Age-Related Changes in the Properties of Batters Made from Flour Milled from Freshly Harvested Soft Wheat[1]

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ABSTRACT

We noted a consistent pattern of age-related changes in the properties of wheat and flour over two consecutive crop years. The onset temperature of starch gelatinization in wheat endosperm increased slightly as a function of postharvest time. Freshly milled flours had low distilled water binding capacity (DWBC) and produced batters of low viscosity at ambient temperature and during heating. DWBC of flours, both untreated and chlorinated, was lowest immediately after milling, increased during the first week, and changed little after that. The time required to reach the maximum DWBC value decreased as wheat age increased. Batter viscosity at ambient temperature and minimum viscosity during heating both increased as a function of flour age. DWBC was strongly correlated with cake-baking quality of flours milled from freshly harvested wheats.

Shelke et al (1992) provide quantitative evidence of the well-known "new-crop" phenomenon in soft wheats. Batter specific gravity decreased substantially with flour storage after milling and with postharvest aging of wheat. These changes paralleled changes in the cake-baking quality of the flours. Age-related changes in batter specific gravity and in the ability of the batter to resist collapse during baking implicate batter viscosity, at one or more points in the baking process, as an underlying cause of the phenomenon.

Shelke et al (1990) developed a technique for monitoring batter viscosity as a function of batter temperature and determined the effects of typical cake formula ingredients on batter viscosity at ambient temperature and during heating. We used that technique to study the effects of flour age and/or wheat age on the viscosity of batters made from soft red winter wheats. In addition, we investigated flour properties that affect batter viscosity.

MATERIALS AND METHODS

Flours

Flours used in the study were composites of three new-crop soft red winter wheat cultivars (Becker, Caldwell, and Cardinal in the 1988 crop year [year 1] and Becker, Caldwell, and Hillsdale in the 1989 crop year [year 2]). Wheat storage, milling, chlorination, and flour storage were as described by Shelke et al (1992).

Distilled Water Binding Capacity

Flour samples (5 g, as-is) were slurried with 50 ml of distilled water, held for 30 min at room temperature, and then centrifuged at 1,500 × *g* for 10 min. Containers were drained for 10 min at a 30° angle to remove supernatants, and the resulting residues were weighed. Distilled water binding capacity (DWBC) was calculated and reported as the amount of water retained by the flour as a percentage of the original flour weight (14.0% mb). The means of triplicate determinations are reported (SD = ±3%).

Electrical Resistance Oven Heating

White layer cake batters were prepared according to AACC method 10-90 (AACC 1983). The method of Shelke et al (1990) was used to heat the batter in the electrical resistance oven and simultaneously measure batter viscosity during heating. The means of duplicate determinations are reported. Shelke et al (1992) report data on the volume, symmetry index, and crust and crumb quality of cakes baked in the conventional oven.

Differential Scanning Calorimetry

Differential scanning calorimetry (DSC) analyses were performed in duplicate on endosperms isolated from wheat kernels (cultivars Becker, Caldwell, and Hillsdale) at weekly intervals for the first 10 weeks of the 16-week storage period. Whole wheat kernels were crushed with a mortar and pestle, bran-free endosperm fragments were isolated from the resulting grist, and endosperm and water (1:3) were placed in aluminum DSC pans. The pans were sealed, and thermograms were obtained as described by Zeleznak and Hoseney (1986).

RESULTS AND DISCUSSION

Batter Viscosity

Viscosity of batters at ambient temperature (Figs. 1 and 2) increased as a function of postmilling time (flour age). With chlorinated flours, viscosity rose rapidly during the first three days after milling, then approached a stable (plateau) value after 14 days. Viscosity of batters made from untreated flours showed a roughly linear increase during the 14 days after milling (Fig. 2). The age of wheat at milling did not affect batter viscosity significantly.

The minimum viscosity maintained by a batter during heating was also considered to be important because it reflects the ability of the batter to retain gas bubbles and to resist settling of starch. Irrespective of wheat age, freshly milled flours produced batters with a low minimum viscosity (Figs. 3 and 4). The minimum viscosity of heated batters increased as a function of flour age.

