Cake Batter Viscosity and Expansion upon Heating

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ABSTRACT

A technique using a modified viscograph that enables continuous measurement of cake batter viscosity on a complete cake formula from 20 to approximately 100°C is described. Batter viscosity, influenced by batter moisture content and flour chlorination, was compared with cake expansion during baking. Statistically significant variation in the cake expansion during baking of two cake flours was attributed to differences in apparent viscosity of the batter.

Miller and Trimbo (1965) used a farinograph to study cake batter consistency during heating and reported consistency curves of 84–96°C. Russo and Doe (1970) observed chlorinated and unchlorinated flour with starch in a buffered slurry containing sugar and heated in an amylograph; the chlorinated flour and starch showed an increased pasting rate and higher viscosity at a given temperature. More recently, Paton et al (1981) and Voisey (1979) used a force transducer to measure cohesive forces that develop in cakes during baking. Mizukoshi et al (1979, 1980) measured starch pasting and the temperature at which protein coagulates in sponge cake batters with a unique light transmission system in a heated paraffin bath. Data (unpublished) from our laboratory suggest that varietal differences in cake volumes occur because of the residue of hexane-extracted flours and, therefore, may have rheological origin. These data should not be confused with the findings of Kissell et al (1979), which suggest that chlorinated flours give better cake volume than do unchlorinated flours by altering the hexane-extractable lipids. In this study, a modified viscograph (amylograph) was used to continuously follow changes of apparent viscosity cake batter during heating from 20 to ~100°C. This data was used indirectly to determine the relationship of cake batter viscosity (consistency) and expansion during baking. This technique may lead to a better understanding of varietal differences among cake flours and the rheological consequences of optimizing cake batter moisture content (liquid level) to achieve better cake contour and volume.

MATERIALS AND METHODS

Flour Treatments

A 50% patent cake flour (10.1% protein, 0.35% ash, AACC methods 46-12 and 8-01, respectively) was milled on a Miag mill from Arthur variety soft red winter wheat in our Wooster facility. Another 50% patent cake flour (8.3% protein, 0.35% ash) made from unbleached and blended soft red winter wheat was obtained from a commercial source. Both flours were pin milled at 9,000 rpm. A portion of each flour was chlorinated to pH 4.8 (Kissell and Marshall 1972). Bleached flours were tested at five batter liquid levels.

Batter Liquid Levels and Baking Measurements

Optimum baking absorption was determined by baking cakes at several liquid levels and observing contour and displacement volume. Optima of 140 and 150% of flour weight were chosen for the bleached Arthur and commercial flours, respectively. Other liquid levels were 110, 120, 160, and 170% for the Arthur flour, and 120, 130, 170, and 180% for the commercial flour. The content of solids in each liquid level was adjusted to the optimum batter weight; cakes having optimum batter liquid contained 425 g of batter.

Cakes were baked according to AACC (1976) white layer cake method 10-90. Cake expansion during baking was monitored with balsa wood scales (Clements and Donelson 1981). The scale and a thermocouple wire were held in the center of the cake with the crossbeam of a tripod stand. The thermocouple sensor was placed 1 cm from the bottom of the pan, just below the surface of the cold batter. All cake expansion and temperature data are the means of duplicate observations made at half-minute intervals.

Batter Viscosity Measurements

Apparent viscosities of the cake batters were measured with a modified viscograph (C. W. Brabender, South Hackensack, NJ). The heating element was wired directly to a variable autotransformer adjusted to 100 V (440 W). This gave a heating rate, measured by a thermocouple in the viscograph bowl, that approximated that of the baking oven. Both the oven and viscograph batters reached 95°C in approximately 18 min. The outer two pins of the viscograph spindle were removed, leaving only four pins to permit measurement of maximum apparent viscosity without the use of weights. The glass portion of the viscograph thermoregulator was replaced with a wooden dowel ¼ in. (6.4 mm) in diameter, to which the thermocouple wire was attached. The dowel extended down 9.5 cm from the thermoregulator housing, and the thermocouple sensor was 1.5 cm from the bottom of the bowl. Viscograms were obtained on 250 g of batter, except those that were adjusted to optimum weight. All viscograph temperature and apparent viscosity measurements are the means of replicate observations made at half-minute intervals. The viscosity curves were often extended beyond 500 Brabender units (BU) because the batter would begin setting in this range; batter that was torn by the spindle pins gave reduced viscosity readings.

