STUDIES OF THE HIGH-PROTEIN FINES AND COARSE FRACTIONS OF A SOUTHWEST AND AN INTERMOUNTAIN FLOUR[1]

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ABSTRACT

Starches and glutens prepared from the high-protein (HP) fines and coarse fractions air-classified from a southwest and an intermountain flour were compared in terms of bread-baking, chemical, and physical properties. With the particular fractions tested and the procedures used, the southwest starches and glutens were shown to be better baking materials by a reconstituted dough baking test than the intermountain components, and the starches and glutens of the coarse fractions were generally better than those of the HP fines fractions, at least in loaf-volume-producing ability. Variations in the baking properties of the starches exceeded variations due to the glutens. In baking tests where the starches from the flour fractions were the only variable, inverse trends were observed between loaf volumes and the percent of damaged granules and relative number of smaller granules in the starches.

The separation of flour into fractions of differing chemical and physical properties by air-classification procedures has both commercial and academic significance. These techniques, on the one hand, have created new possibilities for the production of high-quality flours with undeviating performance, required by the increasingly mechanized bakeries of today. On the other hand, air-classified flour fractions have provided new materials for research on flour and dough.

A number of investigators have furnished information on air-classified flour fractions. Data on analytical indices and/or amounts of fractions derived by air-classification have been reported, for example, by Wichser (30), Elias and Scott (7), Gracza (8,9), Sullivan *et al.* (28), and Pfeifer and Griffin (20). Jones, Halton, and Stevens (14) gave information on the technology of air-classification, as well as on the properties of air-classified flour fractions. Baking data obtained on air-classified flours both for bread and pastries was reported by Rotsch and Tessmer (23). The results of bread-baking studies on flours air-classified in the United States were presented by Grosh *et al.* (12), and by Gracza and Norris (10).

The present studies were directed at comparing some of the properties of starches and glutens washed from the high-protein (HP) fines and coarse fractions of two flours milled from wheats originating from

[1]Manuscript received April 1963. Contribution from the Research Laboratories, Continental Baking Co., Rye, N.Y.

various geographical locations. Several investigators (13,19,24) have demonstrated that starches of various flours possess different baking properties; it seemed of interest to augment this work and determine to what extent the starches, as well as glutens, of different air-classified fractions of flour vary in their baking and analytical properties. As supplemental information, data were also obtained on the baking, chemical, and physical properties of the flour fractions from which the starches and glutens were derived.

Materials and Methods

The flour fractions studied in this work were air-classified from flours conventionally milled from hard wheats grown in the southwest and intermountain areas of the United States. The flour fractions were unmalted, but were optimally treated with chlorine dioxide as judged by a baking test (southwest coarse 3.3 p.p.m., HP fines 15 p.p.m.; intermountain coarse 1.1 p.p.m., HP fines 18 p.p.m.).

The control wheat starch employed in part of the study was a commercial sample. A commercial patent bread flour (12.2% protein, 0.45% ash on 14% moisture basis) milled from a blend of hard red winter and spring wheats served as the source of the control gluten, whose preparation is shortly described.

Protein, ash, fat (acid hydrolysis), pH, crude fiber, and gassing power determinations were made by standard procedures (1). Alkaline water retention capacity (AWRC) tests were run according to the method of Yamazaki (31). Water-soluble pentosans were estimated by the orcinol method described by Elder *et al.* (6). Prime starch and tailings in the air-classified flour fractions were determined by the hand washing method of Seck and Kempf (26). Starch was also determined polarimetrically by a modification of Ewers' procedure[2]. Starch damage measurements were obtained by the method of Donelson and Yamazaki (5). Phosphorus was determined by an AOAC procedure (2).

Farinograms were made by the constant-flour method (1) and by a modified procedure involving reconstituted doughs. For this latter work, sufficient wet gluten (thawed from the frozen state just prior to use) and starch to yield 300 g. "flour" (14% moisture basis), with a protein content of 11.5%, were placed in the farinograph bowl. Enough water was added to provide an absorption of 52.4% (with two exceptions, to be noted), also on 14% moisture basis; then the mixer was immediately started and allowed to run for at least 20 min.

Amylograph tests on the flour fractions were made by a standard procedure (1), while cycled (heating, holding, cooling) amylograms on

[2] Ewers, E.; cited in ref. 18, p. 187.

starches were obtained according to the method of Lindemann (16).

Particle size distribution analyses were conducted by a modified Andreasen pipet method (4). Size distribution analyses on starches[3] were run by a slight modification of the Whitby procedure (29).

Gluten in the flour fractions was quantitatively estimated by the method of Lindemann (17), employing 10-g. samples on a dry basis. For preparation of gluten, as well as starch, on a larger scale, the method of Bechtel and Meisner (3) was utilized essentially as reported by the authors. The glutens were stored at 0°F. until used. The starches, after air-drying, were ground in a Wiley mill using a 0.5-mm. sieve.

Sponge dough baking tests on the flour fractions were carried out by a laboratory procedure designed to reflect commercial practice.

This procedure, yielding two 1-lb. loaves per dough, has been previously described (21). Optimum malted barley flour and bromate levels (the latter were used in conjunction with that amount of the other salts normally contributed by 0.5% Arkady-type yeast food) as well as dough absorptions and mixing times were predetermined for each flour fraction.

