Relation of Cultivar and Flour Particle Size Distribution to Cake Volume[1]

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ABSTRACT

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Intermediate-cut air-classified fractions from flours of different cultivars representing several wheat classes, and therefore differing in granularity, were similar in mass median diameter but formed cakes with significantly different volumes. Similarly, flours reconstituted from fractions separated by wet-fractionation and representing different cultivars were similar in mass median diameter but formed cakes differing in volume. These results suggest that in addition to particle size itself, heritable endosperm-fracturing properties are important in influencing layer-cake quality.

Several workers have studied the relation between flour particle size and cake quality. Miller et al (1967), using a pin mill to alter flour properties, found that cake quality improved as flour particle size decreased. They also reported that excessive pin milling increased starch damage and adversely affected quality. Rees (1971) pointed to the importance of particle size in cake flours, and Yamazaki and Donelson (1972) reported a highly significant correlation between particle size and cake volume.

This article reports the cake volume responses of flours, derived from diverse wheat types that yield patent flours differing in particle-size distribution, that had been air classified or wet fractionated and reconstituted so that they were similar in particle-size distribution.

MATERIALS AND METHODS

Wheats representing the major classes and subclasses in the United States (except durum) were used in the study. These included samples of the cultivars Chris (hard red spring), Eagle (hard red winter), Paha (club), Nugaines (Western common white), Arthur, Redcoat, and Blueboy (soft red winter), and Avon and Yorkstar (Eastern soft white winter). Sublots of each were conditioned and milled with the MIAG Multomat pilot mill to yield a straight-grade flour and a 50% (based on wheat weight) patent flour in separate millings. A portion of each patent flour was passed through the Alpine Kolloplex pin mill at 9,000 rpm, treated with chlorine gas to approximately pH 4.65 (Kissell and Marshall 1972), and baked into cakes according to Kissell (1959). Another sample was pin milled at 18,000 rpm to yield data on particle-size distribution.

Part of the straight-grade flour from each milling was passed through the pin mill at 12,000 rpm and classified in a Pillsbury turbo-classifier to yield three fractions, a high-protein fine fraction, a high-starch intermediate fraction, and a residual coarse fraction. The intermediate fraction was rehydrated to approximately 13% moisture content, chlorinated as above, and also baked into cakes.

Another part of the unreduced and untreated straight-grade flour of each cultivar was wet fractionated according to Yamazaki (1955), except that the dough was formed with two parts flour and one part water, mixed in a Waring Blendor to a uniform suspension, and centrifuged at 1,000 × g for 10 min. Recovered quantities of the ground fractions (gluten, starch, starch tailings, and water-solubles) were dry blended, passed through the pin mill at 9,000 rpm, rehydrated, and chlorinated as above. Cakes were baked with the reconstituted flours by the doughing procedure described by Donelson and Wilson (1960).

For all flours and fractions, protein was determined by AACC method 46-12, but with copper sulfate instead of mercuric oxide; ash, by method 08-01, but with furnace temperature at 555°C; and moisture, by method 44-16 (AACC 1976). Flour mass median diameter (MMD) and 80% range (a measure of particle distribution dispersion) data were obtained with a Coulter Counter model TA and 4% ammonium thiocyanate in anhydrous isopropyl alcohol as conducting vehicle.

Cake volume was measured by a rapeseed displacement technique. Cake internal score was a composite of scores for crumb cell uniformity, size, and wall thickness and for crumb grain and color; it was based on 100% for an ideal cake. All reported cake volumes are means of at least duplicate bakes (pooled standard deviation = 5.3 ml) at the optimum liquid level (Wilson and Donelson 1963).

RESULTS AND DISCUSSION

The MMD and 80% range values for the patent flours (Table I) compared favorably with those of similarly treated flours reported by Donelson and Yamazaki (1972). Differences among cultivars in MMD were evident even after pin milling. In contrast, MMD and particle distribution dispersion among the intermediate-cut air-classified flours were nearly uniform. MMD and 80% range values varied slightly among the dry blends of fractionated flour.

