fraction 7	64	64	58	63	65
Fraction 8	61	65	68	54	58

change in AWRC when the Wichita flour was reground, indicating less than average starch damage in this sample.

However, more important than, and in spite of, the negative effects of regrinding, air-classified fractions having good cookie potential were obtained from some varieties when the reground flour was used as the starting material (eight-part fractionation). Pawnee and Triumph varieties yielded fractions with relatively good cookie-baking performance. The considerable reduction in protein content from whole flour to these low-protein fractions contributed to the over-all improvement. However, the main influencing factor was more likely the removal, upon fractionation, of small particles such as tailings starch and fragments of damaged starch granules which were shifted to finer high-protein fractions. These components are known to have large negative effects on cookie quality because of their high water-holding capacity (6,8). Several fractions, notably reground 6, 7, and 8, had lower AWRC values than the reground flour (Table III), indicating that such hydrophilic substances had been removed.

The relation between cookie diameter and AWRC values was statistically significant. When all the data were considered, a correlation coefficient of –0.44** was obtained. The reground samples and their starting flours showed a correlation of –0.87**.

The large cookie diameters for some of the Triumph fractions were complemented by the superior appearance of their top surfaces. Figure 1 shows the range of surface characteristics obtained with the Triumph fractions. All of these cookies are comparable in size (8.1 - 8.4 cm.) to the commercial control sample (8.2 cm.) shown in position A-2. The best surface characteristics were exhibited by the intermediate fraction and reground fraction 6 (B-1 and B-2); the poorest by the coarse residue fraction (A-3). Since size does not differ among these cookies, tailings or other starch characteristics were probably not involved in the different surface types. Of more importance, perhaps, are the differences in protein content and granulation of the samples. For example, the coarse residue fraction contains twice as much protein as the fractions shown in row B and contains mostly endosperm chunk material which remained after the finer particles were removed.



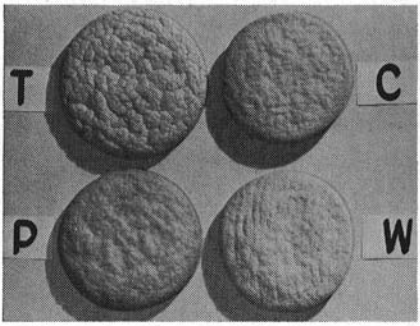


Fig. 1 (left). Cookies from Triumph and Commercial control flours. Row A: 1, parent flour; 2, commercial control; 3, coarse residue. Row B: 1, intermediate; 2, reground No. 6; 3, reground No. 7.

Fig. 2 (right). Cookies from intermediate fractions of Triumph (T), Comanche (C), Pawnee (P), and Wichita (W) flours.

The variety of cookie surface characteristics obtained with low-protein fractions from the same parent flour are interesting in that none of the usual parameters for predicting cookie quality are obvious in a comparison of these fractions (Table IV). For example, the lower ash, maltose, and AWRC values for reground No. 7 compared with those for the intermediate fraction would normally suggest that the former might make a better cookie. However, its top surface was inferior. This suggests that air classification might be a suitable initial step in a fractionation procedure for investigating minor components affecting cookie performance. For example, if it were important to have cookie surfaces similar to B-1 or B-2 (intermediate or reground No. 6) instead of B-3 (reground No. 7), shown in Fig. 1, experimental samples could first be obtained by air-classification techniques. Compositional studies could then be performed by other techniques. Such a procedure has been used by Smith and Mullen (9) in studies on short- and long-mixing flours with reference to characteristics important in bread flours and doughs.

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Variety of the parent flour was important in cookie performance of the fractions, but in a different direction than was observed with bread and dough performance (1). In general, Bison and Comanche wheats yielded poor cookie flours; Wichita, fair; and Pawnee and Triumph, good. Perhaps the "strong-type" protein, exhibited by Bison and Comanche in bread doughs, carries through to the low-protein fractions in smaller concentrations. Figure 2 shows cookies for four intermediate fractions. Cookies made with Comanche fraction spread very little and had very smooth surfaces, which, in many cases, still retained the mark of the knitted cloth wrapped around the rolling pin. Higher AWRC values did not appear to account for all the poor quality characteristics.

Such factors as starch gelatinization and protein hydration and denaturation during baking may have been more rapid, with the result that Comanche cookies "set" earlier in the baking process. It is interesting that Yamazaki (10) used Comanche variety as an example of very poor cookie-quality flour to show how dough characteristics during baking affect cookie size. In his experiment, the Comanche doughs increased in viscosity earlier and at lower temperatures than the others and gave smaller cookies. He attributed this, in part, to the intensive competition for the water among the various flour components – for example, gluten hydration, starch swelling, and gelatinization.