RESULTS AND DISCUSSION

Cake temperature measurements during baking are influenced by the position of the thermocouple in relation to the bottom and edges of the pan. Also, cake batter apparent viscosity measurements resulting from mixing in a viscograph may not be the same as measurements made by other techniques; however, values reported in this study were standardized to allow comparisons of cake expansion and batter viscosity. Cake oven expansion data and batter viscosity were plotted against temperature (Figs. 1 and 2). The approximate 10°C difference between the time of initial starch pasting (batter thickening) and the cessation of batter expansion agrees with data reported by Mizukoshi et al (1980), who heated cake batter in a liquid paraffin bath. Maximum batter expansions of the Arthur variety flour were 4.2, 4.6, 5.3, 5.0, and 4.3 cm for the 110, 120, 140, 160, and 170% levels of liquid, respectively. The 120 and 160% Arthur batter curves are not shown in Fig. 1. The unbleached Arthur batter

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expanded to 3.4 cm. For the commercial flour, maximum batter expansion was 4.2, 4.8, 5.0, 4.2, and 3.8 cm for the 120, 130, 150, 170, and 180% liquid levels, respectively. The 130 and 170% commercial batter curves are not shown in Fig. 2. The unbleached commercial flour expanded to 3.2 cm.

Replacement of the glass portion of the viscograph thermoregulator with wood and the smaller viscograph spindle allowed apparent viscosity measurements of full cake formula batters from 20 to ~100°C, where the batter set. The viscosity of the batters of both flours having optimum liquid levels tended to remain between that of the extreme liquid levels throughout the heating period. The relative viscosity of the unbleached and bleached (at optimum liquid level) batters followed the traditional viscoamylogram patterns for starch or flour buffered slurry. The other cake ingredients did not alter the relative viscosities of the

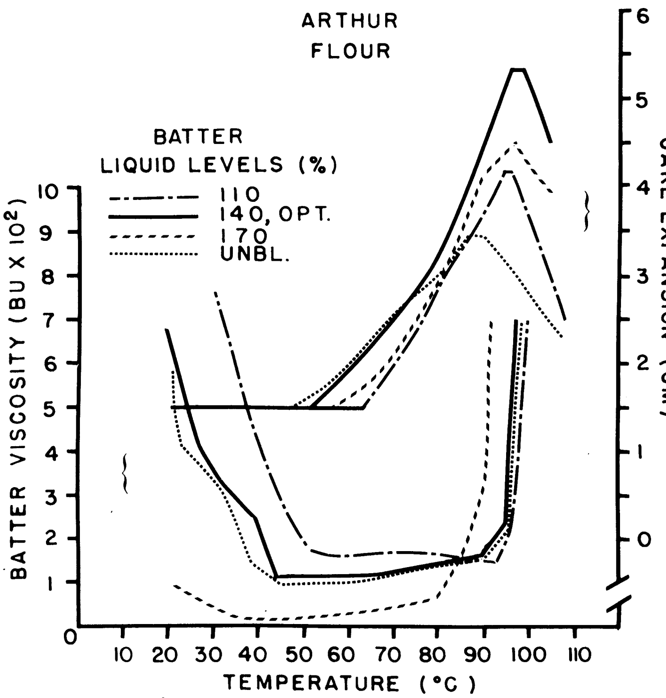

Fig. 1. Relation of cake batter expansion (upper curves) and viscograph apparent viscosity (lower curves) to temperature for five batter liquid levels of bleached Arthur cake flour and an unbleached Arthur flour.

