Influence of Certain Flour Quality Parameters and Postmilling Treatments on Size of Angel Food and High-Ratio White Layer Cakes[1]

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ABSTRACT

Heights of angel food cakes from 23 Allis-Chalmers laboratory-milled, Miag laboratory-milled, and commercially milled cake patent flours were not statistically correlated with high-ratio white layer cake volume, MacMichael viscosity, alkaline water retention capacity, protein, or ash contents. Milling method, pin-milling, turbo-milling, starch addition, and flour chlorination all influenced angel food cake height and/or white layer cake volume. Postmilling cake flour treatments usually reduce particle size and increase starch damage. In this study improvement of white layer cake volume and angel food cake height resulted from reduction of flour particle size rather than increased starch damage. It appears that angel food cake flour must be chlorinated to exhibit significant improvement in cake size from postmilling particle size reduction.

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With the goal of improving the suitability of hard wheats for use in cake production, several researchers have evaluated the influence of certain postmilling flour treatments on the quality of various types of cakes made from several classes of wheat. Of these treatments, air classification and pin-milling were often used (Wichsen 1958, Pence et al 1968, Bean et al 1969). However, cake flours may also be turbo-milled and sequentially air classified to improve white layer cake made from hard wheats (Hanamoto and Bean 1981). In addition, the dilution of protein in hard red spring wheat flour by the substitution of starch for a portion of a pin-milled, air-classified flour fraction has also been reported (Hayashi et al 1976). This improved lean-formula white layer cake score but showed inconsistent improvement in cake volume. Dubois (1959) reported that angel food cake height and overall quality could be dramatically improved by substitution of up to 30% wheat starch for soft wheat cake flour.

Miller et al (1967) examined the effects of pin-milling cake flour on white layer cakes. The authors concluded that layer cake score can be improved by reducing flour particle size to a minimum, but starch damage must simultaneously be kept as low as possible (below 5% in their study).

The granularity of soft wheat flours varies considerably among cultivars. Flour granulation after milling and pin-milling of eastern soft wheat cultivars has been shown to be a heritable trait, with finer granulating flours generally producing larger lean-formula white layer cakes (Yamazaki and Donelson 1972, Chaudhary et al 1981).

This study evaluates the effects of combinations of pin-milling, turbo-milling, chlorination, starch substitution, particle size reduction, and starch damage on white layer and angel food cake flours milled (laboratory and commercial) from soft wheats from the eastern United States. Also evaluated are possible predictive relationships between angel food cake height and various characteristics of soft wheat flour quality, especially white layer cake volume.

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MATERIALS AND METHODS

Flours

Twenty-nine soft wheat 50% patent cake flours were obtained by laboratory milling on an Allis-Chalmers (Yamazaki and Andrews 1982) or a Miag Multomat mill or were obtained from commercial sources. The flours therefore represented a wide variation in milling styles and cake flour quality. Flour protein ranged from 6.7 to 11.5%, and ash ranged from 0.25 to 0.41%. Unless otherwise stated, laboratory flours were passed through a 120-mesh (145 μm) screen. Portions of three flours were turbo-milled on a Pillsbury Hurricane model H-7 turbo-grinder, and portions of these flours were air-classified with a Pillsbury Hurricane turbo-separator model T-11. Air-classified flours used were the coarse-size fractions representing approximately 95% of the original flour and had a reduction in protein content of approximately 1%. Pin-milled flours were processed on an Alpine Kolloplex model 160-Z pin mill at 9,000 rpm unless otherwise stated. Flours were chlorinated to approximately pH 4.8 unless otherwise stated.

Flour Quality Analyses

Adjusted MacMichael viscosities were determined by a modification of AACC method 56-80 (1979). Viscosity measurements were made on a Brookfield viscometer, converted to degrees MacMichael, and then to 0.42% ash and 10% protein levels. Alkaline water retention capacity (AWRC) was determined by the procedure of Yamazaki et al (1968). Damaged starch content was measured according to Donelson and Yamazaki (1972). Flour protein and ash contents were determined by AACC methods 46-12 and 8-01, respectively. All data are means of duplicate determinations. Flour particle-size measurements were made with a Microtrac model 7991-0 particle-size analyzer (Leeds and Northrup Co.), using a dry powder attachment.

Cakes

High-ratio white layer cakes were prepared according to AACC method 10-90 (1979). Angel food cakes were baked according to AACC method 10-15, except that spray-dried egg-white solids without sodium lauryl sulfate were used. Data are means of duplicate bakes, and least significant differences (LSD) were determined for white layer cake volume, angel food cake height, starch damage, AWRC, and particle mean volume diameter.

