Associations Among Soft Wheat Flour Particle Size, Protein Content, Chlorine Response, Kernel Hardness, Milling Quality, White Layer Cake Volume, and Sugar-Snap Cookie Spread[1]

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ABSTRACT

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Eighty-three soft red and white wheat test lines or cultivars were evaluated for several milling quality characteristics (kernel hardness, kernel and flour protein, flour ash), straight-grade and cake patent flour particle size, and cake patent flour chlorine response. Each characteristic was statistically evaluated for associations with sugar-snap cookie diameter and high-ratio white layer cake volume. An additional 136 soft wheats were included to evaluate associations among cookie diameter, flour particle size, and protein content. Across cultivars, both cookie diameter and cake volume were positively associated with soft textured wheats having lower protein contents, which produced more break flour and flour having smaller particle size. Wheats producing straight-grade flour with small particle size also tended to produce patent flours with small particles (both before and after pin-milling). Wheats having better milling quality were more coarsely granulating during milling and tended to produce smaller cakes and cookies. Wheats producing more break flour were finer granulating. Kernel hardness (particle size index) was not correlated with milling quality (endosperm separation index).

Soft wheat flour particle size is a heritable cultivar trait that is little affected by crop year (Donelson and Yamazaki 1972). Within a particular soft wheat flour, reduction of particle size during milling reduces cookie spread, presumably because starch is damaged during particle size reduction (Yamazaki 1959) or because the greater surface area increases dough absorption and subsequent dough viscosity during baking if dough liquid level is kept constant. Within a soft wheat patent cake flour, flour particle size has the opposite effect on cake volume, in that reduction in particle size (usually by pin- or turbo-milling) is beneficial to the size or overall quality of various types of layer cakes (Miller et al 1967). Increased starch damage resulting from such flour treatments after milling has some influence on high-ratio white layer and angel food cake size, but the main benefit of cake flour treatments after milling is particle size reduction (Gaines and Donelson 1985a). The effect of particle size on cake volume has been reported for a small group of cultivars (Yamazaki and Donelson 1972, Chaudhary et al 1981). These included hard and soft cultivars that introduced differences among wheat classes in addition to variation in particle size. Conclusions in the latter article were that a heritable factor that determines flour granularity may also determine differences in cake volume among cultivars and that the correlation between cake volume and flour particle size among cultivars may be incidental. That is not to say a known predictive relationship would not be useful.

The purposes of this study were to evaluate many soft red and soft white wheats grown in climatically diverse locations for associations among several commonly evaluated physicochemical properties (kernel hardness, milling quality, protein content) and two common end-use properties (cake volume and cookie spread) used as indexes of soft wheat flour quality, and to determine the strength and direction of the general associations among flour particle size and milling or baking quality across soft wheat cultivars.

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MATERIALS AND METHODS

Wheats

We evaluated a total of 219 soft red winter and soft white winter wheat test lines and cultivars grown at 17 nurseries in the eastern United States. Eighty-three wheats were evaluated as one set, and 136 were later added to increase the total sample number so that statistical significance in the correlation of flour particle size and cookie diameter could be observed. All wheats were from the 1983 crop year.

Three location composites and 136 test lines and released cultivars were milled and evaluated. The three location composites were of: 34 soft red winter wheat test lines grown in 11 northern midwestern and southeastern U.S. nurseries, 32 soft red winter wheat test lines grown in 11 southeastern U.S. nurseries, and 17 soft white winter wheat test lines grown in one Canadian and two northern midwestern U.S. nurseries.

Milling and Flour Preparation

Straight-grade and 50% patent cake flours were milled from 1,500–2,500 g of cleaned, sound, unshriveled wheat on an Allis-Chalmers mill by the method of Yamazaki and Andrews (1982). Break flour yield (from six break passes), straight-grade flour yield, and endosperm separation index (ESI) (Yamazaki and Andrews 1982) were obtained. ESI is calculated from the combined weight of the "overs" of 32-, 43-, and 54-mesh screens after the third, fourth, and fifth break passes, respectively, along with the overs of a 40-mesh screen after the first reduction pass. This combined weight is added to the weight of bran, and from this total, 17% (theoretical weight of bran and germ) is substracted. That is the ESI value. Patent cake flours were pin-milled on an Alpine Kolloplex model 160-Z pin mill at 9,000 rpm and treated with chlorine gas to pH 4.8 (Kissell and Marshall 1972). Chlorine response was the amount of gas needed to achieve pH 4.8 and is reported as cubic centimeters per gram. Sublots of cake flours were evaluated before pin-milling and chlorination.

