Effect of Formula Water Content on the Spread of Sugar-Snap Cookies[1]

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ABSTRACT

Sugar-snap cookie doughs prepared with a commercial soft wheat flour and standard formula water (25%, fwb) produced baked cookies with a mean diameter of 186 mm. Increasing the formula water to 30% resulted in cookies with a mean diameter of 187 mm and decreasing the formula water to 20% resulted in cookies with a mean diameter of 185 mm. A similar effect was seen when the formula water in cookie doughs prepared with the pure hard red spring cultivar Butte 86 or the pure soft white winter club cultivar Paha was varied. Thus, varying the formula water in cookie dough appeared to have little or no effect on final cookie diameter. Formula water content, however, did affect cookie dough spread rate and set time during baking. Increasing the formula water caused the spread rate to increase but shortened the set time. As a result, final cookie diameter was essentially unchanged.

During baking, the diameter of sugar-snap cookies increases linearly then suddenly becomes fixed (Yamazaki 1959, Abboud et al 1985, Miller et al 1996). Thus, final cookie diameter appears to be controlled by the rate at which the cookie dough spreads and the time at which the cookie dough stops spreading (set time) during baking.

Cookie spread rate appears to be controlled by dough viscosity (Yamazaki 1959, Hoseney et al 1988, Hoseney and Rogers 1994, Miller 1997). Hoseney et al (1988) suggested that the viscosity of the dough is determined by the level of formula water, which acts as a solvent. When more water is present in the dough, more sugar is dissolved during mixing. This lowers initial dough viscosity, and the cookie is able to spread at a faster rate during heating. Flour components that absorb large quantities of water reduce the amount of water that is available to dissolve the sugar in the formula. Thus, initial dough viscosity is higher and the cookie spreads less during baking (Yamazaki 1955, Hoseney and Rogers 1994). Flours with low hydration properties produce cookies with greater spread (Yamazaki 1962).

It has been suggested that cookie set time is determined by an apparent glass transition of the gluten protein in the flour (Doescher et al 1987, Miller et al 1996). Doughs that go through the apparent glass transition at a lower temperature result in cookies with a smaller diameter. Alternative mechanisms of cookie setting have also been suggested (Slade et al 1989, Slade and Levine 1994).

Yamazaki (1959) 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 quality of good and poor quality flours. In general, flours with a low water-retention capacity are considered to be superior for cookie baking (Slade and Levine 1994). The objective of this study was to determine the effect of formula water content on cookie spread.

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MATERIALS AND METHODS

The research was conducted in laboratories located in Manhattan, KS, and in Pullman, WA. Baking was conducted by different individuals at each location.

Cookie Ingredients

A commercially milled, untreated, soft winter wheat flour containing 12.3% moisture, 0.43% ash (14% mb), and 7.62% protein (14% mb), obtained from Mennel Milling Company (Fostoria, OH), was used in the Manhattan, KS, laboratory. Paha soft white winter club and Butte 86 hard red spring cultivars were used in the Pullman, WA, laboratory. The grains were tempered to 13.0 and 14.5% moisture content (fwb), respectively, and milled into straight-grade flours according to the procedure of Jeffers and Rubenthaler (1977), with a modified Quadrumat system. The Paha flour contained 12.9% moisture, 0.38% ash (14% mb), and 8.1% protein (14% mb) and the Butte 86 flour contained 14.0% moisture, 0.40% ash (14% mb), and 12.1% protein (14% mb).

The Manhattan laboratory used superfine sucrose from C&H (Concord, CA); nonfat dry milk (NFDM) from American Ingredients (Kansas City, KS); and Crisco, a commercial all-vegetable shortening containing mono- and diglycerides, manufactured by Proctor and Gamble (Cincinnati, OH).

The Pullman laboratory used superfine baker's special sugar from Speckles (Pleasanton, CA); NFDM from Darigold (Bellvue, WA); Creamtex partially hydrogenated vegetable oil shortening from Van den Bergh Foods (Channahon, OH); and Myverol 18-85 distilled monoglycerides from Eastman (Knoxville, TN).

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

Cookie Dough Preparation and Baking

Sugar-snap cookie doughs were prepared using AACC Method 10-52 (AACC 1995) in Manhattan and a slightly modified AACC Method 10-52 in Pullman. The modifications included increased $NaHCO_3$ (1.06% in Solution A), increased NH_4Cl (0.677% in Solution B), decreased NaCl (0.261% in Solution B), and the addition of 0.24% emulsifier. Formula water was altered to produce cookie doughs of different consistencies. Control doughs had 25% water absorption. The Manhattan laboratory decreased water absorption to 20% (80% of standard) to produce dry, crumbly doughs that could barely be formed into a cohesive mass for rolling and cutting and increased formula water to 30% (120% of standard) to produce wet doughs that were almost too sticky to roll and cut. The Pullman laboratory varied water absorption by 10% increments from 70% of standard (17.5% fwb) to 130% of standard (32.5% fwb) for the Paha flour and from 80% of standard (20% fwb) to 140% of standard (35% fwb) for the Butte 86 flour.