TABLE IV. COOKIE QUALITY CHARACTERISTICS OF SELECTED LOW-PROTEIN FRACTIONS FROM TRIUMPH HRW WHEAT

Fraction	Protein[a] %	Ash[a] %	Maltose value[a]	AWRC %	Top of Surface	Cookie Size cm.
Intermediate	5.4	0.37	148	68	Very good	8.2
Reground No. 6	4.3	0.32	119	68	Very good	8.4
Reground No. 7	5.3	0.32	121	63	Fair	8.3

[a] 14% Moisture basis; reference 7.

Cakes

Table V shows layer cake volumes obtained from duplicate bakes of bleached fractions. All were tested at 130% absorption, which was found to be optimum for good contour. The main volume differences were attributable to the parent flours, and followed the same general pattern as shown with cookies; i.e., Pawnee and Triumph fractions were best and Comanche was poorest. Pawnee fractions consistently gave cakes with higher volume than the other varieties and control flours. This high volume performance was further enhanced by Pawnee's outstanding texture characteristics. Triumph fractions, while not giving as high volumes, yielded cakes with fine, even, velvety texture.

TABLE V. LAYER CAKE VOLUMES AT OPTIMUM CONTOUR
(Commercial control: volume, 1,155 ml.)

Variety	Intermediate Fraction	Reground Fractions R-4	Reground Fractions R-7
	ml.	ml.	ml.
Bison	1,120	1,195	1,135
Comanche	1,010	1,160	1,080
Pawnee	1,190	1,225	1,210
Triumph	1,125	1,205	1,140
Wichita	1,110	1,190	1,095

All of the air-classified fractions yielded finer-textured cakes than the commercial flours, but they were not necessarily better. The finer textures were most likely due to the finer particle size achieved in pin-milling and air classification.

The poorest texture was obtained with Comanche fractions, which also tended to yield cakes with lower volume. With Comanche, the fine grain structure was interspersed with large holes from air bubbles trapped throughout the batters, which were also considerably thicker than the other batters. Increasing the liquid level to thin the batter, and perhaps improve texture, resulted in cakes that had peaked contours and light-colored crusts – common faults when absorption is too high.

Of the fractions, reground No. 4 yielded cakes with the highest volume for each variety, but the crusts of cakes from this fraction all exhibited some cracking not observed with the other fractions or with the control flours. These slight differences in cake volume, cookie size, and surface characteristics of cakes and cookies among the fractions suggest that somewhat different proteins or other flour constituents are separated into the different fractions.

Some fractions were tested in the Kissell lean-formula cake (11), which puts more stress on functional properties of the flour because of omission of eggs and milk. Volume results were similar to those obtained with the full formula, but contour results from the absorption series suggested limited water tolerance for the air-classified fractions as compared with the controls. This was not obvious in the full formula when the fractions performed similarly to the control flours. Apparently the eggs and milk mask this characteristic of the fractions.

Testing the bleached fractions in an angel cake formula showed up characteristics not revealed by cookie or layer cake tests. Figure 3 shows results obtained with a commercial cake flour and some reground fractions (R-4). The batters containing the air-classified fractions, regardless of variety, increased tremendously in

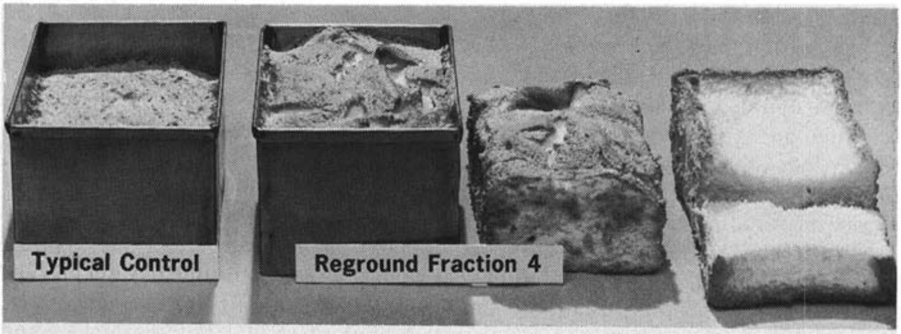

Fig. 3 Small angelfood cakes showing the extreme expansion and shrinkage which occurred with low-protein fractions regardless of variety.

volume during baking and appeared to retain this volume after cooling in an inverted position. Actually, the cakes had shrunk internally to about half their expanded volume, as shown by the concave bottom of the cut cake. All the low-protein fractions tested showed the same behavior, regardless of variety or fractionation procedure. This extreme expansion and shrinkage also occurs when wheat starch is substituted for all of the flour in angel cakes. Such results point out the important role of wheat protein for maintaining structure in an angel cake system where it is present in a ratio of only about 1 part wheat protein to 6 parts egg-white protein.