The particle-size distributions (as log normal probability curves, Herdan 1960) of the patent flours before and after pin milling, of the intermediate-cut air-classified flours, and of the fractionated flour blends before and after pin milling are presented for Chris, Arthur, and Avon in Figs. 1, 2, and 3, respectively. The data were typical for hard wheat, soft red winter wheat, and Eastern soft white wheat flours and for fractions used in this study.

The effect of pin milling on the particle-size distribution of patent flours differed with wheat class. Chris particles were significantly reduced in size over the entire spectrum of spherical equivalent diameters (SED) upon pin milling at 9,000 rpm (Fig. 1). In contrast, Arthur flour, already considerably finer than Chris, did not respond in a similar manner (Fig. 2). The coarser particles in Avon were readily reduced by pin milling to yield a flour with a smaller MMD than that of Arthur (Fig. 3, Table I). When Chris patent flour was pin milled at 18,000 rpm, MMD was reduced from 54 to 29 μm, but the profile (Fig. 1, curve C) was conspicuously different from the profiles for the soft wheat flours because few particles were smaller in SED than 10 μm. When pin milled at 18,000 rpm, Arthur and Avon flours exhibited a new mode of particle-size distribution, and about 30% by weight of the flours had an MMD considerably smaller than 10 μm. The appearance of this mode may reflect the increased release of small-granule starch as well as the further reduction of amorphous protein particles.

For each flour, whether reduced or not, the constituent materials, such as aggregates and free starch, determined the distribution mode, and some flours appeared to show as many as

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three modes. Within each mode, the distribution appeared to conform to the log normal type.

Profiles of the intermediate-cut air-classified fractions shown in the three figures (curves D) were remarkably similar. This similarity was also reflected in their MMD (Table I). In all fractions the principal distribution appeared to be in the SED range corresponding to that of free large-granule starch, although modest signs of some aggregation appeared (a second mode at the higher SED level).

Profiles of the dry blends of fractionated flours before (curves E) and after (curves F) pin milling at 9,000 rpm showed that corresponding distribution patterns were quite similar with regard to number of modes, MMD, and curve slopes. These similarities indicate that fractionation and subsequent treatment of fractions minimized inherent MMD differences in the patent flours. Blends after pin milling retained the two-mode distribution, the SED of the lower mode appearing to correspond to that of the free large-granule starch in the blend. In all three illustrated distributions, the

