

The Relationship between Flour Particle Size and Cake-Volume Potential among Eastern Soft Wheats¹

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ABSTRACT

A high negative correlation has been found for white layer cake volume vs. mass-median diameter of laboratory-milled cake flours obtained from pure-variety wheats. Cake volume was also highly associated inversely with mass-median diameters of straight-grade and coarsely milled flours, and directly with the quantity of sifted meal from wheats milled to obtain patent flours for cake baking. Varietal differences in cake potential for these wheats thus appeared to be associated largely with inherent differences in endosperm friability.

A soft-wheat flour milled for high-ratio layer cakes usually consists of a blend of mill streams with the lowest ash and protein contents (1). Such a flour is normally finer in average particle size than the remaining streams. However, before being baked, the flour is usually further reduced in average particle size by passage through a pin mill or by other means, and is then treated with chlorine gas. The reaction between chlorine and flour has been shown to be surface-dependent (2), thus is more effective with flours of smaller average particle size than those with larger particles. While the action of chlorine in modifying various flour components is yet to be completely elucidated, the reaction between the gas and the starch fraction has been found to result in a hydrolytic depolymerization of the starch molecule (3). One of the results is thought to be an increase in the hydration properties of starch. At any rate, the cake-improving effect of chlorine on flour has been demonstrated repeatedly.

Under uniform conditions of laboratory milling, soft wheats exhibit endosperm-fracturing properties which are characteristic of variety (4). When such flours are further reduced in average particle size, such as by means of a pin mill, varietal differences in average particle size still persist (4). It appears probable, therefore, that the efficacy of chlorine treatment in improving cake potential remains a function of the variety from which the flour was milled.

This report presents data bearing on the possible relation between cake quality and certain flour particle-size parameters among Eastern soft wheats.

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MATERIALS AND METHODS

Wheats of variety sets grown at Wooster, Ohio, for the crop years 1963-1966, inclusive, were used in the study. Each set consisted of ten varieties: Comanche (HRW), Purkof (semi-HRW), Kawvale (semi-HRW), Clarkan (SRW), Trumbull (SRW), Fairfield (SRW), Thorne (SRW), Avon (SWW), [Anderson (SRW) in 1963], Blackhawk (SRW), and American Banner (SWW)—which represented the range in wheat properties normally encountered in a soft-wheat breeding program.

Various particle-size parameters for these wheats and their milled products were given in the previous publication (4). These included wheat particle-size index, and mass-median diameter (MMD) of flour obtained on the Quadrumat³ and Allis-Chalmers mills and pin-milled patent flour from an Allis-Chalmers mill. The 40 pin-milled patent-grade flours referred to in the publication (4) were treated with chlorine gas to bring flour pH to approximately 4.7. Each flour was baked in duplicate into white layer cakes, using the research-type cake formulation developed by Kissell (5) at optimum liquid-absorption levels for the individual flours. Cake volumes were obtained by a rapeseed displacement procedure. In independent bakes using the formulation, a least-significant-difference value at the 5% level of probability for duplicate bakes of 8.6 ml. was obtained in our laboratory.

RESULTS AND DISCUSSION

Table I presents correlation-coefficients data between cake volume and various particle-size parameters for the wheats and flours used in the study. It is interesting to note that adjustment of data for crop-year variation did not bring about large improvements in *r* values, except for the MMD of Allis-milled patent flours, for which the contribution of the association to total variance increased from 63 to 74%.

To ascertain the extent to which the associations between cake-volume potential and particle-size parameters were applicable to varieties, cake-volume and particle-size data for each variety were averaged and correlations were made using the mean values thus obtained. Figure 1 presents scattergrams and correlation coefficients for the various relationships. Varietal MMD of the pin-milled Allis-Chalmers patent flours was very highly correlated with varietal cake volume ($r = -0.94$) for the flours tested. Additionally, varietal particle-size index was significantly associated with varietal cake volume ($r = 0.88$).

TABLE I. CORRELATION COEFFICIENTS FOR RELATIONSHIPS BETWEEN CAKE VOLUME AND SEVERAL WHEAT AND FLOUR PARTICLE-SIZE PARAMETERS^a

Relationship	n	Pooled Data r	Data Adjusted for Crop year r
Cake volume vs.			
Wheat particle-size index	40	0.791	0.808
MMD Quadrumat flour	30	-0.766	-0.774
MMD Allis straight-grade flour	30	-0.725	-0.762
MMD Allis patent flour	40	-0.794	-0.862

^aFor ten varieties grown at Wooster, Ohio, 1963-1966 seasons. All coefficients are significant at the 0.1% level of probability.

³Quadrumat is a trademark of Brabender Instruments, Inc., South Hackensack, N.J.; Allis-Chalmers is a trademark of Allis-Chalmers, Milwaukee, Wis.

