Age-Related Changes in the Cake-Baking Quality of Flour Milled from Freshly Harvested Soft Wheat[1]

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ABSTRACT

We monitored the milling and cake-baking quality of freshly harvested soft red winter wheat composites from two crop years over a 16-week period after harvest. In both years, composites of three varieties were milled biweekly, and a portion of the flour was chlorinated immediately after milling. The quality of white layer cakes produced from the untreated and chlorinated flours was assessed over a two-week period following each milling. Flour particle size analyses indicated that the kernels did not become harder with time after harvest. Regardless of chlorination, freshly milled flours produced batters with high specific gravity. Batter specific gravity decreased greatly during the first two days after milling and continued to fall thereafter at a lower rate. Immediately after milling, all flours (regardless of chlorine treatment) produced collapsed cakes. The cake-baking quality of the flours improved with both wheat and flour age. Flour milled from freshly harvested soft wheat changed rapidly in the time immediately after milling. The rate of postmilling changes slowed as a function of prior wheat storage time. Chlorine treatment improved cake-baking quality and dampened but did not prevent the observed postmilling fluctuations in quality.

The uncontrolled variation in product quality that often accompanies the introduction of freshly harvested or "new-crop" wheat is widely recognized but poorly understood. The annual introduction of flour milled from new-crop wheat compels manufacturers of dry bakery mixes to adjust formulations and/or processing conditions several times to reestablish and maintain product quality. This approach is time-consuming and often less than completely successful.

Before the new-crop phenomenon can be dealt with, its fundamental causes must be understood. This cannot be done until the changes that occur in the raw materials (wheat and/or flour) and in the products (cake and bread) are identified and quantified. Previous work relating to this phenomenon is sparse (Shellenberger 1939, Jones and Gersdorff 1941, Bayfield et al 1943, Bothast et al 1981, Clements and Donelson 1982). In spite of the importance of changes in end-product quality associated with wheat or flour age, no rigorous studies have documented them.

The studies presented here were undertaken to identify and measure changes in the properties and performance of soft wheats and their flours as a function of both wheat age and flour age. The milling and cake-baking properties of flours milled from newly harvested or stored soft wheats were followed over two crop years.

MATERIALS AND METHODS

Wheat Sample Analysis and Storage

The study covered the 1988 and 1989 crop years. Three cultivars of soft red winter wheat (*Triticum aestivum* L.) were obtained immediately after harvest from Greis Seed Farm (Fremont, OH). Cultivars Caldwell, Becker, and Cardinal were used for year 1 studies, and cultivars Caldwell, Becker, and Hillsdale were used for year 2 studies. The moisture, protein (N $\times$ 5.7), and ash contents of the wheats were determined by AACC methods 44-40, 46-12, and 08-01 (AACC 1983), respectively.

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To prepare composites, we blended equal amounts of the three cultivars in each year. The composites were cleaned by repeated passage through a Carter dockage tester (Carter-Day Company, Minneapolis, MN) fitted with a no. 2 riddle. Aliquots of 7,000 g (as-is) were sealed in polyethylene bags and stored at 25 ± 3°C for subsequent milling and testing. Wheat samples were removed for milling and analysis at two-week intervals over a storage period of 16 weeks.

Milling and Chlorination

A reference sample of the wheat composite was initially milled to determine the roll gaps necessary to obtain the following break releases (calculated as percentage of a 200-g sample sifted through a 20-light-wire screen after 30 sec): first break, 35%; second break, 45%; third break, 40%; fourth break, 20%; and fifth break, 30% (cleanup). Roll gaps for sizing, second sizing, and first tail were set at 0.01, 0.0076, and 0.0076 cm, respectively. All other roll gaps were adjusted to produce maximum flour. Once gaps were determined from the reference sample, they were held constant for all remaining millings.

Wheat aliquots (7,000 g, as-is) were tempered overnight to 15.5% moisture content and milled on a Ross experimental mill (Ross Machine and Mill Supply, Inc., Oklahoma City, OK) to approximately 70% extraction using the flow shown in Figure 1. This mill flow was designed to produce a flour identical in granulation to a commercial cake flour (Mennel Milling Co., Fostoria, OH). When necessary, flour was dried after milling at ambient temperature to 11.5% moisture content.