Dough weight before baking was determined in the Pullman laboratory. Dough weight was determined by weighing the baking pan and the two cut and trimmed dough pieces and then subtracting the weight of the pan.

The cookies were baked for 10 min at 205°C in a reel oven (National Manufacturing, Lincoln, NE). Cookie diameter was measured after the cookies had cooled completely. The average of three measurements for two cookies is reported.

Time-Lapse Photography

In the Manhattan laboratory, photographs of the cookies were taken during baking with a camera mounted to the oven door. Guidelines were drawn 8.9 cm from one end of a baking sheet (parallel to the edge) and down the center to form a cross. Cookie dough was placed on the sheet, rolled, and cut so that the cookie was centered over the cross to assure that the cut cookie was in the same position in every trial. A small metal bar of known dimension was placed at a marked position on the guideline beside the cookie, so the actual diameter of the cookie could be determined from the photographs. The baking sheet was placed on a stationary shelf in the oven. The shelf was adjusted so that the camera was at the same level as the cookie. Photographs were taken of the cookies at 30-sec intervals during baking. Cookie diameter was measured directly from the photographs and plotted as a function of baking time to determine set time and spread rate. Set time was the time at which the cookie stopped increasing in diameter. Spread rate was determined by measuring the slope of the line between 1 min (the time when the cookie began to spread) and the set time. A minimum of two replicates was baked for each treatment.

Data Analysis

Data were evaluated by the analysis of variance (ANOVA), general linear models, and correlation analysis procedures of the Statistical Analysis System (SAS Institute, Cary NC).

RESULTS AND DISCUSSION

Varying the formula water content of cookie dough had little or no effect on final cookie diameter. Cookies baked in Manhattan using commercial soft wheat flour and the standard formula containing 25% formula water had a mean diameter of 186 mm. Cookies baked with 20% formula water had a mean diameter of

TABLE I
Analysis of Variance (ANOVA) of Diameters of Cookies Made from Paha Soft White Club Wheat and Butte 86 Hard Red Spring Wheat Flours and Baked at Seven Levels of Formula Water With and Without Emulsifier

		Paha		Butte 86	
Source	df	*F* Value	*P* Value	*F* Value	*P* Value
Formula water (*W*)	6	5.13	0.0012	73.57	<0.0001
Emulsifier (*E*)	1	20.39	<0.0001	4.15	0.051
$W \times E$	6	0.48	0.82	2.87	0.026
R^2		0.66		0.94	

TABLE II
Correlations among Dough Weight, Baked Diameter, and Formula Water Level for Cookies Made with Paha Soft White Club Wheat and Butte 86 Hard Red Spring Wheat Flours

	Paha		Butte 86	
Variable	Diameter	Weight	Diameter	Weight
Formula water	–0.31*[a]	–0.86**	0.94**	–0.80**
Weight	0.60**	. . .	–0.72**	. . .

[a] *,** = $P \leq 0.05$ and ≤ 0.0001, respectively.

TABLE III
Effect of Formula Water Level on Spread Rate and Set Time of Sugar-Snap Cookies Baked with Commercial Soft Wheat Flour[a]

Water (%)[b]	Spread Rate (mm/min)	Set Time (min)
20	5.3c	6.3a
25	6.5b	5.8ab
30	7.5a	5.4bc

[a] Means in a column followed by different letters are significantly different ($P \leq 0.05$).
[b] Flour weight basis (25% is standard).

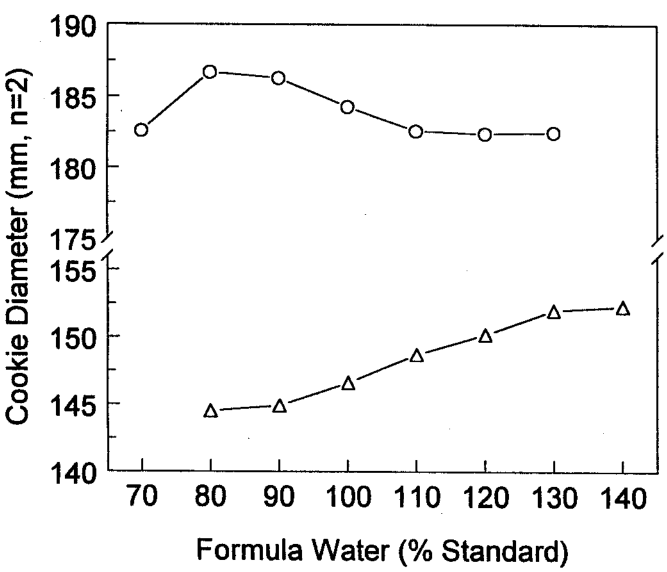

Fig. 1. Diameter of cookies (averages of two) made with Paha soft white club wheat (○) and Butte 86 hard red spring wheat (Δ) flours baked at six levels of formula water. Standard formula water is 25% (fwb). Least significant differences ($P < 0.05$) are 2.4 mm for Paha and 1.1 mm for Butte 86.

