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

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ABSTRACT

High-protein fractions air-classified from flours of five HRW wheat varieties (Bison, Comanche, Pawnee, Triumph, and Wichita) were added to three base flours (9.4 to 10.6% protein) in amounts to give blends of 12% protein. Bread and dough properties of the blends were significantly influenced by both the high-protein (HP) fraction and base flour. In addition, farinograph stabilities and loaf volumes were significantly affected by the interaction of HP fraction and base flour and by the method of obtaining the HP fraction. The HP fractions contributed only about 20 to 30% of the protein in the blends, but some dough and baking characteristics of their parent flours remained evident. Specifically, the long-mixing properties of Bison and Comanche, mellow properties of Triumph and Wichita, and weak properties of Pawnee parent flours were observed. The HP fraction separated from a flour reground only once gave longer mixing stabilities and larger loaf volumes in blends than did either of the two fractions separated from the corresponding flour reground three times. Quality of protein in HP fractions was probably most responsible for differences in their characteristics, but the behavior of other components, particularly starch and ash, may affect the suitability of a sample for air classification when HP fractions are an important product.

Air classification affords a process for tailor-making flours suitable for an array of end products. In publications describing the characteristics of air-classified flour fractions, various grinding and classifying schemes have been employed, depending on the number of fractions desired. Wichser (1) obtained three fractions from a hard winter wheat flour. His parent flour, high-protein (HP) fines, and chunk endosperm fractions were suitable for bread; the low-protein fines fraction yielded good-quality angelfood and layer cakes. A four-stage fractionation system was employed by Bode and co-workers (2) in their studies comparing a soft and a hard wheat flour. Both wheat classes yielded HP fractions suitable for bread and low-protein fractions suitable for cake. In these and other studies, good commercial flour blends were used as the starting materials, so differences among individual lots of wheats, whether due to wheat variety or environmental conditions, were masked.

In a comprehensive study on flour fractionation by air classification, workers at the Northern Regional Research Laboratory milled and fractionated several pure-variety samples of hard and soft wheat grown in various areas of the country (3-6). Wheats included were Pacific Northwest; Kansas HRW; Montana and North Dakota HRS; and Indiana, Ohio, and Michigan soft wheats. This report is concerned with the bread- baking quality of the HP fractions obtained from the Kansas HRW wheats. A companion paper (7) reports on the cake- and cookie-baking performance of the low-protein fractions.

MATERIALS AND METHODS

One sample of each of five Kansas varieties, representing a range of baking

[1] Presented at the 50th Annual Meeting, Kansas City, Missouri, April 1965. Contribution from Western Regional Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Albany, California 94710.

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qualities, was studied: Bison, Comanche, Pawnee, Triumph, and Wichita. The wheats were milled on a MIAG Multomat mill and air-classified in a Pillsbury laboratory-model classifier by two fractionation procedures, each yielding high- and low-protein fractions (4). In a four-part fractionation procedure, a coarse residue fraction was first classified from the as-milled flour at a cut point of 40μ. The remaining flour was reground once by passing through an Alpine pin mill operated at 18,000 r.p.m. to free as much protein as possible. Then the fines, semifines, and intermediate fractions were separated. In an eight- part fractionation, the as-milled parent flour was reground by three passes through the pin mill at 14,000 r.p.m.; then each fraction was separated in order from 1 to 7. Fraction 8 was the residual coarse fraction after separation of the finer fractions. After milling and fractionation, the flours were shipped to this Laboratory where they were stored below 0°F. (−18°C.) until tested. A more detailed description of the preparation of fractions has been published (4).

For bread and dough evaluations, HP fractions from as-milled and reground flours were added to three different base flours (ranging in protein content from 9.4 to 10.6%), in sufficient quantities to bring the protein content of the blends to 12%. Table I lists the protein contents of the parent flours, HP fractions, and base flours and the amount of fraction in each blend. The fractions ranged in protein content from 16.1% (Pawnee R-2) to 31.7% (Bison R-1) because of differences in their response to fractionation. Consequently, greater amounts of Pawnee and other lower-protein fractions were necessary to bring blends to 12% protein, with the result that these fractions contributed more of the total protein to their blends.