Baking tests involving reconstituted doughs were based on the method of Bechtel and Meisner (3). Glutens were defrosted about 2 hr. prior to use. The formula and procedure employed were as follows:

	Sponge	*Dough*	*Total, 14% m.b.*
	g.	*g.*	%
Gluten	*	*	*
Starch	*	*	*
Water	*	*	59.7
Yeast	16.3	...	1.95
Arkady	8.0	...	0.96
Rhozyme-33	0.18	...	0.022
Salt	...	16.3	1.95
Sugar	...	32.6	3.9
Milk	...	32.6	3.9
Lard	...	16.3	1.95

* Sufficient wet gluten was used to yield a flour of 11.5% protein, 14% m. b. Starch was added such that a "flour" of 834 g., 14% m.b., was produced. The sponges contained 50% "flour." Absorption of the sponge was 62.7% of the sponge flour on 14% m. b. Water contained in glutens was considered in determining absorptions.

Sponges were mixed 2 min. in speed 1 followed by 4 min. in speed 2 in a Hobart A-120 mixer equipped with McDuffee bowl and fork. Because the starch tended to settle and cake in the bottom of the bowl, it was necessary to stop the machine periodically and pack the sponge ingredients together by hand, until a roughly coherent sponge was formed. Sponge fermentation was 4.5 hr. Doughs were mixed 3 min.

[3] The authors are grateful to S. I. Greenberg, The Pillsbury Co., for these analyses.

in speed 1 and 10 min. in speed 2. Doughs were allowed no floor time. After scaling into 19-oz. pieces, an intermediate proof of 10 min. was given, followed by moulding in a Thompson drum moulder. The doughs were proofed to height, and baked for 21 min. at 415°F.

Results and Discussion

Baking Studies with Reconstituted Doughs. The starches and glutens isolated from the air-classified flour fractions were comparatively bake-tested by means of the synthetic dough system described in the previous

TABLE I
RESULTS OF RECONSTITUTED-DOUGH BAKING TESTS ON STARCHES AND GLUTENS FROM AIR-CLASSIFIED FLOUR FRACTIONS

	Southwest		Intermountain		Control[a]
	HP Fines	Coarse	HP Fines	Coarse	
	Starch and gluten				
Volume, cc.	2377	2688	2213	2770	2967
Volume based on control, %	80.1	90.6	74.6	93.4	100
Grain	6.0	8.0	5.0	7.6	8.0
Texture	sl. firm	firm	sl. soft, harsh	firm	sl. firm
	Starch comparison using control gluten				
Volume, cc.	2808	2860	2327	2844	3006
Volume based on control, %	93.4	95.1	77.4	94.6	100
Grain	8.0	7.6	6.5	7.0	7.7
Texture	sl. soft	sl. firm	sl. soft +	sl. firm	sl. firm
	Gluten comparison using control starch				
Volume, cc.	2917	2963	2729	2947	3026
Volume based on control, %	96.4	97.9	90.2	97.4	100
Grain	6.8	7.5	6.0	7.0	7.0
Texture	sl. firm	sl. firm	firm +	sl. firm	sl. firm

[a] Reconstituted dough made with control wheat starch and control gluten (see "Materials and Methods").

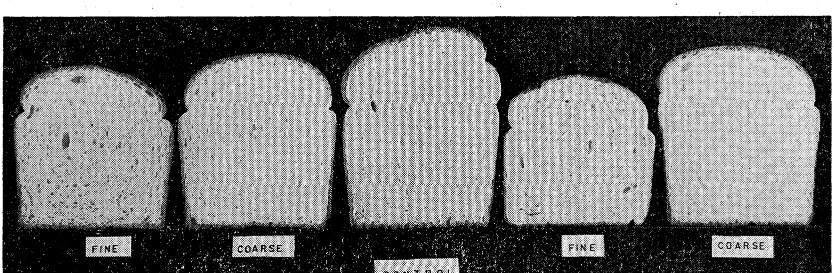


Fig. 1. Bread made by reconstituted dough method. Two loaves on left were made with starch and gluten components from, respectively, southwest HP-fines and coarse flour fractions. Two loaves on right were made with starch and gluten components from, respectively, intermountain HP-fines and coarse flour fractions.

section. Three series, in effect, were run. In the first series, each dough was made with the starch and gluten derived from a particular flour fraction. Doughs for the second series were made with starches from the various flour fractions in combination with a control gluten. For the third series, doughs were prepared with glutens from the different flour fractions and a control starch. Table I summarizes the baking data obtained; photographs of the bread appear in Figs. 1, 2, and 3.

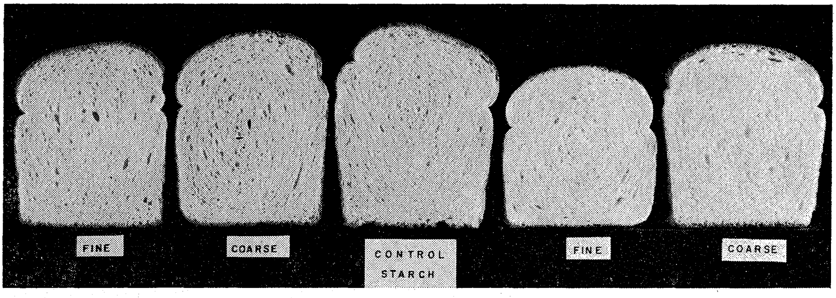


Fig. 2. Bread made with different starches and a control gluten. Two loaves on left were made with starches from, respectively, southwest, HP-fines and coarse flour fractions. Two loaves on right were made with starches from, respectively, intermountain HP-fines and coarse flour fractions.