RESULTS AND DISCUSSION

Postmilling Treatments vs. Flour Particle Size

Pin-milling at 9,000 rpm slightly reduced the upper half of the distribution for flour particle size and eliminated the typical bimodal distribution pattern of an untreated 50% patent flour (Fig. 1). Pin-milling at 18,000 rpm reduced the range of particle size by approximately one-half and greatly increased the volume percentage of flour between 10 and 40 μm. The turbo-mill reduced the range of particle size by two-thirds and also increased the volume percentage of particles between 10 and 40 μm.

Angel Food Cake Height vs. Flour Quality Parameters

To determine whether angel food cake height can be predicted from characteristics of flour quality routinely evaluated by this laboratory, correlation coefficients were calculated for angel food cake height, high-ratio white layer cake volume, adjusted MacMichael viscosity, AWRC, ash, and protein content for 23 flours (Table I). No significant correlation was observed. In another study, however, flour protein changes were inversely correlated with angel food cake height, but white layer cake volume was not affected (Gaines and Donelson 1985). In this study as well, no significant correlations were found between the flour characteristics measured and white layer cake volume. There was, however, a small but significant correlation (0.67, $n = 18$, $P = 0.01$) between white layer cake volume and angel food cake height for flours milled in this laboratory. Although seven were Miag milled and 11 were Allis-Chalmers milled, these flours received the same postmilling treatment (9,000 rpm pin-milling). Angel food cake height also appeared to be influenced by the method of milling. Mean angel food cake heights for Allis-Chalmers, Miag, and commercially milled flours were 6.5, 7.3, and 8.5 cm, respectively. These measurements suggested a possible influence on angel food cake size of flour particle size or starch damage resulting from milling procedures or postmilling flour treatments.

To investigate effects on cake size, four flours were treated with combinations of milling variations, pin-milling, turbo-milling, air classification, starch addition, and chlorination (Table II). Damaged starch content, AWRC, and flour particle mean diameter were examined as indexes of the severity of flour treatments.

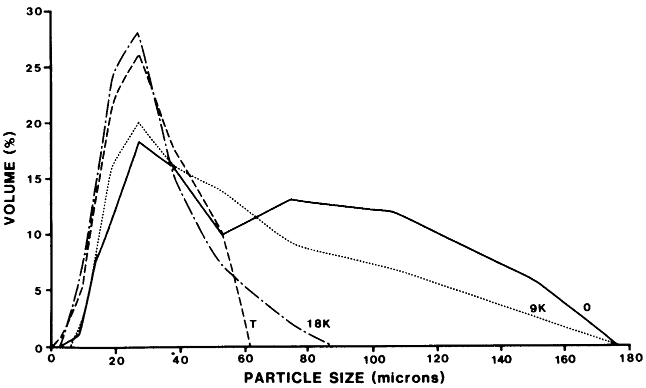

Fig. 1. Typical particle-size distributions of a flour with no postmilling treatment (——), a 9,000 rpm pin-milled flour (····), an 18,000 rpm pin-milled flour (– · –), and a turbo-milled flour (– – –).

TABLE I
Milling Method, Protein and Ash Contents, Alkaline Water Retention Capacity (AWRC), MacMichael Viscosity, White Layer Cake Volume, and Angel Food Cake Volume of 23 Soft Wheat Flours

Flour	Protein (%)	Ash (%)	AWRC (%)	Adjusted MacMichael Viscosity (°M)	White Layer Cake Volume[a] (cm³)	Angel Food Cake Height[b] (cm)
Miag milled						
1	10.6	0.32	58.7	···	1,113	7.0
2	7.7	0.31	54.2	58	1,093	7.1
3	7.8	0.31	55.2	45	1,094	7.9
4	11.5	0.35	57.9	168	1,031	6.0
5	10.1	0.35	59.4	77	1,100	8.2
6	8.2	0.30	56.4	56	1,081	7.9
7	7.3	0.28	58.4	···	1,137	7.3
Allis-Chalmers milled						
8	9.2	0.31	50.1	31	1,021	7.5
9	9.6	0.28	50.8	47	1,034	5.8
10	9.7	0.30	49.7	51	975	6.2
11	9.1	0.30	50.1	44	1,011	6.0
12	7.5	0.28	53.2	26	1,047	6.4
13	7.7	0.27	51.1	48	1,040	6.3
14	8.2	0.25	52.8	80	1,065	7.2
15	10.0	0.28	54.1	78	1,074	6.9
16	9.1	0.30	52.4	60	1,025	6.0
17	8.6	0.27	52.6	51	1,052	7.3
18	9.5	0.27	52.7	102	1,030	6.3
Commercially milled						
19	9.3	0.37	60.2	···	937	9.1
20	8.2	0.35	58.9	53	1,025	8.6
21	6.7	0.37	85.2	130	999	8.3
22	7.0	0.38	88.6	143	1,025	8.0
23	7.7	0.41	···	···	1,005	8.6

[a]Least significant difference for white layer cake volume = 17.2 cm³.
[b]Least significant difference for angel food cake height = 0.42 cm.