Batters made from chlorinated flours had higher viscosity throughout the heating process than batters made from the corresponding untreated flours. This was particularly true at the point of minimum viscosity (Fig. 4). Minimum viscosity of batters

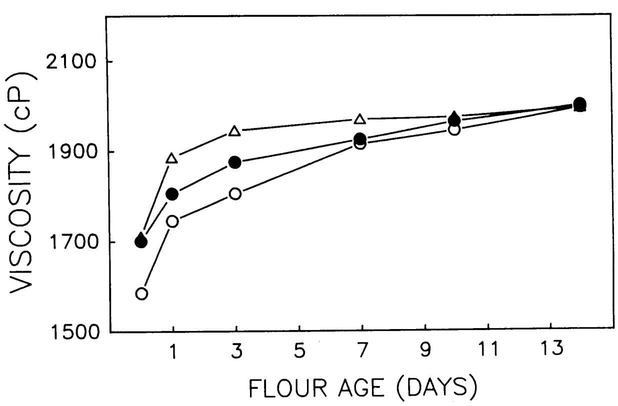

Fig. 1. Viscosity at ambient temperature of cake batters made from chlorinated flours produced from new-crop soft red winter wheat as a function of wheat age (○, zero weeks; ●, four weeks; △, 12 weeks) and flour age (year 1).

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made from chlorinated flours rose rapidly during the first 48 hr after milling and continued to increase at a reduced rate over the remainder of the postmilling storage period (Figs. 3 and 4). Although untreated flours produced batters of lower minimum viscosity during heating, the values also increased with time after milling. The oxidizing and depolymerizing action of chlorine on starch (Johnson et al 1980) may explain the difference in viscosity at all temperatures between batters made from chlorinated and from untreated flours; however, it is not clear whether this mechanism also explains the increase in viscosity as a result of flour aging.

Batters produced from young flours expanded more during heating than did batters prepared from older flours. The difference in expansion is an expression of the inability of batters prepared from young flours (because of low viscosity) to resist the pressure caused by the leavening gases.

The viscosity of batters heated in the electrical resistance oven increases rapidly at about 80–85°C. This increase is assumed to be primarily the result of starch gelatinization (Shelke et al 1990). The onset temperature of this rapid increase in batter viscosity increased with wheat age and reached a maximum in batters made from wheats stored for 10 weeks (year 1) and six weeks (year 2) after harvest (Table I).

DSC

Why the onset temperature of the rapid increase in viscosity increased as a function of wheat age was not clear. The increase could be the result of leavening; however, there was no reason to assume that leavening would be triggered at different temperatures because the wheat had aged. Therefore, we hypothesized that the gelatinization temperature of starch might have increased.

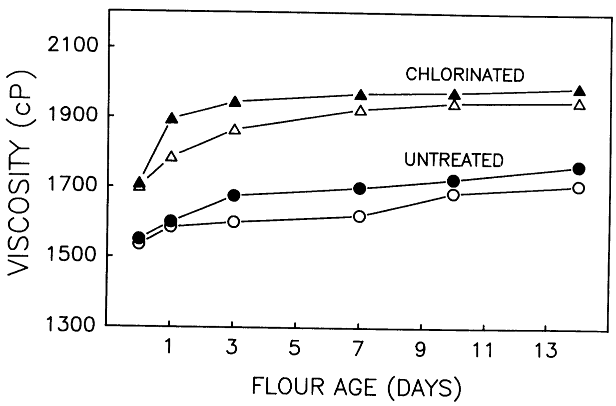

Fig. 2. Viscosity at ambient temperature of cake batters made from chlorinated and untreated flours produced from new-crop soft red winter wheat as a function of wheat age (○ and △, zero weeks; ● and ▲, 12 weeks) and flour age (year 2).

TABLE I
Effect of Wheat Age on the Onset Temperature of Rapid Increase in Viscosity of Heated Batters Made from New-Crop Soft Red Winter Wheats

Wheat Age (weeks)	Temperature (°C)[a] of Viscosity Increase Year 1	Year 2
0	82.0	81.5
2	83.0	83.0
4	86.0	83.5
6	88.0	88.0
8	89.0	88.0
10	90.0	88.0
12	90.0	88.0
14	90.0	88.0
16	90.0	...

[a]Means of duplicate analyses, SD = ±0.5.

During the second year of the study, we used DSC analysis of endosperm from the various cultivars to investigate this possibility.

The onset temperature of starch gelatinization as a function of wheat age is shown in Table II. The onset temperature of gelatinization increased 2–3°C for all cultivars in the first three weeks after harvest. No subsequent changes were found with extended storage. These data show that starch gelatinization does indeed change in the immediate postharvest period. This change is assumed to be annealing, which increases gelatinization temperature (Yost and Hoseney 1986).