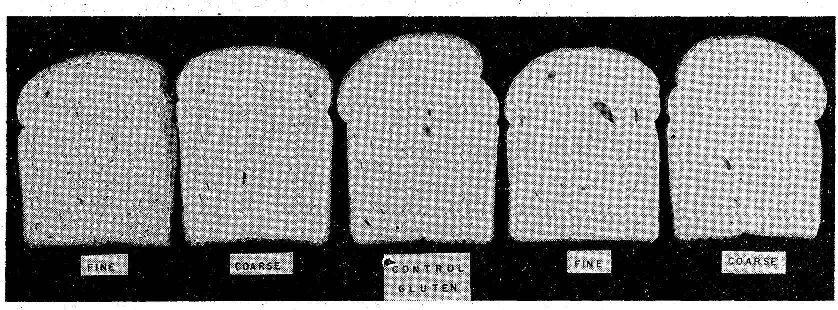


Fig. 3. Bread made with different glutens and a control starch. Two loaves on left were made with glutens from, respectively, southwest HP-fines and coarse flour fractions. Two loaves on right were made with glutens from, respectively, intermountain HP-fines and coarse flour fractions.

The upper portion of Table I (bread shown in Fig. 1) shows that the bread made of intermountain coarse-fraction components had slightly greater volume than that of the southwest fraction; the latter bread, however, possessed a somewhat better grain structure. Both doughs made with the HP-fines starch and gluten components produced bread of poorer over-all quality than that made from the coarse flour fraction components. The intermountain HP-fines starch and gluten yielded bread that was particularly poor, having the lowest volume and grain score in the series. This bread, on the other hand, was notable for possessing a somewhat softer crumb than the others.

The second series in Table I (bread shown in Fig. 2) compares bread made with the various starches and the control gluten. The most striking feature of these data was the low volume and poor grain structure due to the intermountain HP-fines starch. The bread made with this starch had approximately 77% as much volume as the control, compared to 93% to 95% for bread made with the other starches. These latter loaves varied relatively little in loaf volume. The southwest starches, both that of the HP-fines and coarse fractions, produced bread with better grain than the bread made with either of the intermountain flour fraction starches. Bread made with the southwest HP-fines starch had the finest grain in this series. Both of the HP-fines starches produced bread with a softer crumb than that made with the starches from the coarse fractions. The intermountain HP-fines starch was the more effective in this respect, indicating that the greater softness noted in the bread prepared with the intermountain HP-fines components was a function of the starch.

These data demonstrate substantial baking differences between the starches washed from air-classified flour fractions. The results thus extend the findings of Sandstedt (24), Harris and Sibbitt (13), and Pence *et al.* (19), who reported differences in the baking properties of starches prepared from flours of different wheat varieties.

The third series of Table I (bread shown in Fig. 3) demonstrates the effects of gluten variation in the loaves. Again, the intermountain HP-fines component produced the loaves of lowest volume, but not by as large a margin as in the instance of the starch series. The intermountain HP-fines loaves had about 90% of the control volume, compared to roughly 96 to 98% for the other loaves. Relatively small differences appeared in the grain scores. In general, the HP-fines glutens made bread of poorer quality than the coarse fraction glutens, and the intermountain glutens made bread inferior to the southwest glutens.

Smaller over-all baking differences were found between the glutens than between the starches. The poor performance of the intermountain HP-fines components noted in the first series was evidently due primarily to starch. The reasons for the poor performance of the southwest HP-fines components are not so clear, since both components produced relatively good bread when baked individually; possibly an interaction between starch and gluten was a factor.

Analytical Indices of Starches and Glutens. The starches and

TABLE II
ANALYTICAL INDICES OF STARCHES AND CRUDE GLUTENS PREPARED FROM AIR-CLASSIFIED FLOUR FRACTIONS

	Southwest		Intermountain		Control
	HP Fines	Coarse	HP Fines	Coarse	
			Starches		
Protein, %[a]	0.35	0.29	0.33	0.26	0.30
Ash, %	0.19	0.20	0.18	0.16	0.15
Crude fiber, %	0.073	0.055	0.056	0.039	0.048
Fat, %	0.057	0.044	0.041	0.033	0.010
Starch damage, %	8.7	2.6	13.6	3.4	2.3
pH	5.90	5.95	5.95	6.25	4.50
			Glutens		
Protein, %	75.7	70.2	77.1	71.7	70.3
Ash, %	0.73	0.63	0.86	0.64	0.96
Fat, %	6.10	5.15	6.71	4.75	2.98
Carbohydrate, %[b]	17.5	24.0	15.3	22.9	25.8
Phosphorus, %	0.0078	0.0024	0.0064	0.0056	0.0043

[a] Protein and other test results on dry basis.
[b] Found by difference.