Flour Analysis

The particle size index (PSI) of wheat kernels was adjusted to PSI at 11% moisture (Yamazaki and Donelson 1983). Kernel and flour protein and ash contents (AACC 1983) were adjusted to a 14% moisture basis. Flour particle size profile measurements were reported from a Microtrac Model 7991-0 Particle Size Analyzer (Leeds and Northrup) with a dry powder attachment; these data are the mean volume diameter (MVD), which is the mean diameter of the volume of sample detected by the instrument. Protein and ash contents were determined by AACC methods 46-12 and 8-01, respectively (1983).

Baking

High-ratio white layer cakes were prepared at the optimum liquid level using AACC method 10-90 (1983) but scaling the recipe to one-half. Batter weights were 425 g as prescribed. Sugar-snap cookies (Finney et al 1950) were prepared with the dough liquid level optimized for handling properties. Cookie diameters are the mean of two cookie widths. Reported cake and cookie data are the means of duplicate values. Room temperature was controlled at 21 ± 1°C, and relative humidity ranged from 34 to 48%.

RESULTS AND DISCUSSION

Mean values and ranges of the various wheat and flour analyses of 83 soft red and white wheats (Table I) covered the normal values for soft wheats at our laboratory (except for PSI values, which are slightly high). The ranges and resulting correlation coefficients could have been increased by including hard wheats, but those values would be atypical in terms of soft wheat quality.

Straight-Grade, Patent, and Pin-Milled Patent Flour Particle Size

Correlation coefficients were determined among all data (Table II). The particle size (MVD) of the straight-grade flours, cake flours that were not pin-milled, and pin-milled cake flours were positively correlated, meaning that wheats that are finer granulating as a straight-grade flour will be generally of smaller particle size as a 50% patent flour, even after pin-milling that reduces MVD by approximately one-half. A smaller flour particle size was generally associated with larger cakes and cookies, lower protein content, more break flour yield, and softer textured wheats. Smaller straight-grade flour particle size was generally associated with lesser milling quality (higher ESI values).

Flour Yield and Milling Quality

Approximately 58% of each cake flour was break flour (having received no reduction side passes). The amount of break flour produced was negatively correlated with flour particle size, indicating that wheats yielding more break flour are usually finer granulating. Those wheats also tended to produce larger high-ratio white layer cakes. Break flour yield was not correlated with straight-grade flour yield, although the respective flour MVDs were correlated. Break flour yield is influenced by inherent flour granularity, whereas straight-grade flour yield depends on the ease of separation of endosperm from bran flakes. That is why the ESI statistic was developed (Yamazaki and Andrews 1982). The lower the ESI value the better is the milling quality. In this study, ESI is used as the main milling quality statistic. ESI was negatively correlated with straight-grade flour yield and MVD. The latter correlation shows that the better milling soft wheats tend to produce coarser granulating flour. However, those coarser flours from better milling wheats tend to produce cakes with smaller volumes. Indeed, ESI and cake volume were positively correlated.

Kernel Hardness

Soft wheat milling quality (as measured by ESI) was not correlated with kernel hardness (as measured by PSI). However, kernel hardness was correlated with many other soft wheat characteristics. Softer wheat kernels were lower in protein content, produced smaller flour particle size and more break flour, baked larger cakes and cookies, and required less chlorine to achieve pH 4.8 in cake flours.

Protein and Ash Contents

Lower protein wheats generally produced larger cakes and cookies and smaller flour particle size and required more chlorine to achieve pH 4.8. More chlorine may have been needed because of the increased surface area of the smaller particles from lower protein wheats. Why more chlorine was needed by harder textured kernels is unknown. Chlorine response apparently is independent of the factor(s) controlling the correlation between kernel hardness and protein content. Lower protein wheats generally had softer kernel texture and better milling quality and produced more break flour. In this study, straight-grade and cake flour ash contents were not significantly correlated with the other flour quality characteristics studied.

Cookie Spread

Positive associations were found among cookie diameter, break flour yield, and PSI. Although cookies (from 83 flours) were made from straight-grade flour, cookie diameter was not correlated with straight-grade flour particle size, yield, or protein content. For the 83 flours, cookie diameter was negatively correlated with wheat and cake flour protein contents as well as with cake flour particle size. That latter correlation suggested that the sample size should be increased to observe associations among cookie spread and straight-grade flour particle size and protein content. Therefore, 136 additional soft wheat samples were included in the correlation, and significantly negative correlations were observed between cookie diameter and straight-grade flour MVD ($r = -0.31$, $P = 0.001$, n = 219) and between cookie diameter and straight-grade flour protein content ($r = -0.32$, $P = 0.001$, $n = 219$).