For baking tests the Finney-Barmore formula (8) was used in a straight-dough, 3-hr. fermentation procedure, 100 g. flour per batch, scaled 150 g. dough per loaf instead of the whole dough as mixed. After 55 min. of proofing, loaves were baked at 425°F. for 25 min. Volumes were measured by seed displacement. Duplicate bakes were made on each blend.

Dough-mixing characteristics were measured in the farinograph (50-g. bowl and constant-flour-weight procedure) (9). The farinograph absorption giving 500-B.U. consistency with flour-water doughs was increased by 2% for baking because of the milk solids in the bread formula.

RESULTS AND DISCUSSION

Bread

Figure 1 shows the relation between loaf volumes obtained from duplicate bakes of the blends and base flours. The broken line across each box represents actual loaf volumes obtained with each base flour; the solid line across each box represents the base flour volume calculated to 12% protein as follows. Accepting that loaf volume increases with protein content, a correction of 35 ml. for each percent protein was used for the protein range covered by the base and parent flours. This value was based on experience at the Western Wheat Quality Laboratory, Pullman, Washington, where a rating schedule for satisfactory loaf volume allows 42 ml. for each percent of protein difference between 10 and 12% protein (10). Their baking procedure uses the whole dough obtained with the Finney-Barmore formula – approximately 180 g. In the study reported here, 150 g. dough was baked, so 35 ml. correction appeared reasonable. Use of any other factor would show the same relative differences among the flours.

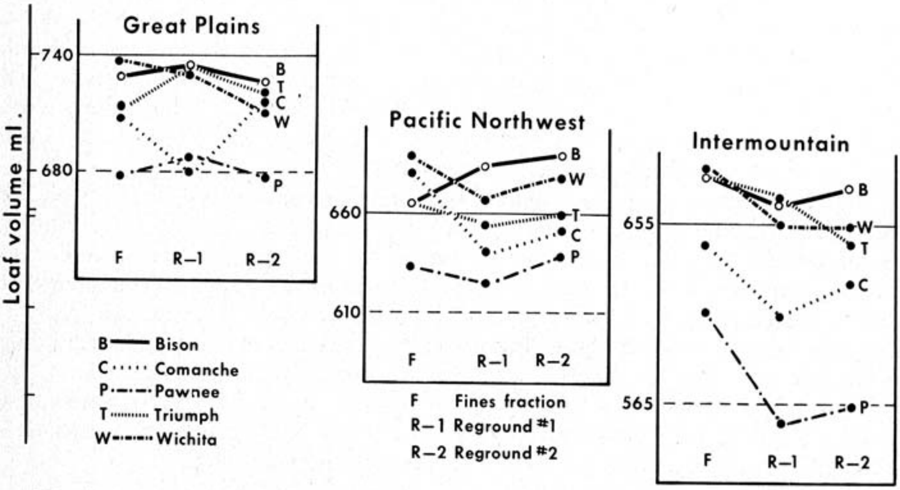

Fig. 1. Loaf volumes for flour blends of high-protein fraction and base flour in relation to volumes for base flour alone. Blends contained 12% protein and loaf volumes are indicated by points. Points from one variety are connected by a line. Volumes for base flours alone are indicated by a dotted line drawn across the appropriate box; these volumes, estimated at 12% protein, are indicated by solid line across box.

The points in Fig. 1 indicate the volumes actually obtained with the 12%-protein blends containing a HP fraction and a base flour. The points for each variety are connected in the order: fines (F), reground No. 1 (R-1), reground No. 2 (R-2). In general, the Bison, Triumph, and Wichita fractions tended to bring loaf volumes of blends close to or above those estimated for the base flour alone at 12% protein. Comanche fractions varied in their effects on loaf volume, and Pawnee fractions contributed little or no volume increase to blends in spite of increased protein content. The relative volume performance of the fractions generally paralleled that of the parent flours (see table below). This becomes clearer as the strength of the base flour decreases. For example, blends with Great Plains base flour show only small differences, Pawnee blends being the only ones consistently low in loaf volume. The poorer performance of Pawnee and Comanche fractions is more apparent as results with Pacific Northwest and Intermountain base flours are examined. Presumably, the low loaf-volume potentialities of the weaker base flours (660 and 655 ml. at 12% protein *vs.* 740 ml.) show up the deficiencies of the high-protein fractions more readily.