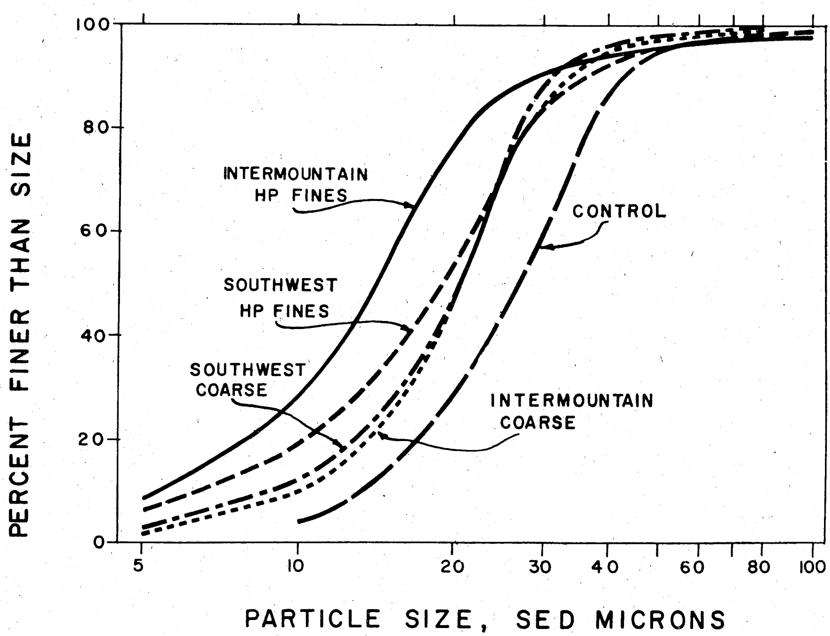


Fig. 4. Cumulative particle size distributions of the starches isolated from the various air-classified flour fractions.

glutens were analytically examined to determine any differences that would relate to baking behavior. Table II summarizes the analytical data; cumulative particle size distributions of the starches are graphically presented in Fig. 4.

Inspection of these data indicated that some of the values obtained did vary with baking quality, as measured by loaf volume. These values are shown tabulated in Table III, together with the loaf volume produced by the appropriate flour fraction components.

TABLE III
COMPARISON OF LOAF VOLUMES FROM RECONSTITUTED DOUGHS TO SOME ANALYTICAL VALUES OF STARCHES AND GLUTENS FROM AIR-CLASSIFIED FLOUR FRACTIONS

	Control	Southwest Coarse	Intermountain Coarse	Southwest HP Fines	Intermountain HP Fines
			Starches		
Loaf volume, cc.	3006	2860	2844	2808	2327
Starch damage, %	2.3	2.6	3.4	8.7	12.6
Percent of starch by wt. within 0–10 SED μ range	4.3	12.0	10.2	19.9	27.9
			Glutens		
Loaf volume, cc.	3026	2963	2947	2917	2729
Protein, %	70.3	70.2	71.7	75.7	77.1
Fat, %	2.98	5.15	4.75	6.10	6.71
Carbohydrate (by difference), %	25.8	24.0	22.9	17.5	15.3

Of the available data on the starches, trends in the negative direction were apparent between starch damage values and loaf volume, and between the relative amount of small granules in the starches and loaf volume. The ill effects of starch damage in breadmaking are well established in the literature (e.g. 21,25). The relative role of starch-granule size is not so clear. Grewe and Bailey (11), in 1927, found that starch-granule size variations in flour could not be correlated with baking properties, but Stamberg (27) cited other researches showing conflicting reports. Further work on this problem might be rewarding.

The gluten data showed trends for loaf volume with percent protein, fat, and carbohydrate in the gluten. In considering these relationships, it must be recalled that the baking procedure employed involved doughs with fixed protein levels, and not fixed gluten levels.

The relationship between loaf volume and both percent protein and fat in the gluten was inverse, whereas that between volume and carbohydrate was direct. Since the doughs were made with a constant level of protein, differences in the baking properties of the glutens were due to some constituent(s) other than protein, or perhaps to the "quality" of the protein. In this context, it may be pointed out that Jones and Dimler (15) recently reported the glutens from a given wheat flour and from its high- and low-protein fractions to be electrophoretically identical and to contain the same relative amount of each gluten component.

Physical Studies of Starches and Glutens. To further characterize the starches and glutens, a study employing a modified farinograph technique was conducted; in addition, the pasting properties of the starches were studied.

Figure 5A,B,C illustrates the results of the farinograph investigation. Essentially two series of doughs were made. In the "starch" series, the starches prepared from the four flour fractions were compared, using the control gluten for doughing; in the "gluten" series, the glutens from the fractions were compared in doughs produced with the control starch. A constant absorption (52.4%) was used, except for the doughs made with the southwest and intermountain HP-fines starches; 3.7 and 10% more absorption, respectively, were used in these doughs to keep their curves on the chart.

The series showing the effect of starch variation indicated that the starches from both coarse flour fractions produced similar curves. They differed from control principally by being displaced downwards roughly 40 to 60 B.U., thus demonstrating reduced hydration properties.

Vastly different curves were produced by the starches from the fines fractions. These two curves showed the latter starches to possess much greater water-binding powers than either the two coarse-fraction starches or the control starch. The demonstration of increased water-binding capacity by the starches from the fines fractions was entirely compatible with the data on both the "condition" of the starches (i.e.

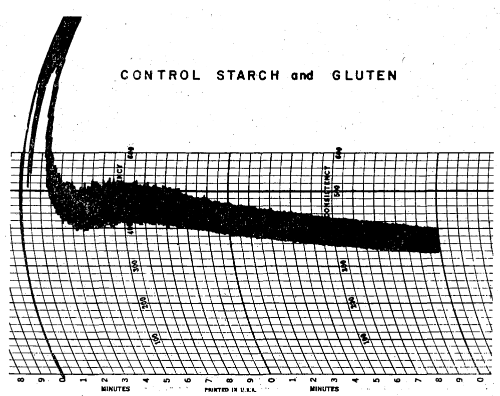


Fig. 5A. Control farinogram obtained from starch and gluten doughs. (See also Figs. 5B and 5C.)