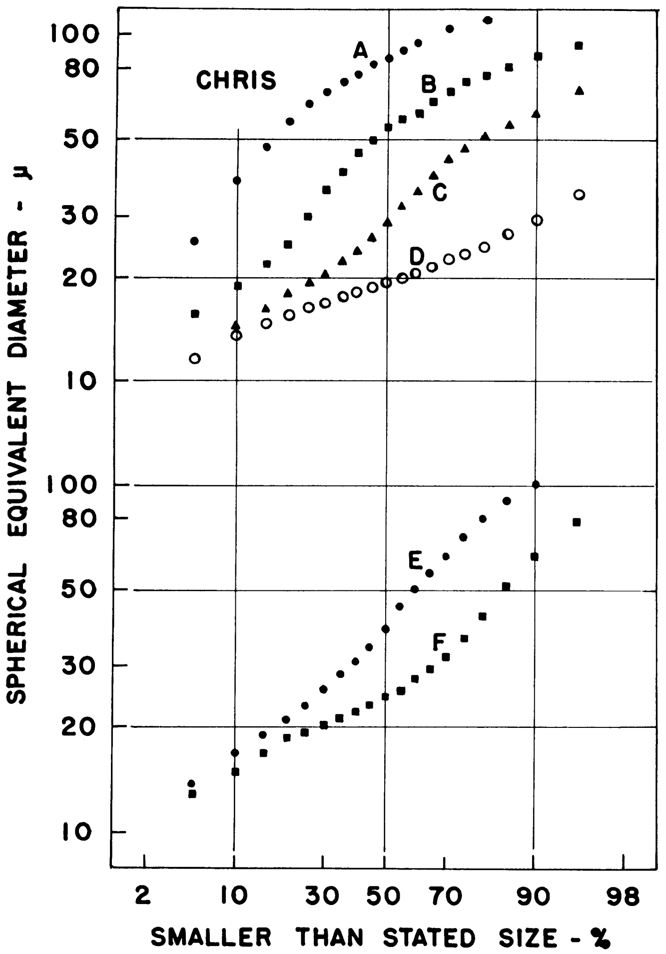

Fig. 1. Particle size distribution profiles for Chris: **A**, patent flour; **B**, patent flour pin milled at 9,000 rpm; **C**, patent flour pin milled at 18,000 rpm; **D**, intermediate-size air-classified flour; **E**, blend of recovered wet-fractionated flour fractions without further reduction and (**F**) after pin milling at 9,000 rpm.

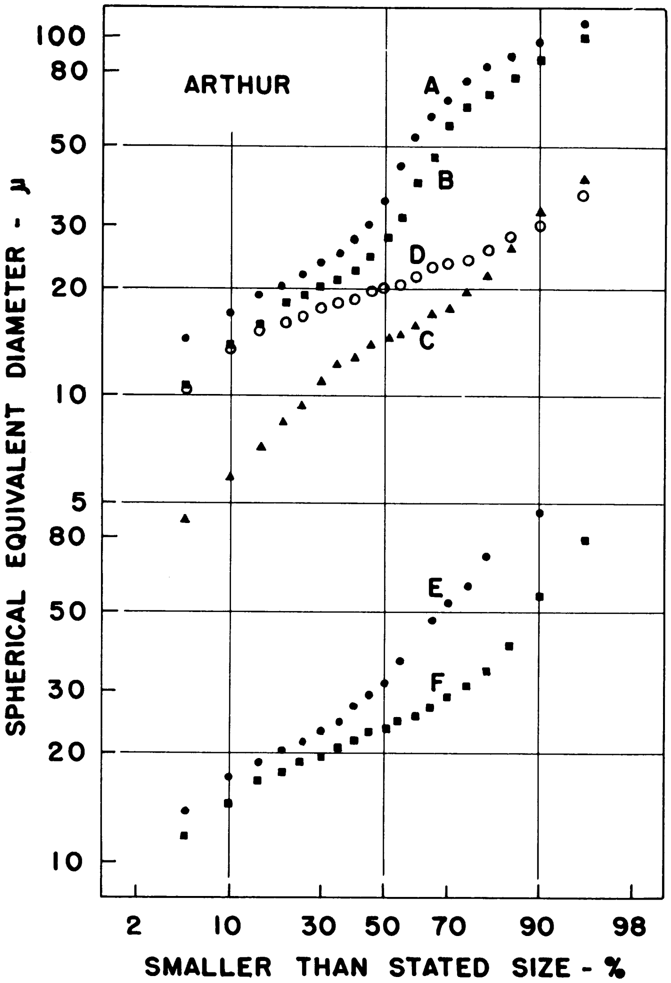

Fig. 2. Particle size distribution profiles for Arthur: **A**, patent flour; **B**, patent flour pin milled at 9,000 rpm; **C**, patent flour pin milled at 18,000 rpm; **D**, intermediate-size air-classified flour; **E**, blend of recovered wet-fractionated flour fractions without further reduction and (**F**) after pin milling at 9,000 rpm.

