NOTE

Use of Elongational Viscosity to Estimate Cookie Diameter[1]

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ABSTRACT

Cookie diameter is a function of spread rate and set time during baking. Dough viscosity appears to control cookie spread rate and, thus, will affect final cookie diameter. The technique of lubricated uniaxial compression was used to measure the elongational viscosity of cookie dough. Full-formula cookie doughs made with a commercial hard wheat flour had a significantly higher elongational viscosity ($5.88 \times 10^6 \pm 9.17 \times 10^4$ Pa·S) than cookie doughs made with a commercial soft wheat flour ($2.17 \times 10^6 \pm 1.05 \times 10^4$ Pa·S). Elongational viscosity correlated significantly ($P < 0.05$) with the diameter ($r = -0.796$) of cookies made with flours from various soft wheat cultivars. Using a simplified cookie formula decreased the testing time without greatly changing the correlation coefficient ($r = -0.738$). Thus, lubricated uniaxial compression appears to be an appropriate technique to measure the viscosity of cookie doughs and may be useful for predicting the cookie baking quality of soft wheat flours.

The baking test is the best technique currently available to determine the cookie baking quality of soft wheat flour. However, baking is time-consuming and requires specialized equipment and trained personnel. A rapid, simple test to predict the cookie baking quality of flour would be quite useful to wheat breeders, flour millers, and cookie manufacturers. For this reason, many researchers have attempted to use other tests to predict cookie quality.

The alkaline water retention capacity (AWRC) test is currently the best physicochemical test available to predict the cookie baking quality of flour. AWRC measures the water-holding capacity of flour under alkaline conditions against a centrifugal force. Yamazaki (1953) showed that the AWRC of the flour correlated highly with cookie diameter. However, other researchers have not reported such a high correlation (Abboud et al 1985a, Nemeth et al 1994).

Some researchers have attempted to use the alveograph to evaluate the cookie baking potential of soft wheat flours. However, none of the alveograph parameters correlated with cookie diameter or AWRC (Rasper et al 1986, Bettge et al 1989, Nemeth et al 1994).

The physical-textural properties of cookie dough have been measured with the Instron universal testing machine (UTM). Gaines et al (1988) used a "two-bite" texture profile analysis to measure dough stiffness, flow, consistency, adhesion, and cohesion. Abboud et al (1985b) and Gaines and Finney (1989) measured the force required to drive a probe 3 mm into the dough. The resistance of the dough to probing was taken as a measure of dough consistency.

Cookie diameter is a function of spread rate and set time during baking. Although all cookies began spreading at the same time during baking, the rate of diameter increase was greater for cookies made with good quality flour (Abboud et al 1985a). Because gravity and the amount of leavening in the formula are constant, the viscosity of the dough appears to control the rate at which cookies spread during baking (Yamazaki 1959a, Hoseney et al 1988, Hoseney and Rogers 1994). Doughs with lower viscosity are able to spread at a faster rate (Yamazaki 1955, Hoseney et al 1988, Hoseney and Rogers 1994). Yamazaki (1959b) suggested that a change in the limited quantity of water present and an intense competition for water among flour components may contribute to the differences between the cookie baking properties of good and poor quality flours. In general, flours with a low water-retention capacity are considered to be superior for cookie baking.

Yamazaki (1962) used a heated mixograph to record changes in cookie dough viscosity during heating. He was not completely satisfied with the results because of a concern that the water distribution in the doughs may have been disturbed by the constant agitation during measurement. No other authors have described methods to measure cookie dough viscosity. However, the technique of lubricated uniaxial compression has been used to measure the biaxial elongational viscosity of wheat flour doughs (Bagley and Christianson 1986, Cullen-Refai et al 1988, Lin et al 1993).

The objectives of this study were to determine whether the technique of lubricated uniaxial compression could be used to measure differences in the elongational viscosity of cookie doughs and to determine whether dough viscosity could be a useful tool to predict the cookie baking quality of soft wheat flours.

MATERIALS AND METHODS

Cookie Ingredients

A commercially milled, untreated, soft winter wheat flour containing 12.3% moisture, 0.43% ash, and 7.62% protein (14% mb) was obtained from Mennel Milling (Fostoria, OH). A commercially milled, untreated, hard red winter wheat flour was obtained from Cargill (Wichita, KS) and contained 12.7% moisture, 0.50% ash, and 10.8% protein (14% mb). Samples of the pure soft wheat cultivars Argee, Caldwell, Cardinal, Daws, Gore, Lewjaw, and Stephens were provided by the USDA Soft Wheat Lab (Wooster, OH) and the Western Wheat Quality Lab (Pullman, WA). The pure cultivars were milled into straight-grade flour.

Superfine sucrose was obtained from C&H (Concord, CA). Nonfat dry milk was supplied by American Ingredients (Kansas City, KS). Crisco, a commercial all-vegetable shortening containing mono- and diglycerides manufactured by Proctor and Gamble

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(Cincinnati, OH), was used. Sodium bicarbonate, sodium chloride, and ammonium chloride were reagent-grade. All ingredient levels are expressed on a flour weight basis (fwb) unless otherwise specified.