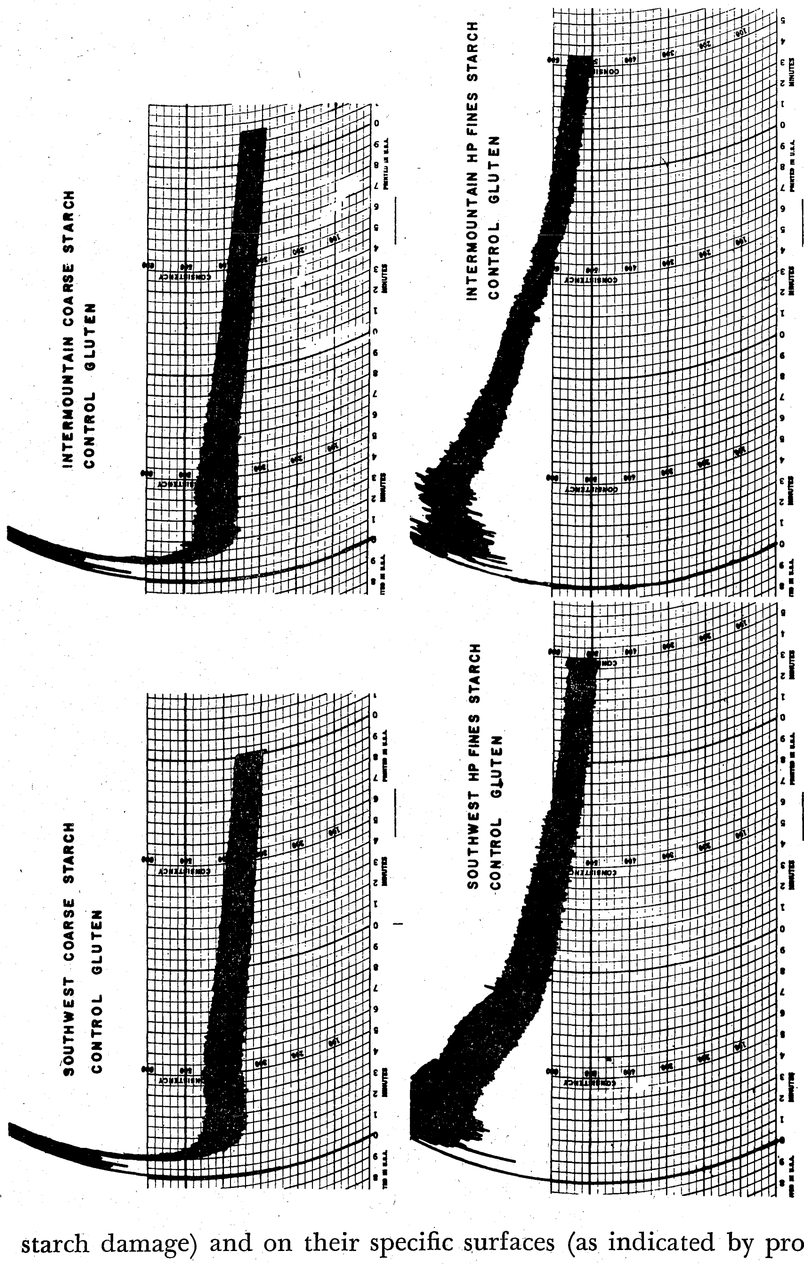


Fig. 5B. Curves made with starches from the various air-classified flour fractions and a control gluten. (See Fig. 5A for control.)

starch damage) and on their specific surfaces (as indicated by proportions of small granules in size distributions).

The curves in Fig. 5 showing the effect of gluten variation were generally similar to those of the control, except for that of the inter-