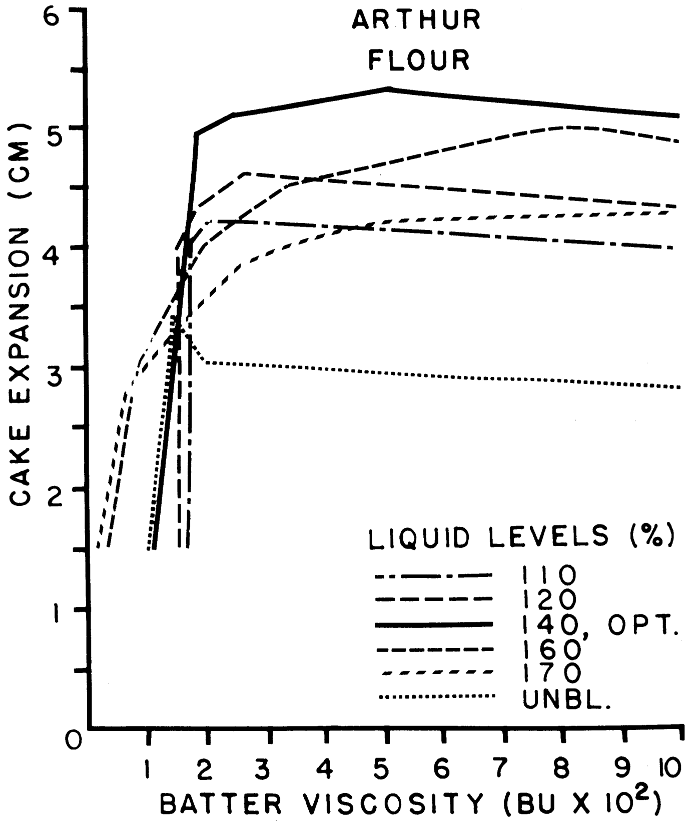

Fig. 3. Relation of cake batter expansion and viscograph apparent viscosity for five batter liquid levels of bleached Arthur cake flour and an unbleached Arthur flour.

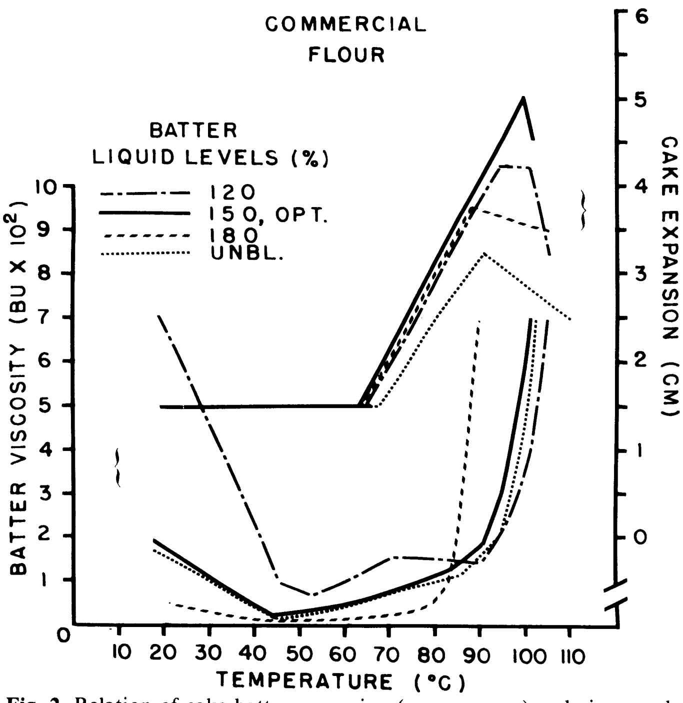

Fig. 2. Relation of cake batter expansion (upper curves) and viscograph apparent viscosity (lower curves) to temperature for five batter liquid levels of bleached commercial cake flour and an unbleached commercial flour.