TABLE I
Analytical and Particle-Size Data for Patent Flours Pin Milled at 9,000 rpm, for Intermediate-Cut Air-Classified Flours, and for Dry Blends of Fractionated Flour Pin Milled at 9,000 rpm

		Patent Flour				Air-Classified Flour					Blend of Fractions		
Cultivar	Wheat Class[a]	Protein (%)	Ash (%)	MMD[b] (µm)	80% Range (µm)	Yield (%)	Protein (%)	Ash (%)	MMD (µm)	80% Range (µm)	Fraction Recovery (%)	MMD (µm)	80% Range (µm)
Chris	HRS	13.4	0.33	54	19–88	17.4	9.1	0.42	20	14–30	92.7	25	15–60
Eagle	HRW	9.7	0.33	49	17–98	28.1	6.7	0.47	21	14–31	94.0	23	15–39
Paha	Club	7.4	0.35	32	14–91	33.0	4.8	0.34	19	13–28	96.0	25	15–59
Nugaines	SWW	5.8	0.30	25	14–75	34.5	3.9	0.35	19	14–28	95.0	26	16–69
Arthur	SRW	9.4	0.34	28	14–87	36.7	6.3	0.33	20	13–30	97.3	24	15–57
Blueboy	SRW	6.9	0.30	22	12–76	41.5	5.3	0.36	20	13–31	98.6	22	14–47
Redcoat	SRW	8.6	0.33	26	13–90	38.2	5.3	0.36	21	14–32	94.1	25	16–39
Avon	SWW	6.7	0.27	22	14–84	37.6	4.4	0.33	20	14–31	93.0	23	15–41
Yorkstar	SWW	7.0	0.32	21	13–59	41.4	5.1	0.37	20	14–30	95.2	27	17–45

[a] HRS = Hard red spring, HRW = hard red winter, SWW = soft white winter, SRW = soft red winter.
[b] Mass median diameter.

TABLE II
Volumes[a] and Internal Scores for Cakes Baked[b] from Patent Flours Pin Milled at 9,000 rpm, from Intermediate-Cut Air-Classified Flours, and from Blends of Fractionated Flour Pin Milled at 9,000 rpm

		Patent Flour		Air-Classified Flour		Blend of Fractions	
Cultivar	Wheat Class	Volume (ml)	Score[c] (%)	Volume (ml)	Score (%)	Volume (ml)	Score (%)
Chris	HRS	503 c	48	525 cd	79	473 e	55
Eagle	HRW	509 c	61	536 bcd	73	507 d	59
Paha	Club	509 c	75	532 cd	82	469 e	64
Nugaines	SWW	552 ab	73	541 bc	75	535 c	64
Arthur	SRW	538 b	73	551 b	86	608 a	66
Blueboy	SRW	563 a	73	575 a	86	608 a	71
Redcoat	SRW	537 b	68	520 d	82	539 c	79
Avon	SWW	540 b	71	524 cd	82	547 c	74
Yorkstar	SWW	568 a	73	571 a	70	580 b	79

[a] Volumes followed by the same letter are not significantly different from each other at the 5% level of probability (Duncan's multiple range test).
[b] At optimum liquid level; means of duplicate bakes.
[c] Composite of scores for crumb cell size, uniformity, and wall thickness and for crumb grain and color. Based on 100% for an ideal cake.