Loaf Volumes for As-Milled Parent Flours
(Volumes corrected to 12% protein)

Bison	755 *ml.*
Comanche	665
Pawnee	635
Triumph	700
Wichita	695

Results obtained from a single sample of each variety should normally be viewed with caution, since intravarietal variations can be large in conventionally milled flours. Additional air-classified samples might show at least equally large variations. However, the over-all dough and bread properties of the parent flours suggest that these samples are fairly typical of the varieties they represent. Bison and Comanche are considered strong wheats, Triumph and Wichita mellow, and Pawnee mellow to weak. While the sample of Comanche used in the present work consistently yielded rather low bread volumes, its strong characteristics were evident in dough properties which will be noted later.

Of the fractions, the fines tended to increase volume slightly more than the reground fractions (average volume: fines = 679 ml.; R-1 and R-2 = 666 ml.). Although the reground fractions were present in the blends in the smallest and largest quantities (Table I), their effects on loaf volume were similar. The somewhat better performance of the fines fraction from the four-part fractionation, particularly with the weakest base flour (Intermountain), suggests that the triple regrinding procedure necessary for the eight-part fractionation may have damaged some components. Also, removal of coarse residue fraction in the four-part fractionation before the fines were classified may have minimized the quantity of components susceptible to damage during the subsequent single regrinding step.

TABLE I. PROTEIN CONTENT OF FLOURS AND FRACTIONS AND WEIGHT % OF FRACTION IN 12%-PROTEIN BLENDS[a]

	Bison	Comanche	Pawnee	Triumph	Wichita
Parent, % protein	10.8	12.9	9.2	10.6	11.0
Fines fraction, % protein	27.9	27.8	19.1	25.4	24.9
Wt. % in blend with:					
Great Plains	9.7	9.7	19.3	11.3	11.6
Intermountain	14.0	14.1	26.8	16.2	16.8
Pacific Northwest	8.1	8.1	16.4	9.5	9.8
Reground No. 1, % protein	31.7	30.1	22.1	28.2	29.4
Wt. % in blend with:					
Great Plains	7.9	8.6	14.4	09.5	8.9
Intermountain	11.7	12.6	20.5	13.8	13.0
Pacific Northwest	6.6	7.2	12.2	7.9	7.4
Reground No. 2, % protein	24.2	25.0	16.1	22.6	23.9
Wt. % in blend with:					
Great Plains	12.2	11.6	29.3	13.8	12.5
Intermountain	17.6	16.7	38.8	19.7	17.9
Pacific Northwest	10.3	9.7	25.4	11.7	10.5

[a]All values, 14% moisture basis. Protein content of base flours: Great Plains, 10.3%; Intermountain, 9.4%; Pacific Northwest 10.6%.

The volume difference attributed to variety was influenced by the base flour, as noted earlier. The stronger Great Plains flour was improved less than Pacific Northwest flour and considerably less than Intermountain flour. However, while the improvement was less, actual volumes obtained were higher with the stronger base flour. These differences between base flours should not be construed as representing geographical area differences – only relative strength differences among flours, all of which could probably be obtained from a single area. Because their protein contents are nearly equal, the Pacific Northwest and Great Plains base flours are fortified with approximately the same amount of each fraction, and thus performance differences between blends containing the same fraction are directly related to the strength of the base flour. In contrast, the lower-protein Intermountain flour needed a much higher proportion of fraction to bring the blends to 12%. Consequently, the influence of the variety samples is amplified with this base flour, even though at 12% protein its estimated loaf volume was essentially equal to that of Pacific Northwest base flour.

Dough Properties

Peak times and stability values were determined from farinograph mixing curves for the parent flours, base flours, and blends of fraction and base flour in the same proportions as given in Table I.