The pH of the flour was measured immediately after each milling (AACC method 02-52 [AACC 1983]). A portion of the flour was chlorinated to pH 4.6 ± 0.1 with a laboratory-scale chlorinator constructed as described by Kissell and Marshall (1972). The process involved two steps. Initially, 0.3 ml of Cl_2 per gram of flour was vented into the flour, and the pH of a 10-g (as-is) aliquot of the treated flour was measured in order to calculate *R*, the pH response factor (Kissell and Marshall 1972). Then the *R* value was used to calculate the amount of chlorine necessary to reduce the pH to the desired value of 4.6, and that volume was vented into the flour.

Flour Storage

Immediately after treatment, both chlorinated and unchlorinated flours were divided into 2,400-g aliquots, which were sealed into individual polyethylene bags and stored at ambient temperature (25 ± 3°C). Samples were removed from storage and tested at two-day intervals during the storage period of 14 days.

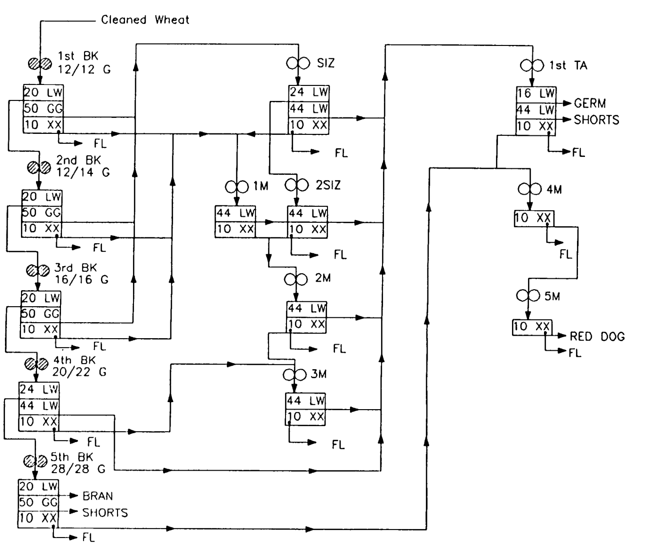

Fig. 1. Schematic diagram of the mill flow system used to produce experimental flours.

Particle Size Distribution

Flour particle size distribution was analyzed in triplicate with an Alpine air sifter (Alpine, Augsburg, Germany) equipped with U.S. sieves nos. 400 (38-μm), 200 (75-μm), 140 (106-μm), and 100 (150-μm). Results were expressed as the percentage of the 200-g sample retained on each sieve.

Cake Baking

Optimum absorptions were determined separately for untreated and chlorinated flours one day after the first milling of each crop year and were maintained at those levels for the subsequent 16-week study period. Cakes were prepared immediately after milling and one, three, seven, 10, and 14 days after each milling.

Eight-inch white layer cakes were prepared in duplicate according to AACC method 10-90 (AACC 1983) from freshly milled flour and from flour samples stored for up to 14 days after each milling. Batter was mixed in a Hobart mixer (Hobart Corporation, Troy, OH). Batter specific gravity was determined with a container of known volume and was reported as the ratio of batter weight to an equivalent volume of water. The means of duplicate readings were reported. Cake weight and volume (obtained by rapeseed displacement) were determined after cakes were baked and cooled. Cake uniformity and symmetry indices were determined with the AACC cake template (method 10-91 [AACC 1983]). Crumb grain of the cake undercrust region was assessed visually. At each baking trial, reference cakes were prepared in duplicate from a commercial cake flour (pH 4.6) (Mennel Milling Co.).

RESULTS AND DISCUSSION

Wheat and Flour Analyses

Analytical results for the wheat cultivars are presented in Table I. Harvest dates of the cultivars for each year's composite differed by ± 2 days. Results for a typical milling are presented in Table II. The milling procedure was held constant throughout the study for each year. Wheat age did not have a significant effect on either the proximate composition or the milling extraction rate of the composites for either year (*data not shown*).