Yamazaki (1959) observed that, *within* a cultivar, smaller cookies resulted when flour particle size was reduced and starch damage increased. However, in this study of many cultivars and composites, flours having generally smaller particle size baked larger cookies. These observations have also been reported of cookies made from whole wheat flours (Gaines and Donelson 1985b).

Cake Volume

Larger cake volume generally resulted from softer textured wheats with lower protein content, which produced smaller flour particle size on milling. Those wheats also tended to have lesser milling quality. In this study, no significant correlation was observed between cake volume and cookie diameter or the amount of chlorine required to achieve pH 4.8.

CONCLUSIONS

Greater cake volume and larger cookie spread are generally associated (among cultivars) with soft textured wheats of low protein content, which produce high break flour yield and have smaller flour particle size. The heritable trait of relative straight-grade flour particle size generally extends to 50% patent cake flours before and after pin-milling. Wheats having better milling quality are generally coarsely granulating during milling and, in general, produce smaller cakes and cookies. Soft wheats that are finer

TABLE I
Range and Mean Values of 15 Quality Characteristics of 83 Soft Red and White Winter Wheats

Analyses	Range[a]	Mean[a]	Pooled Standard Deviations[b]
Cake volume (cm^3)	951–1,098	1,018	±9.2
Cake flour particle size (μ)			
Pin-milled	35.5–51.7	41.8	±1.64[c]
Not pin-milled	67.0–85.4	75.2	±1.80[c]
Cake flour protein (%)	6.2–10.4	8.6	±0.06
Cake flour ash (%)	0.249–0.321	0.286	±0.0027
Chlorine response (cc/g)	2.03–3.52	2.82	...[d]
Cookie diameter (cm)	17.3–18.8	17.9	±0.10
Straight-grade flour			
Particle size (μ)	68.8–83.4	77.1	±1.60[c]
Protein (%)	7.0–11.4	9.3	±0.05
Ash (%)	0.347–0.414	0.378	±0.0031
Yield (%)	74.1–78.0	75.8	±0.31
Wheat protein (%)	8.0–12.7	10.6	±0.07
Particle size index (%)	39.8–68.3	51.0	±0.99
Endosperm separation index (%)	8.8–14.5	11.0	±0.36
Break flour yield (%)	27.6–40.7	32.0	±0.57

[a] Range and mean of 83 wheats.
[b] Mean of duplicate observations, except as noted.
[c] Mean of four observations.
[d] Single observation only.

TABLE II

Correlation Coefficients[a] Among Various Milling, Baking, and Wheat Kernel Quality Characteristics

Source	Cake Volume	Cookie Diameter	Straight-Grade Flour Particle Size	Cake Flour Particle Size: Not Pin-Milled	Cake Flour Particle Size: Pin-Milled	Wheat Protein	Straight-Grade Flour Protein	Cake Flour Protein	Flour Yield: Straight-Grade	Flour Yield: Break	Particle Size Index	Endosperm Separation Index	Chlorine Response
Cake volume	...												
Cookie diameter	ns	...											
Straight-grade flour particle size	−0.52	−0.31[b]	...										
Cake flour particle size													
Not pin-milled	−0.42	−0.46	0.48	...									
Pin-milled	−0.57	−0.34	0.51	0.67	...								
Wheat protein	−0.27	−0.25	ns	0.51	−0.46	...							
Straight-grade flour protein	−0.25	−0.32[b]	ns	0.45	0.40	0.96	...						
Cake flour protein	−0.24	−0.22	ns	0.48	0.37	0.95	0.97	...					
Flour yield													
Straight-grade	ns	ns	0.28	ns	ns	ns	ns	ns	...				
Break	0.45	0.30	−0.55	−0.81	−0.70	−0.61	−0.56	−0.56	ns	...			
Particle size index	0.61	0.34	−0.55	−0.72	−0.75	−0.55	−0.44	−0.44	ns	0.73	...		
Endosperm separation index	0.30	ns	−0.29	ns	ns	0.24	0.22	ns	−0.83	ns	ns	...	
Chlorine response	ns	ns	ns	−0.41	−0.29	−0.68	−0.72	−0.73	ns	0.46	−0.72	ns	...

[a] $n = 83$; ns = not significant at the 0.05 level of probability.
[b] $n = 219$.

granulating during standardized milling tend to produce larger cookies, but if the particle size of any particular flour is reduced by a more severe milling treatment, cookie size will decrease. Those results suggest that soft wheat flour particle size analysis can be a useful indicator of general cake and cookie flour quality if the milling procedure is standardized. The opposite or counter influence of flour particle size on milling and baking qualities suggests the continued need for cultivar testing to maintain development of soft wheat cultivars that have both good milling and baking qualities.

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