Analysis of variance of the data showed that both the stabilities and the peak times were highly significantly affected by the base flours and by the variety source of HP fraction. Stabilities also were significantly influenced by fractionation procedure and by an interaction between HP fraction and base flour, but peak times did not show the latter two effects. Consequently, only the stability values are presented (Table II); trends in peak time values are generally similar. The blends containing fines fraction had an average stability of 9.7 min. compared with 8.5 and 8.6 min. for the blends containing reground fractions 1 and 2, respectively. As with the bread doughs, the fines fraction was present in a quantity intermediate between the two reground fractions, so proportion of fraction in the blend was not influential. That the reground fractions gave lower stabilities (Table II) as well as lower loaf volumes (Fig. 1) substantiates the observations made earlier that regrinding has altered some constituent of the flour. Alternatively, perhaps, the protein in each fraction represents a somewhat different part of the endosperm, and thus a different array of components.

Of particular interest were the stability changes brought about by HP fractions as they affected base flours. The extremely long-mixing stabilities of the parent Bison and Comanche flours (noted near the bottom of Table II) apparently carried through to their fractions. This in turn considerably lengthened the mixing stability of the base flours, particularly the weaker one, Intermountain. Part of the greater stability effect on this base flour is due to a larger proportion of fraction in the blend, but no doubt complementary effects of the proteins in the base flour and fractions are involved. It should be noted that Triumph and Wichita parent flours had shorter stability values than the base flours, yet their fractions, for the most part, increased the stability of the blends – particularly of the blends containing Intermountain flour. Pawnee flour, with the shortest stability, yielded fractions which had little effect on the stability of the base flours.

TABLE II. FARINOGRAPH STABILITY VALUES FOR FLOURS AND BLENDS[a]

	Bison *min.*	Comanche *min.*	Pawnee *min.*	Triumph *min.*	Wichita *min.*
Fines fraction plus:					
Great Plains	10.6	9.5	7.8	8.0	7.9
Intermountain	16.2	15.8	8.2	10.4	9.4
Pacific Northwest	8.7	9.5	5.3	10.7	7.1
R-1 fraction plus:					
Great Plains	8.9	10.3	7.5	7.1	7.6
Intermountain	13.7	12.3	8.5	9.2	9.1
Pacific Northwest	6.7	8.5	5.4	6.3	6.0
R-2 fraction plus:					
Great Plains	9.5	9.5	7.0	7.3	6.6
Intermountain	12.3	16.7	6.8	8.5	9.4
Pacific Northwest	8.6	8.5	5.9	5.8	6.2
Parent flour	26.0	24.5	3.0	4.0	5.0

	Great Plains *min.*	Intermountain *min.*	Pacific Northwest *min.*
Base flour	7.2	6.4	5.4

[a]Blends of fraction and base flour contain 12% protein.

Other workers have shown that simple blends of flours do not necessarily have farinograph characteristics averaged from the individual flours (11). Our work has shown that this is true also of air-classified fractions. Our long-mixing flours apparently yielded long-mixing fractions, but this characteristic influenced different base flours to different extents. The short-mixing flours yielded fractions (apparently with short stabilities) which also showed a range of effects in blends, depending on the base flour used. Considering that the base flours contributed about 70 to 80% of the total protein in the 12%-protein blends, it is surprising that the differences among HP fractions show up so clearly.

It is common practice to attribute dough and bread performance characteristics to the quality of protein in the flour being tested – in this case to the quality of protein shifted to HP fractions during air classification. However, since air classification also affects other constituents, some of these may have a direct bearing on fraction performance and should be considered.