DWBC

The age-related change in the viscosity of batters produced from freshly milled flours could reflect differences in the rate or extent of flour hydration. To assess this possibility, we determined the DWBC of the chlorinated and untreated flours as a function of wheat and flour age (Fig. 5). Clearly, the DWBC of flours from wheats of different ages increased significantly

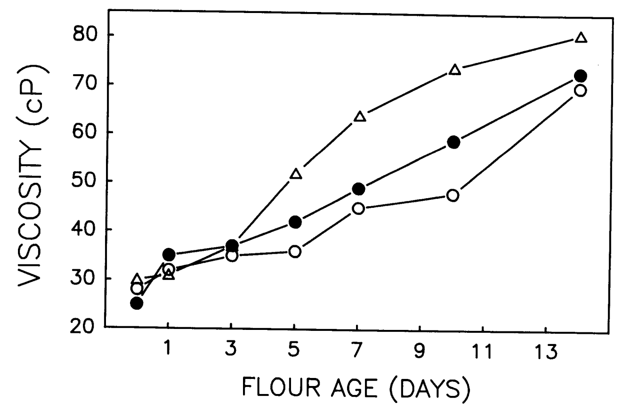

Fig. 3. Minimum viscosity of heated cake batters made from chlorinated flours produced from new-crop soft red winter wheat as a function of wheat age (○, zero weeks; ●, four weeks; △, 12 weeks) and flour age (year 1).

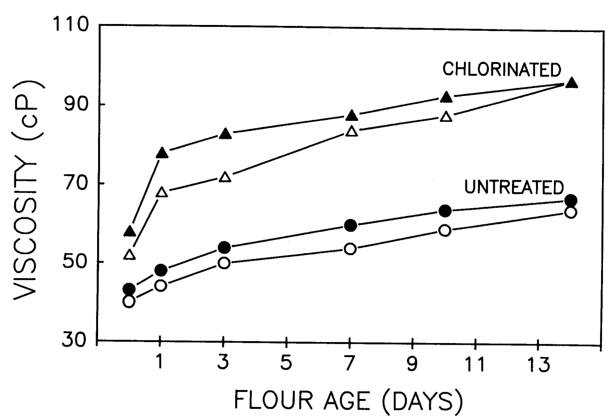

Fig. 4. Minimum viscosity of heated cake batters made from chlorinated and untreated flours produced from new-crop soft red winter wheat as a function of wheat age (○ and △, zero weeks; ● and ▲, 12 weeks) and flour age (year 2).

TABLE II
Onset Temperature (°C)[a] of Starch Gelatinization as a Function of Soft Red Winter Wheat Age (Year 2)

Cultivar	Week 0	1	2	3	4	10
Caldwell	54.0	55.0	56.0	56.0	56.0	56.0
Hillsdale	56.0	57.0	59.0	59.0	59.0	59.0
Becker	56.0	58.0	58.0	58.0	58.0	58.0

[a]Means of duplicate analyses, SD = ±0.5.