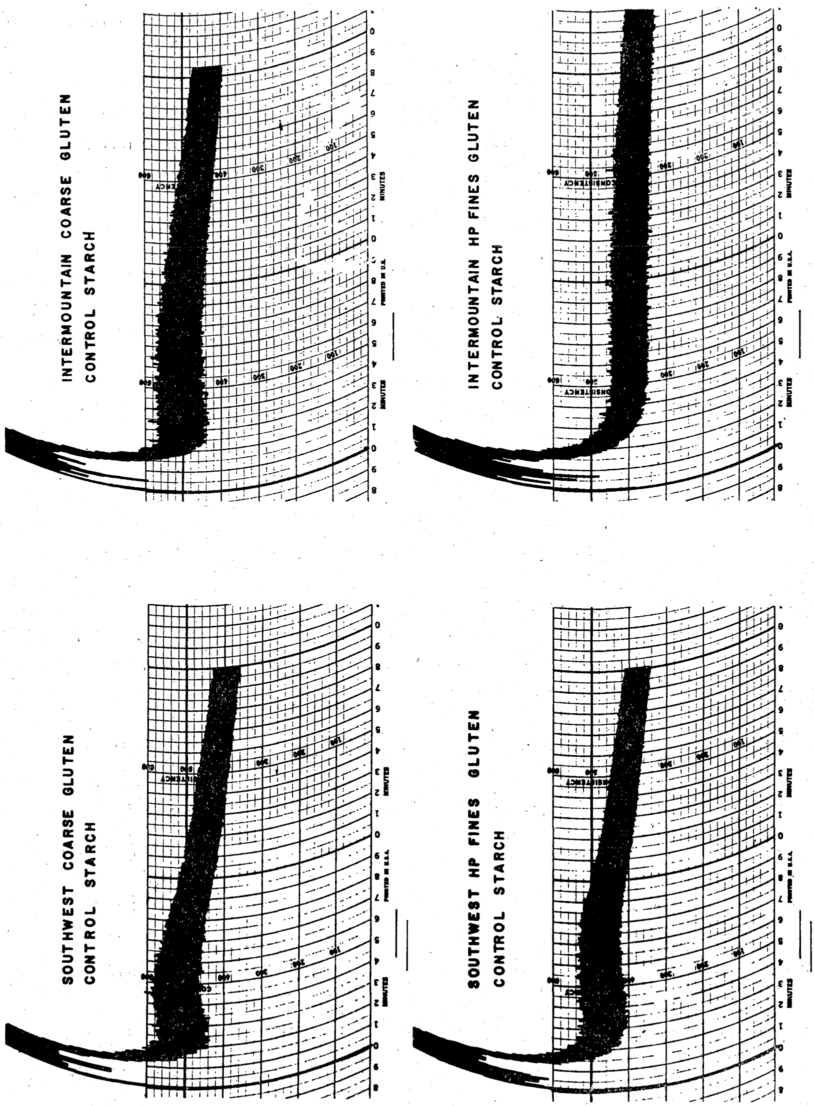


Fig. 5C. Curves made with glutens from the various flour fractions and a control starch. (See Fig. 5A for control.)

mountain HP fines. This latter curve was flatter, and showed appreciably lower consistency than the others. Evidently this gluten had somewhat lower hydration capacity compared to the other glutens.

Figure 6 shows cycled (heating-holding-cooling) amylograph curves obtained with the various starches.

After heating to 92°F., greater viscosities were achieved by the starches prepared from the HP fines, particularly that from the south-

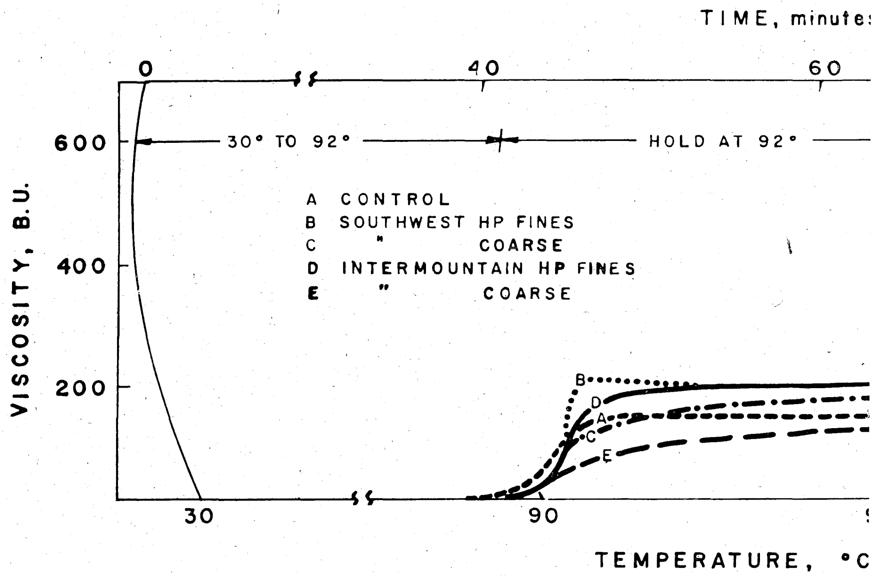


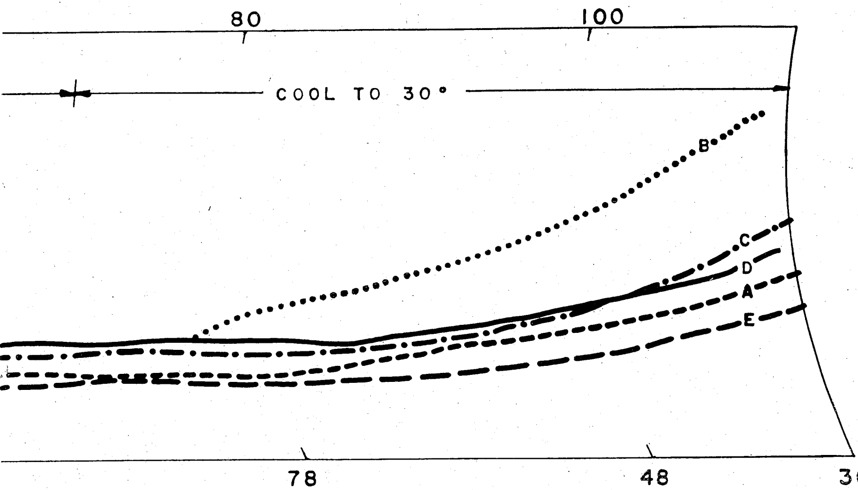
Fig. 6 (extending across opposite page). Amylograms obtained with 7.8% (dry basis) starch pastes. Suspensions were heated to 92°C., held at that temperature for 30 min., then cooled to 30°C.

west flour. The lowest viscosity was attained by the starch from the intermountain coarse fraction; the paste made from this starch was the least viscous throughout the three cycles. At the end of the cooling cycle, the viscosity of the paste made with starch from the southwest flour HP fines was considerably greater than that of the others.

Analytical and Physical Indices of Flour Fractions. Results of analytical and farinograph tests performed on the air-classified flour fractions from which the starches and glutens were derived are presented in Table IV. Cumulative particle size distributions of the flour fractions are shown in Fig. 7.