TABLE II
Order of Milling Variation, Postmilling Flour Treatment, White Layer Cake Volume, Angel Food Cake Height, Starch Damage, Alkaline Water Retention Capacity (AWRC), and Flour Particle Size of Six Soft Wheat Flours

Flour	Treatment Order[a]	White Layer Cake Volume[b] (cm³)	Angel Food Cake Height[b] (cm)	Starch Damage (%)	AWRC[b] (%)	Particle Mean Volume Diameter[b] (μm)
A	U	840 a	7.7 a	2.5 ab	55.2 a	44.8 e
	U,T	889 b	7.9 abc	3.2 d	59.7 bc	28.7 ab
	U,T,C	942 c	8.2 bcd	2.8 c	58.4 b	28.9 abc
	U,T,C,B	1,089 e	9.3 f	2.7 bc	61.7 d	30.7 bc
	U,T,B	1,097 e	8.6 de	3.1 d	60.5 cd	28.2 a
	9K,B	1,048 d	8.1 ab	2.5 a	55.9 a	39.1 d
	U,T,B+30%S	···	9.2 f	2.7 bc	···	27.4 a
B	9K,B	975 a	6.8 a	1.9 a	53.6 a	45.7 a
	9K,B,T	1,086 c	7.7 b	2.5 b	58.1 b	27.6 b
	9K,B,C	1,038 b	6.5 a	1.9 a	53.6 a	42.4 c
	9K,B,T,C	1,121 d	7.9 b	2.3 b	58.0 b	28.2 b
C	9K,B	1,010 b	6.5 b	2.1 a	52.3 a	45.0 a
	9K,B,T	1,081 c	7.8 c	2.2 a	58.3 c	27.9 b
	9K,B,T,C	1,109 d	7.8 c	2.2 a	58.4 c	29.3 b
	9K,B,B	979 a	5.9 a	2.0 a	56.5 b	···
D	9K,B	1,019 a	6.8 ab	2.0 a	52.6 a	44.1 e
	9K,B,18K	1,103 b	7.3 ce	3.2 c	58.4 b	24.1 a
	9K,B+15%S	···	7.0 abc	2.0 a	···	44.0 e
	9K,B+22.5%S	···	7.1 bc	1.9 a	···	43.0 e
	9K,B+30%S	···	7.6 de	1.9 a	···	40.2 cd
	9K,B+37.5%S	···	7.9 f	1.9 a	···	39.2 c
	9K,B+45%S	···	8.9 h	1.9 a	···	40.6 cd
	9K,B+15%BMS	···	6.6 a	3.1 c	···	41.5 de
	9K,B+30%BMS	···	7.3 cd	4.2 d	···	36.6 b
	9K,B,18K+30%S	···	8.4 g	2.8 b	···	25.3 a
E	U	···	5.9 a	2.2 a	51.2 a	52.0 a
	U,18K	···	5.9 a	3.2 b	62.1 b	25.6 b
F	9K,B	1,017 a	7.2 a	1.9 a	57.1 a	36.3 a
	0,9K,B	1,010 a	7.0 a	2.4 b	67.8 c	51.0 b
	F,9K,B	1,079 b	7.9 b	1.9 a	59.8 b	29.0 c

[a]Letters represent order of flour treatment: U = unchlorinated, T = turbo-milled, C = air classified, B = chlorinated, 9K = pin-milled at 9,000 rpm, 18K = pin-milled at 18,000 rpm, S = substitution with prime starch, BMS = substitution with ball-milled starch containing 9.4% damaged starch, 0 = overs of a 270-mesh (53 μm) screen, F = through a 270-mesh screen.
[b]Means of each flour followed by the same letter are not significantly different at the 0.05 level of probability. LSD (least significant difference) for white layer cake volume = 19.8 cm³. LSD for angel food cake height = 0.46 cm. LSD for starch damage = 0.23%. LSD for AWRC = 1.6%. LSD for mean diameter = 2.20 μm.

Postmilling Treatments vs. Flour Chlorination

Flour A was a Miag-milled 50% patent cake flour. The size of white layer and angel food cakes progressively increased as flour A was turbo-milled, air classified, and chlorinated. Turbo-milling unchlorinated flour A did not significantly increase angel food cake height, even though damaged starch and AWRC increased and particle size decreased. Air classification or chlorination was required to significantly increase angel food cake height of this unchlorinated flour. Flour that was not turbo-milled did not produce larger angel food cakes after pin-milling at 9,000 rpm and chlorination to pH 4.8, although white layer cake volume improved. Pin-milling and chlorination also did not change the damaged starch content or the AWRC significantly, but particle size decreased slightly. However, chlorination of either the turbo-milled or the turbo-milled and air-classified flours greatly increased the size of both white layer and angel food cakes.