Some deductions may be drawn from the data. Endosperm softness or flour granularity is apparently a varietal trait. Under a given set of conditions for grain grinding or milling, varieties with grain endosperms that fracture more readily produce more fine flour than those with endosperms which are less friable. This varietal distinction carries through pin-milling, and presumably to other similar methods of particle-size reduction. Quadrumat-milled flour is on the average coarser than Allis-Chalmers-milled straight-grade flour, which in turn is coarser than pin-milled Allis-Chalmers-milled patent-grade flour. One can visualize the Quadrumat flour to include a relatively large quantity of multi-cell aggregates consisting of groups of protein matrices in which starch granules are entrained. Allis-Chalmers-milled straight-grade flour has fewer large aggregates because more of them have been reduced through roll compression and shearing action, resulting in the presence in flour of small aggregates, free starch, and free protein particles. Pin-milled patent-grade flour would be expected to include still fewer and smaller

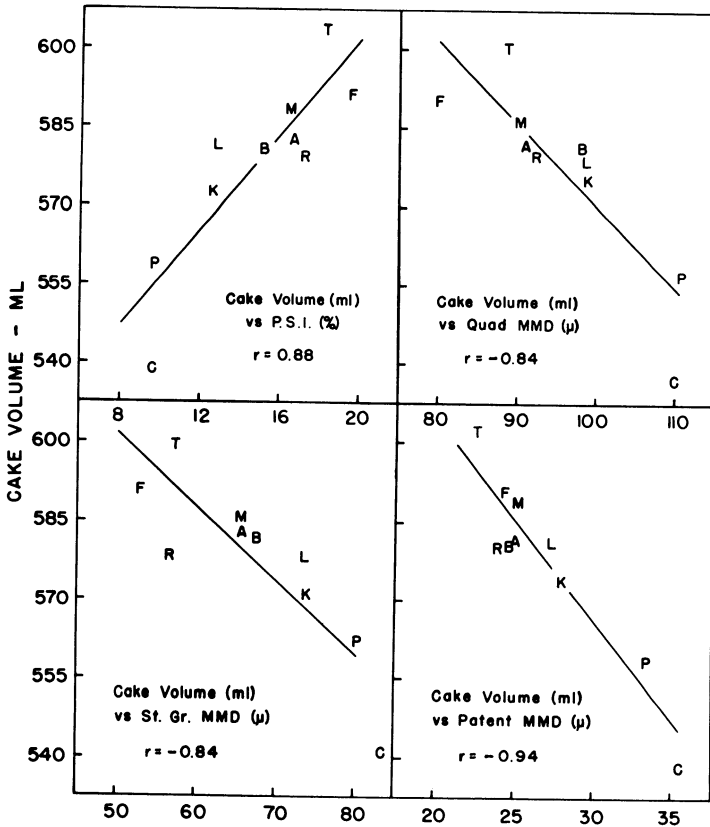


Fig. 1. Scattergrams and correlation coefficients for mean varietal cake volume vs. mean varietal particle-size parameters for ten varieties grown at Wooster, Ohio, of the 1963-1966 crops. Varieties represented are Comanche (C), Purkof (P), Kawvale (K), Clarkan (L), Trumbull (R), Fairfield (F), Thorne (T), Avon (A), Blackhawk (B), and American Banner (M).

aggregates and even more free starch and protein particles. Under conditions of relatively mild size reduction such as the above, limits of reduction are reached when discrete starch granules are released from the protein matrices, with the protein particles reduced to very small size because of their amorphous nature. Thus, the progressively smaller MMD attained by flour as a consequence of increasingly intensive size-reduction procedures may be considered to correspond to the increasing exposure of new starch surface by release of granules from the protein matrix. Likewise, the differences in MMD among flours from varieties which have undergone a given uniform milling procedure may be considered to be attributable to differential release of starch granules from the matrix.

Several investigators have pointed to the very significant improvement in cake volume when the starch fraction had been treated with chlorine and the reconstituted flour baked (6,7). Others have shown that flour treated with varying quantities of chlorine gradually improved in cake volume until the optimum quantity of chlorine had been reacted (8). On the basis of the observations and implications outlined above, it appears logical to believe that the efficacy of flour chlorination as reflected in cake volume is associated with the amount of free starch surface available for chlorination. Support for the conclusion is given by data (Fig. 1) showing that for wheats of different inherent granularity milled in a uniform manner, those granulating more finely tend to produce flours which, upon chlorination, show greater cake-volume potential. It is not to be implied that flour particle size and chlorination reaction are the sole contributors to cake volume. The cake test itself, together with flour properties and processing steps required to prepare the flour for baking, are sources of a large number of possible factors and interactions that may influence the final product. In view of this possibility, however, it is significant that flour particle size does relate to cake volume as well as it appears to do.

Of more than incidental relevance is the fact that certain cuts of an air-classified hard-wheat flour are known to bake cakes of excellent volume. For example, Wichser (9) showed that a lower-protein high-starch fraction was capable of producing a layer cake of high quality. A photomicrograph of the fraction showed a high proportion of free starch granules.

The high correlation found between wheat particle-size index and cake volume suggests that the kernel-texture test can be used in a soft-wheat evaluation program to ascertain the cake potential of a breeding line. With the development of a particle-size-index test which requires only 10 g. wheat (10), the test can be applied to samples available only in small quantities. This test, together with the protein and sifted-meal alkaline-water-retention-capacity tests, comprise a program which has been formulated to screen test lines for processing quality early in a breeding program (11).

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