Starch is markedly affected by regrinding and air-classification treatments. While the total quantity of starch has been reduced in HP fractions, there is a larger proportion of small-granule starch, which may change the water-imbibing and gelatinization characteristics of the flour. There are also more damaged-starch fragments shifted to the fines fractions. Jones and co-workers (12) referred to these as "ghosts" and explained their concentrating in the fines fractions by increased air-drag, causing them to behave like smaller particles. Such damaged granules have the effect of increasing absorption during dough mixing, but lose their water-imbibing properties when degraded by amylases. The higher maltose values of the fractions compared with those of the parent and reground flours (Table III)

TABLE III. MALTOSE VALUES FOR PARENT FLOURS AND HIGH-PROTEIN FRACTIONS[a]

	Bison	Comanche	Pawnee	Triumph	Wichita
Parent, as-milled	114	127	119	117	127
Fines fraction	215	264	329	206	230
Reground parent	147	151	178	186	154
Reground No. 1	248	306	393	234	251
Reground No. 2	207	280	345	211	198

[a]Reference 4.

presumably reflect the shifting of both damaged starch and amylase enzymes to the HP fractions. The concentration of amylases in air-classified fractions has been considered to be proportional to the protein content of the fractions (12,13). Then, in the samples used in this study, Pawnee fractions with their lower protein contents (Table I) should have the lowest enzyme levels, and Comanche fractions should have about the same enzyme content as Bison fractions. The maltose values do not fall in that order, and therefore it would seem that starch-damage variations are more significant in their influence on maltose values than amylase concentration in this set of samples.

Assuming that poor baking quality results from high starch damage, large effects would be expected in blends containing Pawnee fractions because more of the Pawnee fractions are needed to bring protein level to 12%. For example, with reground fraction No. 1, Pawnee fractions are present as 12.2 to 20.5% of the total blend (Table I), whereas the same fractions of the other four varieties are required only at 6.6 to 13.8% of the total weight. Similar comparisons can be noted with the other fractions.

The ash content of the fractions varied more among the HRW varieties reported here than among the varieties of any other class of wheat studied in this project (3-6). Table IV shows the wide range of ash content for HP fractions (0.38 to 1.23%) in contrast to the reasonably similar ash content for parent flours. Of particular note is the extremely large shift of mineral constituents to Pawnee HP fractions, which performed poorly in baking tests. By contrast, Triumph, a good performer in this baking study, had relatively little ash shifted to its HP fractions. Pawnee was the only bread flour variety concentrating extremely large quantities of ash in HP fractions. Only the HP fractions of durum wheats contained even more (6). Other workers reporting composition of air-classified fractions indicated shifts similar to those for the other four varieties noted in Table IV (1,2,13).

TABLE IV. ASH CONTENT OF PARENT FLOURS AND HIGH-PROTEIN FRACTIONS[a]

	Bison %	Comanche %	Pawnee %	Triumph %	Wichita %
Parent, as-milled	0.42	0.40	0.40	0.38	0.39
Fines fraction	0.84	0.88	1.23	0.58	0.63
Reground No. 1	0.82	0.82	1.12	0.58	0.62
Reground No. 2	0.72	0.70	1.00	0.54	0.54

[a]All values, 14% moisture basis. Reference 4.

Because of the lower protein and higher ash of the Pawnee fractions, blends containing Pawnee were also unusually high in ash (0.51 to 0.70%). Flour mineral content, by itself, is not commonly believed to be related to baking performance; instead, it is generally considered an indicator of the bran content of the flour, which, if high, is not desirable for white pan bread. Since all the parent flours had reasonable ash content for bread flours, it can probably be assumed that bran particles were not contributing to differences among the fractions. Whether the ash components, *per se,* contributed to the poor baking quality of Pawnee fractions cannot be determined from this study or from present knowledge of ash constituents.

From this study it appears that HP fractions from HRW wheat flours vary in the loaf-volume potential they contribute to a blend in much the same way as the loaf-volume potential of their parent flours. When tested with weak base flours, strong and weak characteristics of parent flours appear to carry through to HP fractions. The mixing curves clearly show that interactions between base flours and the source and treatment of HP fractions occur. They suggest that most of the differences in mixing behavior and loaf volume reflect the nature of the protein components present in a particular blend. However, alterations in starch and ash components during regrinding and air classification must also contribute to the variations in baking performance observed. Whether this pattern holds true for flours from other classes of wheat remains to be evaluated.

Acknowledgments

The authors are indebted to Mrs. Cheryl Knapp for performing the statistical analyses of the data.

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[Received August 25, 1967. Accepted June 10, 1968]