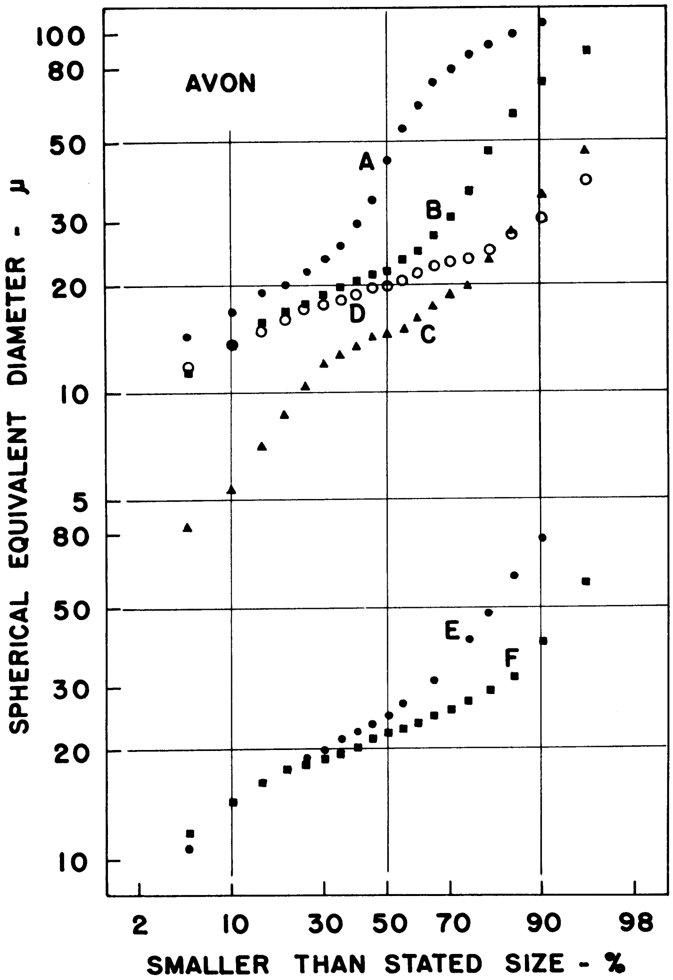

Fig. 3. Particle size distribution profiles for Avon: **A,** patent flour; **B,** patent flour pin milled at 9,000 rpm; **C,** patent flour pin milled at 18,000 rpm; **D,** intermediate-size air-classified flour; **E,** blend of recovered wet-fractionated flour fractions without further reduction and (**F**) after pin milling at 9,000 rpm.

lower modes of curve F represented about 70% of the weight of the particles, which roughly equaled the yield of the prime starch fractions in the fractionation procedure. Apparently, therefore, by employing air classification and wet fractionation, we effectively minimized particle-size differences attributable to wheat class and cultivar and evident in the MMD and 80% range of the patent flours.

Yamazaki and Donelson (1972) reported an r value of −0.94 for the correlation between patent flour MMD and cake volume. In the present work, we obtained a highly significant r value of −0.85 for the same relationship. Thus, as applied to patent flours, particle size appears at least to be indicative of cake volume.

Table II shows, however, that cake volumes differed significantly in spite of air-classification or wet-fractionation procedures to minimize differences in MMD and 80% range. These results indicate that particle-size or size-distribution patterns are not the primary determinant of cake volume. Another flour property or properties, possibly associated with cultivar or wheat class, is probably involved.

Cake volume for patent flour pin milled at 9,000 rpm was significantly correlated with volume for air-classified flour (r = 0.75) and with volume for fraction blend (r = 0.83). These data and the volumes in Table II indicate that cake volumes for coarse granulating flours, represented by Chris and Eagle in our experiment, tended to be low and that those for the fine granulating flours, such as Blueboy and Yorkstar, tended to be high even when flour particle-size differences were minimized through air classification or wet fractionation.

Our patent flours constituted 50% of the streams with the lowest ash and protein contents in milling, whereas the yield of air-classified flours varied from about 13.5% of wheat (17.4% cut yield from straight-grade flour of 77.4% yield from wheat) for Chris to 32.1% (41.5% cut yield from straight-grade flour of 77.3% yield from wheat) for Blueboy. This yield range is the direct result of inherent differences in granulation characteristics of the cultivars. Altering the milling and postmilling procedures to produce equal yields of flours of uniform particle size distribution from wheats as diverse as the ones selected (and they were selected specifically because of their granulation differences) would be extremely difficult; moreover, the characteristics and properties of flours thus treated may well be grossly distorted. We recognize that the air-classified flours were not strictly comparable in composition to the patent flours or the fraction blends. However, we feel that the inherent characteristics of the cultivars' contributions to cake quality were represented in these flours in spite of the unavoidable differences in yield and composition. Since all flours in the series were products of uniform treatment (such as classifier setting and stock feed rate), we believe that the trends noted in cake volumes can be attributed to flour property differences rather than to manipulative differences.

Our findings suggest that a flour characteristic other than flour particle size per se may be a contributor to cake volume. This characteristic appears to be related to flour granulation; it is possible that the component governing flour granularity is also the determinant of cake quality (volume). The identity and mode of function of such a component must be determined in further research.