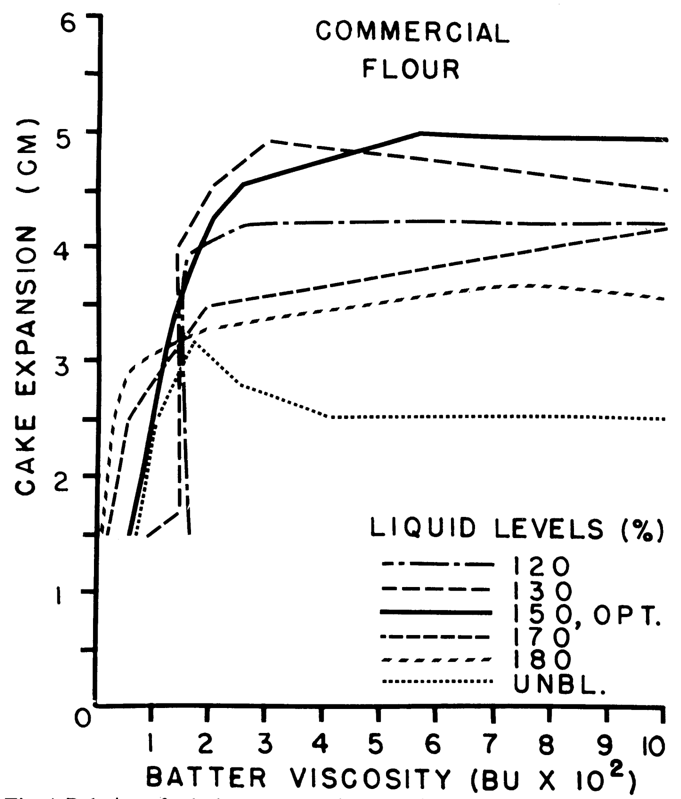

Fig. 4. Relation of cake batter expansion and viscograph apparent viscosity for five batter liquid levels of bleached commercial cake flour and an unbleached commercial flour.

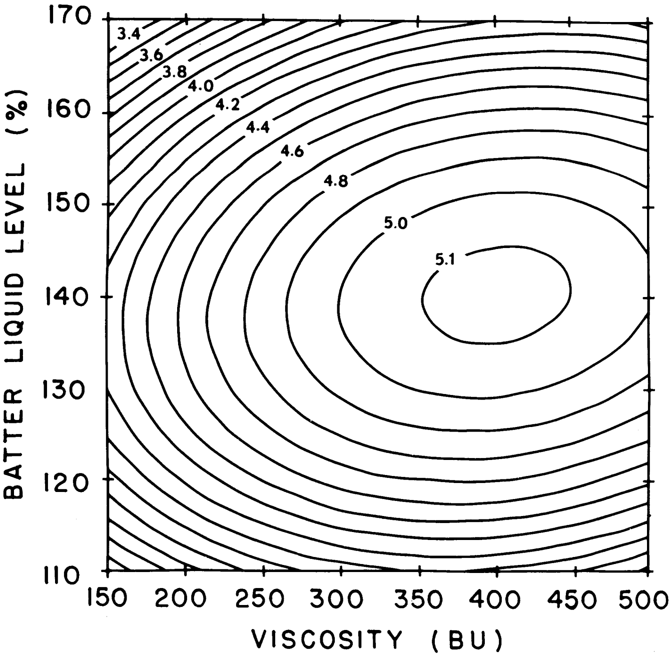

Fig. 5. Arthur flour cake expansion (cm) as a function of batter liquid level and batter apparent viscosity.