Cookie Baking

Cookie doughs were prepared using the AACC sugar-snap cookie formula (Method 10-52, AACC 1995). Water absorption was 25% (fwb). Cookies were baked for 10 min at 205°C. Diameter was measured after the cookies had cooled completely. The average of three measurements per two cookies is reported. A minimum of two replicates was baked for each treatment.

Lubricated Uniaxial Compression

Lubricated uniaxial compression described by Bagley and Christianson (1986) was used to measure the biaxial elongational viscosity of cookie doughs. Cookie dough was deposited in four separate pieces onto a well-greased cookie sheet and rolled to a thickness of 7 mm. A single 40-mm diameter disk was cut from each rolled dough piece. The disks were coated generously with mineral oil to lubricate the dough and prevent adhesion to the probe during testing. The disks were compressed directly on the cookie sheet with a plastic-coated 50-mm diameter probe attached to the TA.XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY and Stable Micro Systems, Godalming, UK). The disks were deformed to 50% strain at a speed of 0.4 mm/sec. Elongational viscosity was calculated as: $2\ F\ h/R^2\ V_z$, where F is peak force needed for dough deformation, h is dough height after compression, R is dough radius after compression, and V_z is cross-arm speed.

Data Analysis

Data were evaluated by regression analysis using the Statistical Analysis System (SAS Institute, Cary, NC) for data analysis.

RESULTS AND DISCUSSION

Full-Formula Cookie Dough Preparation

When cookie doughs were prepared according to AACC Method 10-52 (AACC 1995), the standard error for determining elongational viscosity between replicate doughs made from the same flour was large. Visual examination of the doughs showed that some were wet and sticky, whereas others were rather dry, even though the formula and procedure were constant. Abboud and Hoseney (1984) reported that about half of the sucrose in the AACC sugar-snap cookie formula is dissolved during mixing. As sucrose dissolves, it creates ≈0.6 cm^3/g of additional solution (Ghiasi et al 1983). Therefore, we suspected that the amount of sucrose being dissolved during the creaming step was not uniform from dough to dough. When more sucrose was dissolved during creaming, more solution was produced, resulting in wetter-appearing doughs. The total amount of sucrose that will dissolve is controlled by the sucrose-to-water ratio, temperature, and mixing time of the cream and aqueous components. Mixing the cream, water, and leavening solutions for 10 min (mix 5 min, scrape, mix 5 min) before addition of the flour rather than the standard 5 min outlined in the AACC procedure (mix 3 min, scrape, mix 2 min) resulted in more uniform doughs.

Development of a Simplified Cookie Dough Formula

The driving force behind the development of alternative tests to measure cookie flour quality is that they should be faster and easier to perform than the bake test. The technique of lubricated uniaxial compression is quicker. However, scaling the minor ingredients in the AACC cookie dough formula is tedious and time-consuming. Therefore, a simplified formula was developed.

The simplified formula was based on the AACC 10-52 formula but contained only sucrose (24 g), shortening (12 g), water (10 mL), and flour (40 g on a 14% mb) per dough. The sucrose and shortening were first creamed in a Hobart N-50 mixer (Hobart Canada, North York, Ontario) as described in AACC Method 10-52. A large batch of cream was made, and an aliquot (36 g) was taken and mixed with the water (10 mL) in a cookie dough micromixer (National Manufacturing Co., Lincoln, NE) as follows: mix for 1 min, scrape, then mix for 1 min. The flour was added and mixed as outlined in AACC Method 10-52 (mix 10 sec, scrape, mix 5 sec, scrape, mix 5 sec, scrape, mix 5 sec). Dough viscosity was measured as described above.

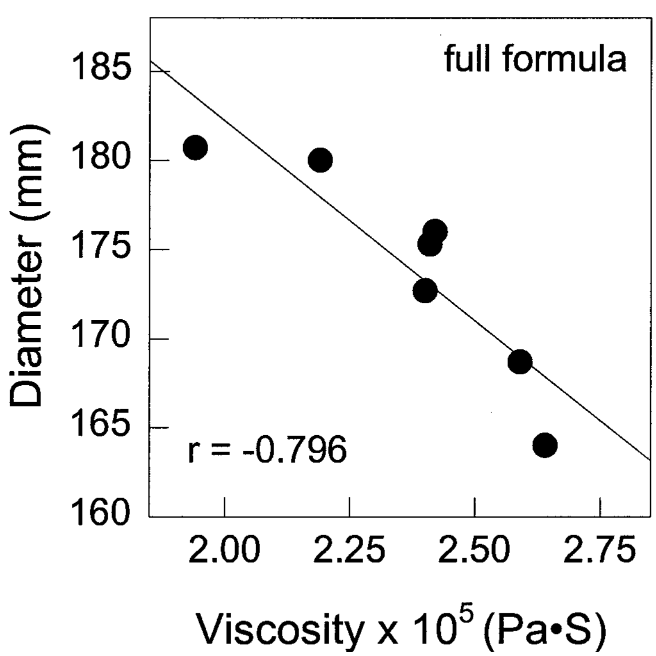

Fig. 1. Effect of dough elongational viscosity on cookie diameter. Cookie doughs were prepared using the full AACC Method 10-52 sugar-snap cookie formula.