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Effects of Neutral Salts upon Wheat Gluten Protein Properties. I. Relationship Between the Hydrophobic Properties of Gluten Proteins and Their Extractability and Turbidity in Neutral Salts[1]

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ABSTRACT

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The effects of increasing concentrations of neutral monovalent sodium salts upon the extractability and turbidity of wheat gluten proteins was studied. At low salt concentrations ($< 0.05\,M$) extractability was almost independent of anion type. However at higher salt concentrations ($0.5-4.0\,M$), gluten protein extractability was highly dependent upon anion type and followed the lyotropic anion series (in increasing order): F^-, Cl^-, Br^-, ClO_4^-, SCN^-. Similar results were obtained by measuring the turbidity of $0.05\,M$ acetic acid-soluble gluten proteins after addition of various levels of salts. At low salt concentrations turbidity increased in the presence of all salts, but at higher salt concentrations turbidity was dependent upon anion type. Electrophoretic and amino acid analyses showed differences in the properties of the gluten proteins extracted by the various salts. These results suggested that at low salt concentrations the solubility and aggregation properties of gluten proteins are largely determined by ionic interactions, whereas at higher salt concentrations hydrophobic interactions predominate. In addition, wheat gluten proteins appear to vary widely in their hydrophobic properties.

In recent years increased interest has been shown in the potentially important effect of hydrophobic bonding upon the properties of gluten proteins. Green and Kasarda (1971) showed the presence of hydrophobic regions on the surface of α-gliadin by means of fluorescence spectroscopy and equilibrium dialysis with the hydrophobic probe *α-p*-toluidinylnaphthalene-6-sulfonate. From these results and other studies, Bernardin and Kasarda (1973) suggested that hydrophobic forces may stabilize gluten structure and thus play an important role in the rheological and baking properties of wheat flour.

Unfortunately the measurement of gluten protein hydrophobic properties has been difficult because of the lack of techniques of adequate specificity and sufficient sensitivity to differentiate the extent of these interactions. One technique that has proven useful in this regard has been hydrophobic interaction chromatography. Caldwell (1979) and Papineau and Godon (1978) have reported the fractionation of gliadin proteins on the basis of apparent hydrophobicity by deabsorption with various buffers from octyl and phenyl Sepharose C1-4B, respectively. Similar studies have also been reported by Chung and Pomeranz (1979), utilizing phenyl Sepharose C1-4B. Their results showed that glutenins from a poor-baking wheat variety were less hydrophobic than glutenins from a good-baking variety. In contrast, gliadins from the poor variety were more hydrophobic than those of the good variety. The results also suggested that glutenins were, in general, more hydrophobic than gliadins. Unfortunately deabsorbing some of the proteins from the column for further study proved difficult or impossible.

A second technique that may prove useful in studying hydrophobic interactions of gluten proteins is differential extractability with soaps. Recent studies by Kobrehel and Bushuk (1977) and Kobrehel and Matignon (1980) have shown differences in the extractability of flour proteins with different soaps at various concentrations.

Previous studies by Gortner et al (1928, 1929) showed that flour protein extractability varied widely in the presence of various inorganic salts. For both anions and cations, extractability followed the lyotropic (Hofmeister) series, with the effects of anions being more pronounced. At the Grain Research Laboratory we have been investigating the use of simple neutral salts of the lyotropic series to study the hydrophobic properties of gluten proteins. The use of these salts is based upon theoretical protein studies, reviewed by Von Hippel and Schleich (1969), Franks (1978), and Melander and Horvath (1977), which have shown that at ionic strengths sufficient to minimize electrostatic interactions, changes in protein properties due to variations in the concentration and nature of anions of the lyotropic series can be directly attributed to hydrophobic interactions. A potential advantage of this technique, compared to those discussed above, is that the salts exert their effects upon water structure by altering the free energy associated with the transfer of an apolar protein residues from a nonpolar to aqueous environment rather than by direct binding to hydrophobic sites on the protein. Thus, changes in protein properties such as extractability can be directly attributed to changes in the inherent hydrophobic properties of the protein

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