Flours B and C were patent, Allis-Chalmers-milled flours that were blends of nine and 10 cultivars, respectively. First they were pin-milled and chlorinated, then subjected to turbo-milling or air classification or both. Whereas turbo-milling unchlorinated flour A had no significant effect on angel food cake height, turbo-milling chlorinated flours B and C dramatically increased cake height. Also contrary to the response of flour A, air classification of chlorinated flours B and C produced no increase in angel food cake height, regardless of whether the flour was previously turbo-milled.

Because cake size and starch damage of chlorinated flours A, B, and C were increased by turbo-milling, flour D was pin-milled at the increased speed of 18,000 rpm. This also dramatically increased angel food cake height, white layer cake volume, damaged starch content, and AWRC, and reduced flour particle size to a level equivalent to turbo-milling. However, when unchlorinated flour E was pin-milled at 18,000 rpm, no increase in angel food cake height occurred. Turbo-milling also did not produce significant improvement in the angel food cake height of unchlorinated flour A. These data suggest that turbo-milled or flours pin-milled at higher speed must be chlorinated to improve angel food cake size significantly.

It is well known that cake flour chlorination increases volume of layer cakes. However, chlorination of eight of the flours from Table I (data not shown) did not increase mean angel food cake height (unchlorinated height = 7.2 cm, chlorinated height = 7.1 cm, $n = 8$). Flour chlorination did produce a much finer and more desirable angel food cake crumb structure, as reported by Harrel (1952).

Flour Particle Size vs. Starch Damage

White layer cakes responded to turbo-milling and air-classification of flours B and C with significantly increased volume. These treatments combined produced the largest layer cakes from flours B and C. Chlorination to pH 4.3 has been recommended for angel food cake flour (Yamazaki and Lord 1971); however, an additional bleaching of flour C to pH 4.2 significantly reduced the size of both white layer and angel food cakes. There was no significant difference in the starch damage of flour C regardless of whether it was turbo-milled, yet turbo-milling increased the size of both types of cakes. Thus, reduced particle size rather than increased starch damage appeared more important in maximizing cake size.

Flour F was a pin-milled, chlorinated patent flour milled three ways on an Allis-Chalmers mill. The first was the usual milling procedure of passing the flour through a 120-mesh (145 μm) screen. A portion of this flour was remilled up to eight passes through the smooth rolls to produce a flour that passed through a 270-mesh (53 μm) screen. The overs of the 270-mesh screen were used as the third flour. The flour that passed through the 270-mesh screen did not significantly differ in starch damage from the flour passed through the 120-mesh screen, though it had a smaller particle size. This flour with finer particle size produced significantly increased volume in white layer cakes and height of angel food cakes. Because the overs of the 270-mesh screen were ground eight times to produce the throughs in sufficient quantity, the overs had significantly increased starch damage and AWRC but did not show increased cake size. The larger particle size of the overs probably resulted from some flaking from the eight passes through the smooth rolls. These data also suggest that flour particle size is more important than damaged starch content in improving the cake size of a given flour.

Starch Substitution vs. Starch Damage

When 30% wheat starch was substituted for turbo-milled and chlorinated flour A, angel food cake height increased and starch damage decreased to levels equivalent to those of air-classified flour A. Thirty percent starch also increased angel food cake height and decreased damaged starch of the 18,000 rpm pin-milled flour D. When 15–45% starch was substituted for flour D, starch damage levels remained constant but angel food cake height steadily increased. Increasing damaged starch levels of flours containing 15 and 30% starch substitution by using ball-milled starch (9.4% starch damage) did not increase angel food cake height. Although the additional factors of protein and perhaps flour lipid dilution are involved, these data also indicate that increased starch damage is not the main factor involved in the beneficial effects of turbo-milling or pin-milling. The effect of flour lipids on angel food cake quality requires further research.

CONCLUSIONS

As with high-ratio white layer cakes, it is not possible to predict angel food cake height solely from the flour quality characteristics measured in this study or from white layer cake volume. Some cake flour milling methods and postmilling treatments increase angel food and white layer cake size by reducing flour particle size rather than by increasing starch damage. Chlorinated, 50% patent angel food and high-ratio white layer cake flour potential is increased by a postmilling treatment more severe than pin-milling at 9,000 rpm. Angel food cake height is very dependent on the severity of postmilling flour treatments. These treatments also require flour chlorination to exhibit cake height improvement.

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