A portion of these data shows differences between the HP fines and coarse fractions that bear out observations previously made on flour fractions of similar natures (9,28). Of further interest are the values for gluten, gluten protein, and soluble protein; the increased ratio of gluten protein to soluble protein in the HP-fines material confirms the recent work of Rohrlich (22), who reported the lowest amount of water-soluble protein to be in the high-protein fraction of the flour he studied.[4]

[4] It was noted after completion of the present manuscript that Wrigley (J. Sci. Food Agr. **14:** 120–124; 1963) also observed the fine-particle fractions of several flours to be richer in gluten proteins than the coarser fractions.



The present HP-fines fractions also contained relatively higher levels of water-soluble pentosans and damaged starch granules than the coarse fractions. The latter values were higher than, but linearly related to, the values reported for the various starches in Table II; these

TABLE IV
ANALYTICAL INDICES AND FARINOGRAPH DATA ON THE AIR-CLASSIFIED FLOUR FRACTIONS

	Southwest		Intermountain	
	HP Fines	Coarse	HP Fines	Coarse
Protein (N × 5.7), %[a]	15.3	12.1	16.6	11.4
Ash, %	0.44	0.42	0.52	0.40
Gluten (dry), %	17.2	12.3	19.6	11.4
Gluten protein, %	13.0	8.7	15.2	8.1
Soluble protein (by difference), %	2.3	3.4	1.4	3.3
Fat (acid hydrolysis), %	2.20	1.52	2.36	1.64
AWRC, %	101	62.7	122	66.0
Pentosans (water-soluble), %	1.49	1.43	2.65	1.89
pH	5.60	5.70	5.85	5.80
Starch (polarimetric method), %	60.9	65.0	57.1	65.9
Starch (water-washed), %	54.5	55.6	46.6	57.4
Tailings, %	10.6	13.2	9.0	13.1
Starch damage, %	12.5	5.3	16.2	6.3
6th-hr. gassing power, mm. Hg	404	215	573	272
Amylograph peak viscosity, B.U.	2040	2750	850	2180
Farinograph Absorption, %	77.0	62.0	83.7	62.0
Dough development time, min.	15.5	6.25	25.5	5.5
Arrival, min.	12.25	3.75	19.5	2.5
Departure, min.	19.0	9.0	34.5	11.5
Tolerance, min.	6.75	5.25	15.0	9.0

[a] Protein and other test results on 14% m. b.

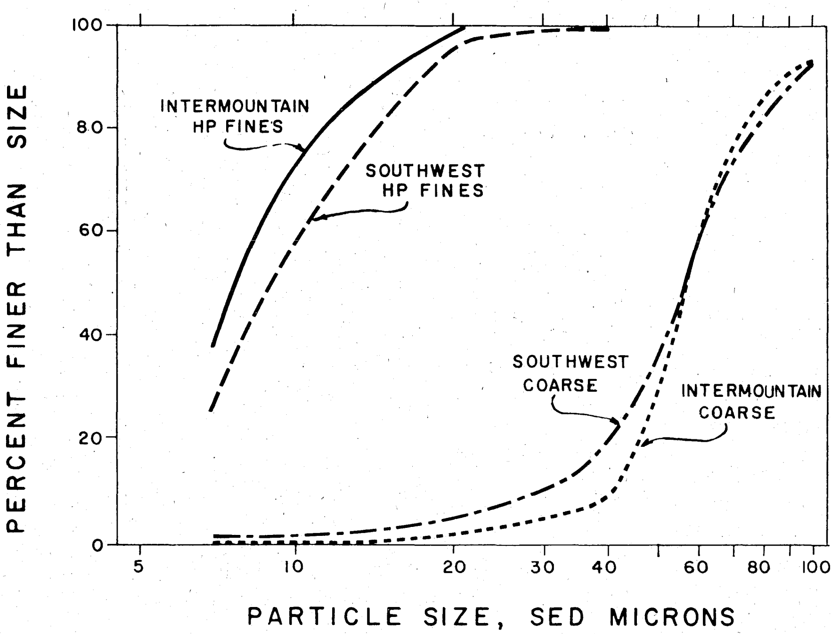


Fig. 7. Cumulative particle size distributions of the four air-classified flour fractions.

data thus indicate that only a portion of the damaged starch granules, or damaged parts of granules, were removed from the flour fractions by virtue of their solubility during the gluten washing procedure.

Table IV also shows more tailings by weight in the coarse fractions than in the HP-fines fractions. The tailings from the latter fractions, especially that of the intermountain HP fines, however, occupied more volume when wet than the tailings of the coarse fractions. This observation points to a considerably greater hydration capacity of the HP-fines tailings compared to the tailings of the coarse fractions.

Baking Behavior of the Flour Fractions. The average results of test bakes on the fractions are summarized in Table V; representative loaves are pictured in Fig. 8. These data show that more mixing and considerably higher absorptions were required for the HP-fines fractions than for the coarse materials. Even with an absorption of 83%, the intermountain HP-fines doughs were puttylike and lifeless; because of this, they were difficult to machine properly.