In year 1, the humidity in the milling laboratory was increased after six weeks to compensate for the expected seasonal decrease

TABLE I
Moisture, Protein, and Ash Contents (%) of Soft Red Winter Wheat Cultivars

Cultivar	Moisture	Protein[a]	Ash[a]
		Year 1	
Caldwell	14.6	8.69	1.56
Becker	13.2	9.07	1.72
Cardinal	12.9	8.35	1.75
		Year 2	
Caldwell	12.9	8.13	1.76
Becker	12.9	9.18	1.73
Hillsdale	13.9	8.69	1.70

[a] Reported on an as-is basis.

TABLE II
Typical Results of a Laboratory Milling of Soft Red Winter Wheat

Mill Stream	Yield (g)	Yield (%)
Red dog	81.0	4.0
Germ	11.0	0.5
Shorts	213.0	10.7
Bran	271.0	13.6
Total flour	1,409.0	71.0
Total feed	576.0	29.0
Total products	1,985.0	96.4
Total loss	74.0	3.6

in relative humidity. Flour samples lost very little moisture during milling and consequently had a higher moisture content (15.1 ± 0.2%) than samples in year 2. However, protein (7.67 ± 0.06%, 14.0% mb) and ash (0.33 ± 0.01%, 14.0% mb) values did not change. In the second year, flour moisture content was reduced (by exposing flour to air currents) to about 11.5% after each milling.

Flour particle size is an indirect measure of wheat hardness. Mean particle size of the flour samples did not change as a function of either wheat or flour age (*data not shown*), indicating that the wheat kernels did not become harder with time after harvest.

Cake-Baking Quality

Batter specific gravity. Batter specific gravity is an important criterion in the evaluation of cake-baking quality of flour. Both time after harvest (wheat age) and time after milling (flour age) affected batter specific gravity (Table III).

The age of the parent wheat did not affect the postmilling change in batter specific gravity. Regardless of chlorine treatment, young flours produced batters with high specific gravity. During all 16 weeks of aging, batter specific gravity decreased considerably in the first 48 hr after each weekly milling. Chlorinated flour was associated with lower batter specific gravity than the corresponding untreated flour, regardless of wheat age. Although chlorination did not prevent the postmilling fluctuation in batter specific gravity (Table III), it significantly reduced the time required to reach a stable specific gravity value from 21 to six days.

For untreated flours, the reduction in batter specific gravity averaged 8.4% in the first 48 hr after milling (Table III). Specific gravity continued to decrease, but at a lower rate, for the remainder of the postmilling period. The specific gravity of batters produced from chlorinated flours decreased by an average of 4.8% during the first two days after each milling, dropped by an additional 10% over the next four days, and did not change further over the remaining eight days. Once the specific gravity values of the cake batters stabilized, they remained constant through the study period (chlorinated flour average = 0.85, SD = 0.03; untreated flour average = 1.02, SD = 0.09).

Cake volume. The volumes of the cakes prepared from the control flour remained constant throughout the study at 850 ± 10 cm^3. In contrast, the volumes of cakes produced from the experimental flours increased as a function of both wheat age and flour age (Figs. 2 and 3). For both untreated and chlorinated flours, cake volume was lowest on the day that the flour was produced and reached a maximum with time up to 14 days after milling. The time required to reach the maximum value decreased significantly as wheat aged. Taken together, these changes appear to be one clear manifestation of the new-crop phenomenon.

The pattern of change depended on flour treatment. Cakes made from untreated flours showed a gradual increase in volume with time after milling, whereas those made from chlorinated flours showed a rapid increase in volume as a function of time. Cakes baked from chlorinated flours had greater volumes than cakes baked from untreated flours for the entire postmilling test period (Fig. 3). The age-related changes in volume were both greater and more rapid for cakes made with the chlorinated flours than for those made with untreated flours.

Symmetry and uniformity indices. Figure 4 presents the symmetry indices of cakes produced from wheat of different ages as a function of flour age. Positive symmetry indices (>0) are desirable because they indicate peaked cakes, whereas negative values indicate collapsed cakes.