Since the air-classified flour fractions contained adequate quantities of protein (5.5 - 8.3%), it was of interest to determine whether the necessary components (protein or other constituents) for angel cake might have been separated with the finer high-protein fractions. To test this idea, a small amount of the fines fraction was substituted for some of the R-4 fraction in an amount to supply 6% protein to the flour blend. Figure 4 shows that this substitution did supply the missing flour components, and the resulting cake was comparable to the control. Substituting one-half as much fines fraction (contributing 3% protein) did not achieve the same correction. Expansion and shrinkage were less, but the cakes were still unacceptable. Tests with other low- and high-protein fractions produced the same results. The possibility that components other than protein are involved is being pursued in another study.

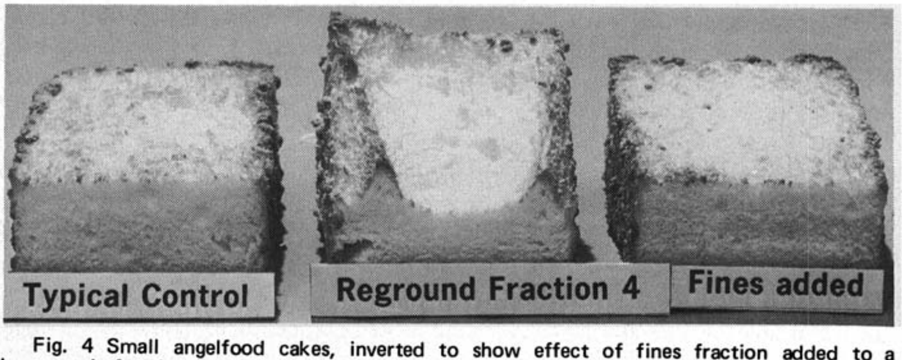

Fig. 4 Small angelfood cakes, inverted to show effect of fines fraction added to a low-protein fraction.

Chlorine Bleaching

Table VI shows the bleach factors for the low-protein fractions tested in cakes. The original pH of the unbleached fractions ranged from 5.8 to 6.0. The amount of chlorine required to reduce the pH to 4.8 - 5.0 varied considerably among the varieties and to a lesser extent among the fractions. The lowest bleach factors, which indicate highest chlorine requirements, are associated with Comanche and Wichita fractions. At the other extreme, Pawnee and Triumph fractions have high bleach factors, indicating a considerably lower chlorine requirement to produce the same pH change. The higher chlorine requirement for Comanche fractions might be due to their higher protein content, the protein tending to buffer the pH change. Such an effect was not evident for the other fractions. For example, Pawnee and Wichita R-7 fractions have the same protein content (5.9%) but the highest and lowest bleach factors for the group.

TABLE VI. BLEACH FACTORS FOR SELECTED LOW-PROTEIN FRACTIONS
(Bleach factor = ΔpH/cc. chlorine/g. flour.)

Variety	Intermediate Fraction	Reground Fractions	
		R-4	R-7
Bison	2.4	2.6	2.6
Comanche	1.9	2.3	2.2
Pawnee	2.6	3.0	3.1
Triumph	2.7	2.5	3.0
Wichita	2.2	2.3	2.2

Two other factors usually considered to affect pH change in bleaching, namely, ash content and total surface area, were ruled out for these samples. The percentage of ash showed no relation to chlorine requirement. Within a fraction group, the particle size distribution was essentially the same for all varieties, so the fractions would have similar total surface areas available for gas absorption.

While a correlation between bleaching requirements and cake performance is suggested by the extremes in both Comanche and Pawnee fractions, results for the other varieties do not support the relationship. Evidence against a relation between chlorine requirement and cake performance was also given by Barrett and Sollars (12), who were concerned with the high pH level and high chlorine requirements for Pacific Northwest soft wheat flours as compared with Eastern soft wheat flours. Bleach factors, calculated from their data, showed a range between 2.0 and 2.4 for the Western flours and close to 3.0 for the Eastern flours. Data of Bode and co-workers (4) showed differences in chlorine requirements between soft and hard wheat flours and their air-classified fractions, but these were easily related to differences in protein and total surface area. In contrast, results shown here did not indicate a relationship.

In general, one of the most important findings of this study was concerned with the influence of the parent flours on the baking behavior of their low-protein fractions. Flour strength, looked for in high-protein fractions, also appeared to carry through to some low-protein fractions, where it was a disadvantage.

While some of the low-protein fractions had the proper balance of components for acceptable cookies and layer cakes, all lacked a constituent necessary for angel cake flour. The missing factor was apparently separated into the high-protein fractions during air classification. Blending some of the high-protein fractions into the low corrected the deficiency.

Acknowledgment

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