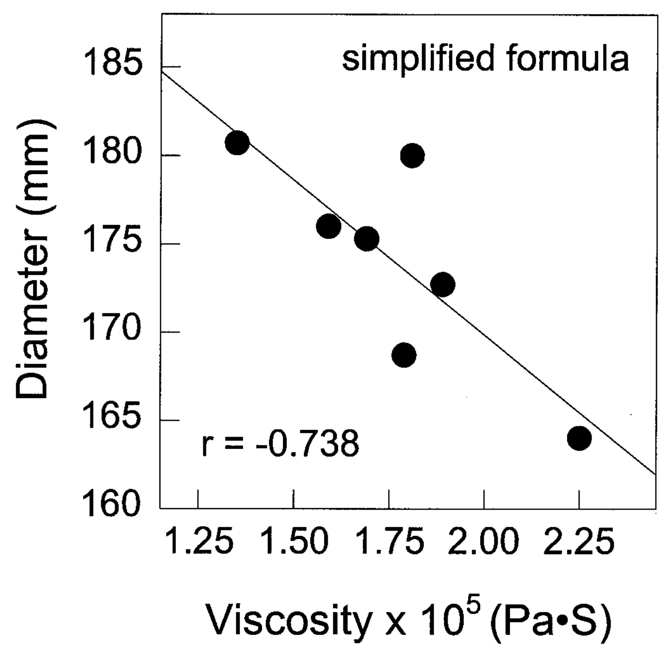

Fig. 2. Effect of dough elongational viscosity on cookie diameter. Cookie doughs were prepared for viscosity measurement using a simplified formula containing only sucrose, shortening, flour, and water. Cookie diameter was determined using the full AACC 10-52 sugar-snap cookie formula.

The elongational viscosity of doughs prepared using the simplified formula was reproducible from dough to dough, even though the mixing time was quite short. Increasing the mixing time of the cream and water did not alter the viscosity value or improve the reproducibility. Presumably, the high absorption capacity of the nonfat dry milk in the complete formula was responsible for the poor reproducibility of full formula doughs.

Effect of Hard Wheat Flour vs. Soft Wheat Flour

To determine whether the technique of lubricated uniaxial compression could be used to differentiate between cookie doughs of different viscosities, cookie doughs prepared with a commercially milled hard wheat flour and a commercially milled soft wheat flour were tested. The difference in viscosity between cookie doughs made with the two types of flour is large. If lubricated uniaxial compression could not show a difference between the two cookie doughs, it would not have showed potential as a tool to predict the baking quality of different soft wheat flours where the viscosity differences are smaller.

As expected, full-formula cookie doughs made with hard wheat flour had a significantly higher elongational viscosity ($5.88 \times 10^6 \pm 9.17 \times 10^4$ Pa·S) than those made with soft wheat flour ($2.17 \times 10^6 \pm 1.05 \times 10^4$ Pa·S). This showed that the technique of lubricated uniaxial compression could differentiate between cookie doughs made with hard wheat and soft wheat flours and therefore showed potential.

Evaluation of Soft Wheat Flours

The differences in viscosity between cookie doughs made with hard wheat and soft wheat flour are large. However, those between doughs made with different soft wheat flours are not. Therefore, to determine whether lubricated uniaxial compression was sensitive enough to differentiate among different soft wheat flours, the elongational viscosity of cookie doughs made with flours from different soft wheat cultivars was measured. These flours produced cookies with various diameters. Cookie doughs were prepared for viscosity measurement using both the full and simplified formulas described above.

Cookie diameter decreased as elongational viscosity increased (Figs. 1 and 2). The elongational viscosity of full-formula cookie dough correlated highly and significantly with cookie diameter ($r = -0.796$; $P < 0.05$) (Fig. 1). Therefore, the technique of lubricated uniaxial compression can be used to measure differences in dough viscosity of cookies made with various soft wheat flours.

Correlation between dough elongational viscosity and cookie diameter using the simplified formula was also good ($r = -0.738$; $P < 0.10$) (Fig. 2). Thus, dough elongational viscosity can be measured satisfactorily using a simplified formula. Viscosity measurement using either the full formula or simplified formula procedures described above appears to be a good indicator of cookie diameter.

CONCLUSIONS

The technique of lubricated uniaxial compression differentiated between cookie doughs made with flours from different soft wheat cultivars. Dough elongational viscosity correlated significantly with cookie diameter for doughs made with the full formula and with a simplified formula containing only sucrose, shortening, water, and flour. Use of the simplified formula eliminates weigh-up of the minor ingredients and preparation of the solutions, so dough preparation time is reduced significantly.

Lubricated uniaxial compression appears to be a simple, appropriate method to measure differences in the viscosity of cookie doughs and may be useful for predicting the cookie baking quality of soft wheat flours.

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