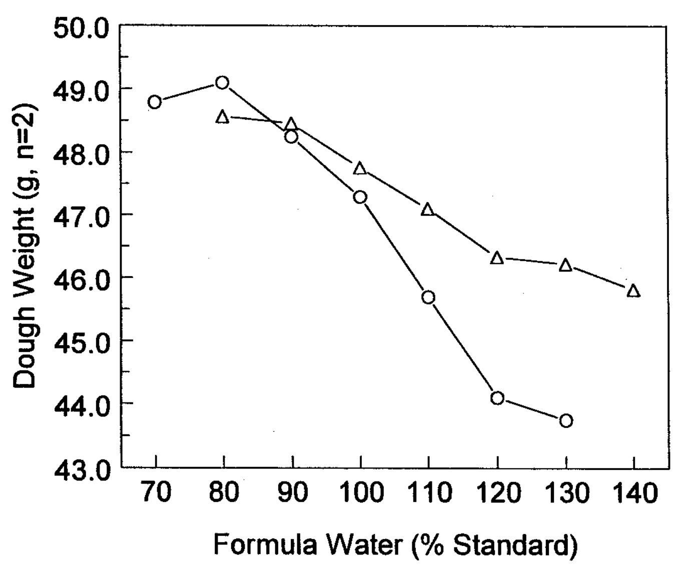

Fig. 2. Weights of cookie doughs (averages of two cookies) made with Paha soft white club wheat (○) and Butte 86 hard red spring wheat (Δ) flours baked at six levels of formula water. Standard formula water is 25% (fwb). Least significant differences ($P < 0.05$) are 0.88 g for Paha and 0.87 g for Butte 86.

185 mm, and those baked with 30% formula water had a mean diameter of 187 mm. Therefore, reducing or increasing the formula water did not appear to significantly ($P < 0.05$) change cookie diameter.

The combined ANOVA for the Paha and Butte 86 flours produced an *F*-value for flour of 9,370.70, with the next largest *F*-value being 28.21 (data not shown). This exceptionally large *F*-value indicated that the two flours produced cookies with very different diameters (independent of other factors) and that, consequently, the data set should be subdivided for each individual flour and reanalyzed. The individual ANOVA results presented in Table I demonstrate that water level had a significant effect on cookie diameter. To examine further this effect, which seemed contradictory to the results from Manhattan, mean cookie diameter was plotted as a function of formula water (Fig. 1). As can be seen, increasing the formula water in doughs made with hard wheat flour increased cookie diameter. However, the change in diameter (≈3.4%) was relatively small.

A different trend was seen in cookies baked with soft wheat flour. Cookie diameter increased by ≈2.5% as formula water was increased from 70 to 80% of standard, then decreased by ≈2.5% as water was increased further to 110% of standard. No change in cookie diameter occurred between 110 and 130% of standard formula water. Again, the changes in cookie diameter were relatively small, ≈2.5%. It should be emphasized that these changes in diameter between cookies made with either Paha or Butte 86 flour, although statistically significant, are quite small in comparison to the differences in cookie diameter between the two flours.

As noted earlier, the level of formula water had a marked effect on dough consistency and handling properties. The weight of cookie doughs made with Paha and Butte 86 flours differed significantly and generally decreased with increasing water content (Fig. 2). The two flours appeared to differ in the relative magnitude of this effect. Although correlation analysis of the Paha and Butte 86 data revealed a relatively strong negative correlation between formula water and uncooked dough weight (Table II), dough weight changes did not explain why cookie diameter changes were relatively small as formula water varied or why cookie diameter differed greatly (by as much as 29%) between cookies baked with the two types of flour.

During baking, the cookie increases in diameter then suddenly becomes fixed. Varying the formula water significantly affected both cookie spread rate and set time (Table III). In general, increasing the formula water caused the spread rate to increase, presumably by lowering dough viscosity. At the same time, increasing formula water shortened the set time. Previous studies have shown that cookie set time is controlled by an apparent glass transition of the gluten in the flour (Doescher et al 1987, Miller et al 1996). The glass transition temperature of polymers is known to decrease with increased levels of plasticizer (Eisenberg 1984). In this case, the plasticizer is water (Slade et al 1989). With more formula water, the cookies spread faster but also set earlier. As a result, the final diameter of the cookie was essentially unchanged. The results from Pullman appear to support the same general conclusion that the changes in diameter were relatively small and similarly might have been due to changes in spread rate and set time that did not quite cancel each other out.

CONCLUSION

The rate at which cookies spread during baking is influenced by the viscosity of the dough. Increasing the formula water content increased cookie spread rate, presumably by decreasing dough viscosity. However, the set time also was lowered. It is well known that the amount of plasticizer has a large effect on the glass transition temperature of polymers. It follows that increasing the water content of the dough will cause the apparent glass transition of the gluten from a glassy solid to a rubbery liquid to occur at a lower temperature. Therefore, although cookie doughs containing more formula water were less viscous and spread at a faster rate, they also set earlier. As a result, cookie diameter was virtually unchanged.

Cookies baked with hard wheat flour and a high water content had a much smaller diameter than cookies baked with soft wheat flour and a low water content. Thus, it appears that the difference in diameter between cookies made with typical soft and hard wheat flours is not directly attributable to formula water.

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