Relatively small differences in over-all baking behavior were found between the two coarse flour fractions. The greatest difference observed was in loaf volume; bread made with the southwest coarse flour had

TABLE V
RESULTS OF SPONGE DOUGH BAKING TESTS ON AIR-CLASSIFIED FLOUR FRACTIONS

	Southwest		Intermountain	
	HP Fines	Coarse	HP Fines	Coarse
Dough mixing time, min.	9.0	6.5	10.0	7.0
Absorption, %	75	63	83	64
Loaf volume, cc.	2635	2811	2540	2688
Specific volume, cc./g.	5.63	5.93	5.45	5.66
Crust color	chestnut	chestnut	dark chestnut	chestnut
Break and shred	smooth	smooth	capped, sl. rough	smooth
Crumb color	sl. dull, creamy	very sl. creamy	sl. dull, creamy	creamy white
Texture	soft	soft	very soft, gummy	soft
Grain	7.3	7.6	6.0	7.8

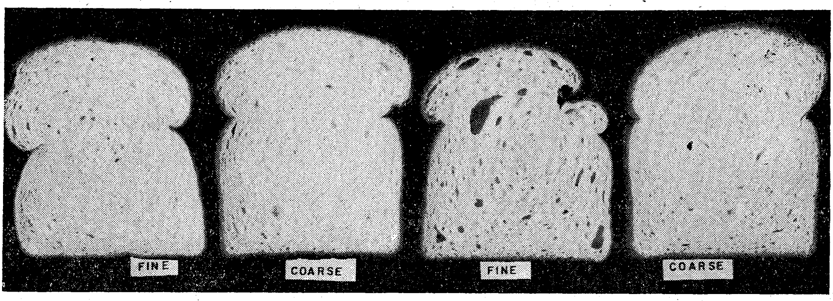


Fig. 8. Bread made with air-classified flour fractions. Two loaves on left were made from southwest HP-fines and coarse fractions respectively. Two loaves on right were made from intermountain HP-fines and coarse fractions respectively.

approximately 4% more volume than bread with the intermountain fraction.

Far greater differences were noted between the HP-fines fractions. The southwest HP fines made bread that was reasonably similar to the bread made with the coarse fractions; the former loaves had only somewhat less volume and poorer grain than the latter loaves. The intermountain HP-fines bread, however, was very poor, having low volume, an open grain with many holes, poor crumb color, and a tendency toward capping. Its crumb was, however, noticeably softer than that of the other loaves in the series; this softness was undoubtedly a function of the starch, as indicated in the baking experiments conducted with reconstituted doughs.

The analytical indices reported in the previous section were examined for possible trends with baking results. In Fig. 9, those analytical indices whose values appeared to vary with changes in loaf volume are shown plotted versus loaf volume.

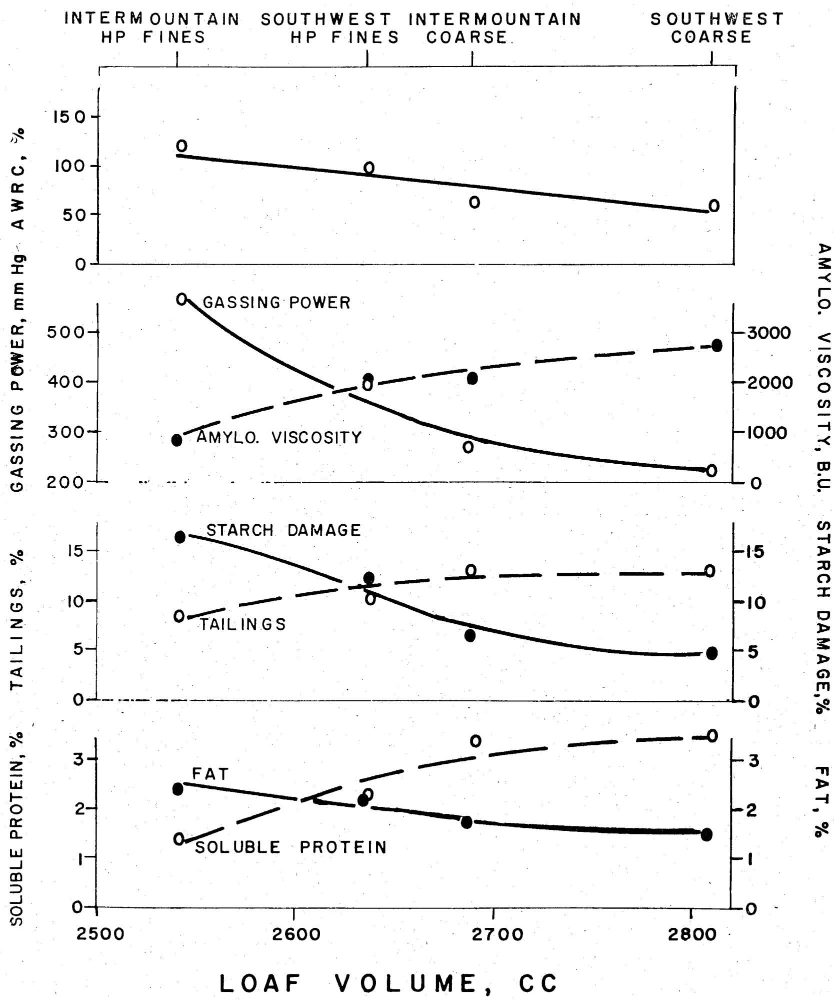


Fig. 9. Relationships between various analytical indices of air-classified flour fractions and loaf volumes produced by the flour fractions.

Thus AWRC, diastatic activity (as indicated by gassing power and amylograph), starch damage, and fat varied inversely with loaf volume, whereas tailings and soluble protein varied directly with volume. These trends do not necessarily reflect cause-and-effect relationships, but do emphasize areas for further research; the role of most of these factors in breadmaking is poorly understood.

Acknowledgments

The authors are grateful to D. B. Pratt, Jr., The Pillsbury Co., for supplying the flour fractions and for suggestions on certain phases of the work. The authors acknowledge with pleasure the assistance of Miss Jocelyn Rosen and R. F. Hert, A. W. Nelson, D. Koedding, A. Juers, and A. Spaeth.

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