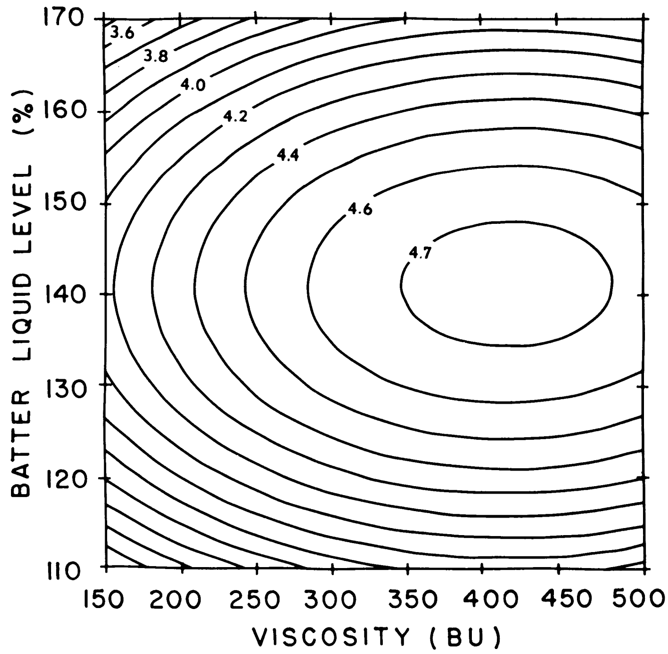

Fig. 6. Commercial flour cake expansion (cm) as a function of batter liquid level and batter apparent viscosity.

flours. Bleached flours at optimum batter moisture contents achieved higher pasting viscosities more rapidly than unbleached flours. Such faster pasting may contribute to the stability and reduced shrinkage of bleached flour cakes on cooling (Kissell and Yamazaki 1979). Those batters with more water and the same solids content had more water available to the starch, allowing it to paste at a lower temperature and faster rate than did batters with lower liquid levels.

The average viscosity at 90°C was 300 BU for all six commercial batters and 200 BU for all Arthur batters. The faster pasting rate of the commercial flour may have contributed to the maximum commercial cake expansion being 0.3 cm smaller and the final commercial cake volume being 41 cm^3 smaller (all treatments averaged).

The relationship of cake batter viscosity and cake expansion during baking is shown in Figs. 3 and 4. The total mean square of both flours was significant ($P = 0.01$) for the relationship of batter viscosity and cake expansion. The expansions of the batters at optimum moisture contents were mostly completed at increasing viscosities of 200–300 BU. For both flours, the faster increase in viscosity of the batter liquid levels that were higher than optimum appeared to retard the batter expansion. The batter liquid levels that were lower than optimum for both flours produced batters that expanded little after viscosity increased and cake expansion that peaked at a relatively low batter viscosity. Such expansion peaks may have resulted from the relatively late viscosity increase of the drier batters; more likely, however, because the drier batters did not expand as well as those of optimum batter moisture content, they may have had a less stable gaseous emulsion structure at increasing viscosity and/or temperature. The average cake expansion values for the six Arthur flour cakes at 200, 300, 400, and 500 BU of viscosity were 4.0, 4.2, 4.3, and 4.3 cm, respectively. The average expansion values of the six commercial flour cakes at 200, 300, 400, and 500 BU were 3.8, 3.9, 3.9, and 4.0 cm, respectively. Therefore, the Arthur flour (0.30 cm, LSD = 0.09, $P = 0.05$) had a 7.6% greater average expansion at these batter viscosities than did the commercial flour. Excluding the unbleached flours, the Arthur flour had a 7.5% (0.30 cm, LSD = 0.10, $P = 0.05$) greater average expansion as batter viscosity increased from 200 to 500 BU.

The unbleached flours stopped expanding with little, if any, influence of batter viscosity increase. Clements and Donelson (1982a, 1982b) showed the essential role of bleached flour lipids in cake expansion. Figures 1–4 show that starch pasting, as affected by chlorination, is probably not responsible for differences in cake batter expansion.

The contour plots of the relationship of cake expansion, batter moisture content, and batter viscosity (Figs. 5 and 6) are statistically parallel, but the Arthur batter expansion data are significantly shifted by 0.3 cm, showing greater cake expansion. The specific cause and effect of this relationship is a matter for further study, but as shown in Figs. 3 and 4, the influence of batter viscosity on cake expansion can be dramatic. A varietally controlled mechanism (perhaps protein quality) that influenced batter rheology during baking may have been responsible for the difference in the batter expansions of the two flours.

These statistically significant relationships between cake batter expansion during baking and batter rheology suggest that this technique may be useful in further investigations of varietally controlled differences in cake volume.

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