TABLE III
Specific Gravity of Batters as a Function of Soft Red Winter Wheat Age and Flour Age

Wheat Age (weeks)	Postmilling Time (days) 0	2	6	14
Chlorinated Flour, Year 1				
0	1.240	0.945	0.845	0.835
2	1.218	0.943	0.849	0.846
4	1.194	0.957	0.850	0.839
6	1.188	0.965	0.838	0.835
8	1.192	0.942	0.845	0.838
10	1.185	0.939	0.829	0.835
12	1.179	0.945	0.831	0.832
14	1.182	0.942	0.830	0.835
16	1.183	0.940	0.828	0.825
Chlorinated Flour, Year 2				
0	1.183	0.934	0.890	0.895
2	1.124	0.924	0.824	0.850
4	1.102	0.960	0.830	0.851
6	1.185	0.971	0.805	0.853
8	1.144	0.921	0.840	0.854
10	1.162	0.899	0.821	0.835
12	1.124	0.889	0.816	0.834
14	1.130	0.895	0.817	0.838
16	1.108	0.899	0.809	0.830
Untreated Flour, Year 2				
0	1.426	1.393	1.243	1.181
2	1.359	1.284	1.204	1.093
4	1.408	1.256	1.183	1.144
6	1.441	1.268	1.191	1.183
8	1.409	1.219	1.202	1.132
10	1.389	1.242	1.209	1.141
12	1.407	1.263	1.158	1.114
14	1.352	1.267	1.147	1.103
16	1.325	1.265	1.143	1.108

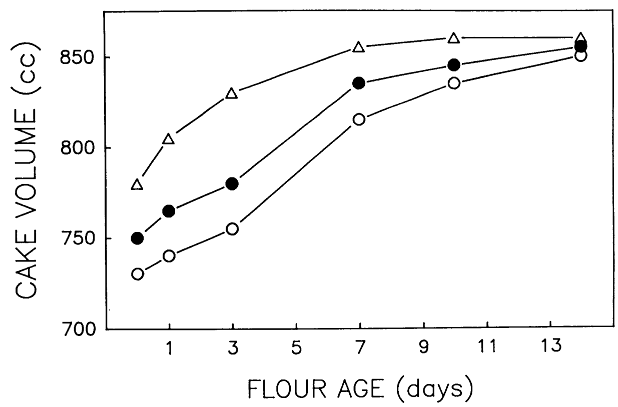

Fig. 2. Volume of cakes prepared with chlorinated flours from new-crop soft red winter wheat as a function of wheat age (○, zero weeks; ●, four weeks; △, 12 weeks) and flour age (year 1).

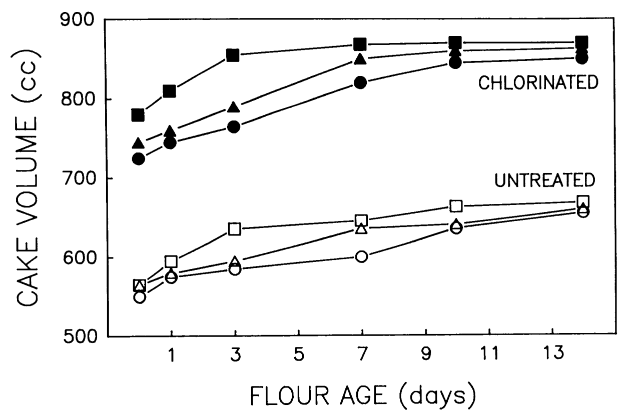

Fig. 3. Volume of cakes prepared with chlorinated or untreated flours from new-crop soft red winter wheat as a function of wheat age (○ and ●, zero weeks; △ and ▲, four weeks; □ and ■, 12 weeks) and flour age (year 2).