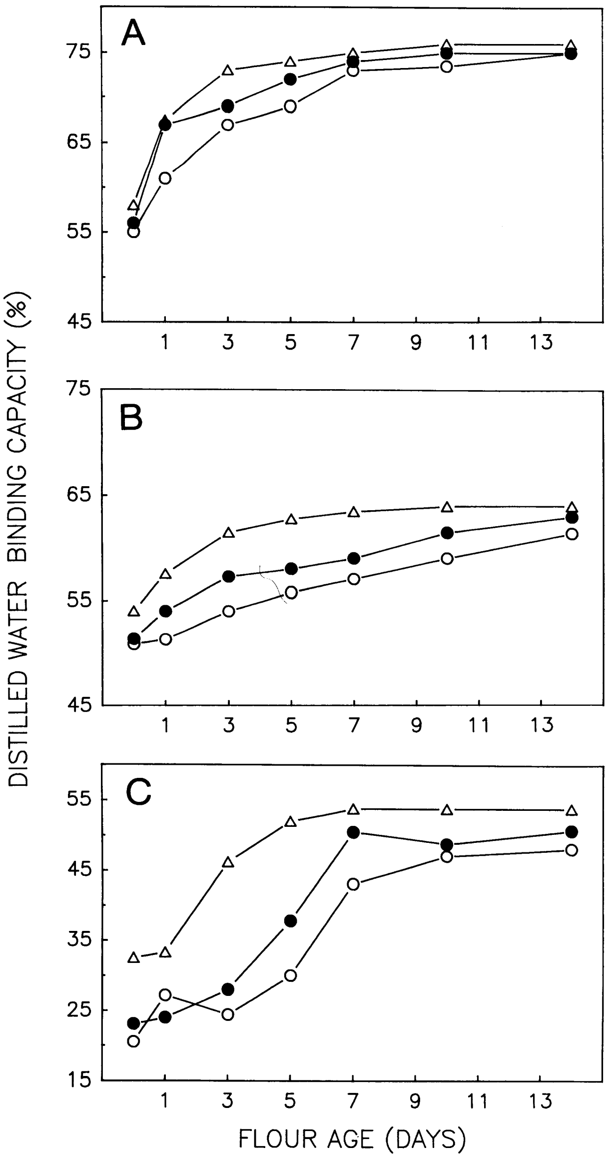

Fig. 5. Distilled water binding capacity of chlorinated flours in year 1 (**A**) and year 2 (**B**) and of untreated flours in year 2 (**C**) produced from new-crop soft red winter wheat as a function of wheat age (○, zero weeks; ●, four weeks; △, 12 weeks) and flour age.

during postmilling storage. The pattern of these changes resembled the pattern of changes previously observed in cake quality (Shelke et al 1992) and reported here for batter viscosity.

DWBC of chlorinated flours increased an average of 28 and 23% during the postmilling period in years 1 and 2, respectively (Figs. 5A and B). DWBC of untreated flours increased about 14% over the same period (Fig. 5C). Throughout the study period, chlorinated flours had higher DWBC than their untreated counterparts. Chlorinated flours also showed a comparatively greater rate of postmilling change in DWBC.

For all flours, DWBC was lowest immediately after milling and increased substantially as the flour aged. The time required for DWBC to reach its maximum value decreased as wheat age increased. Both initial (day 0) and final (day 14) DWBC increased with wheat age (Fig. 6). The difference between day 0 and day 14 DWBC values decreased with increasing wheat age.

Relationship to Cake Properties

Simple correlations ($P < 0.01$) among the flour (DWBC), batter (viscosity at ambient temperature and minimum viscosity during heating), and cake (volume and symmetry index) quality

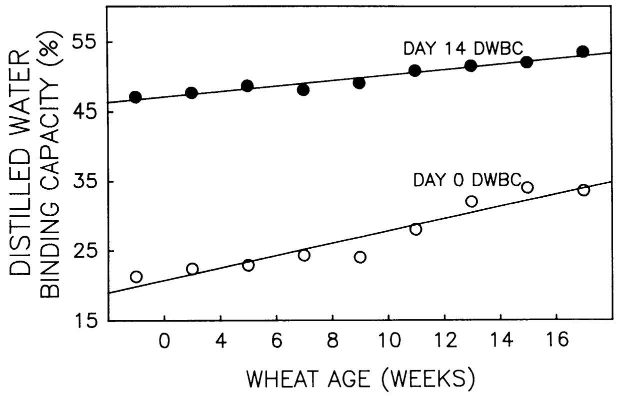

Fig. 6. Initial (○) and final (●) distilled water binding capacity of chlorinated flour produced from new-crop soft red winter wheat as a function of wheat age (year 1).

TABLE III
Simple Correlation Coefficients[a] for Dependent Variables

Variable	Cake Volume	Symmetry Index	$\eta_{amb.}$[b]	$\eta_{min.}$[c]	DWBC[d]
Cake volume	1.000	0.915	0.937	0.888	0.962
Symmetry index		1.000	0.844	0.854	0.874
$\eta_{amb.}$[b]			1.000	0.820	0.881
$\eta_{min.}$[c]				1.000	0.865
DWBC[d]					1.000

[a] Significant at $P < 0.01$.
[b] Batter viscosity at ambient temperature.
[c] Minimum viscosity during heating.
[d] Distilled water binding capacity.

measurements for all possible pairs of variables are presented in Table III. Flour DWBC was highly correlated with batter viscosity, cake volume, and cake symmetry index. Cake volume and cake symmetry index were also highly correlated with batter viscosity measured at ambient temperature and at the minimum point during heating.

CONCLUSION

The age-related changes in DWBC and in the batter properties of freshly milled flours and flours milled from freshly harvested wheats paralleled improvements in their cake-baking qualities (Shelke et al 1992). Immediately after milling, flours from freshly harvested wheats had low DWBC and produced cake batters with low viscosity both at ambient temperature and during heating. Chlorination did not stop the postmilling changes but affected the rate of those changes. Although gelatinization temperature of starch in the endosperm increased as a function of postharvest time, this change was not related to changes in batter viscosity.

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