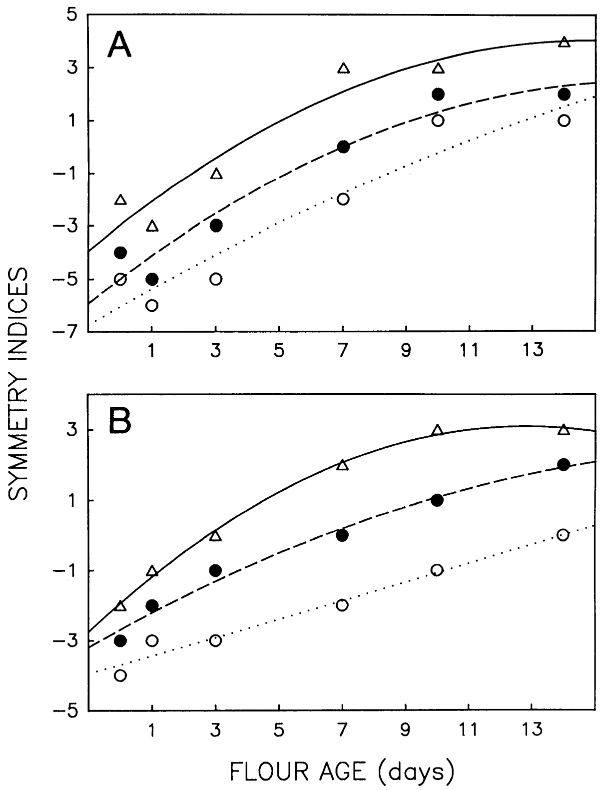

Fig. 4. Symmetry indices of cakes baked from chlorinated flours from new-crop soft red winter wheat in year 1 (**A**) and year 2 (**B**) as a function of wheat age (○, zero weeks; ●, four weeks; △, 12 weeks) and flour age.

Immediately after milling, all flours (untreated and chlorinated) produced collapsed cakes. With chlorinated flour, however, cake symmetry improved as a function of both wheat age and flour age. Specifically, the aging required before chlorinated flours produced cakes with positive symmetry indices decreased as a function of wheat age. In year 1, wheat aged zero, four, and 12 weeks required 10, seven, and three days of flour aging, respectively, to produce cakes with a zero symmetry index (Fig. 4A). The same trend was observed in year 2, although wheats of increasing age required less flour aging to produce cakes with a zero symmetry index (Fig. 4B). Regardless of wheat age, cakes produced from untreated flours never attained a positive symmetry index during the two-week postmilling storage period (*data not shown*).

The "optimum" cake should also have a uniformity index of zero. Positive or negative values indicate that one side of the cake is higher than the other. All cakes baked from flours immediately after milling had negative uniformity indices (*data not shown*), regardless of chlorination. Cake uniformity indices as a function of wheat age and flour age for both years followed a trend very similar to that of cake symmetry indices. This is not surprising, because we would not expect collapsed cakes to be symmetrical.

Internal and external characteristics. Age-related improvements in crumb characteristics paralleled age-related changes in cake volume, uniformity, and symmetry. Until wheats had aged eight and four weeks (years 1 and 2, respectively), chlorinated flours required seven days of aging (storage) before they produced cakes without a gummy undercrust (*data not shown*). As wheat aged beyond the eight (and four) weeks, the postmilling time required to avoid a gummy undercrust was reduced to four days. Chlorinated flours changed more quickly than untreated flours. Chlorine-treated flours milled from wheats stored more than 16 weeks required only three days to produce cakes without the gummy undercrust. These changes clearly parallel the data presented in Figure 4. The postmilling testing period of two weeks was not long enough to reveal improvement in the crumb quality of cakes baked from untreated flours. Although a gummy undercrust may result from a variety of causes, our results suggest that in this study it was likely caused by collapse during baking, before setting of the cake.

In general, cake characteristics improved with flour age after each milling and reached a relatively constant value. The postmilling time required to reach that value decreased as a function of wheat age. These data suggest that the new-crop phenomenon manifests itself in poor final structure of cakes made with flour that is freshly milled and/or is milled from newly harvested wheat. The final structure of cakes improves with increased age of both wheat and flour. Further studies are needed to determine the chemical and physical changes responsible for this phenomenon.

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