# Factors Affecting Cookie Flour Quality[1]

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**ABSTRACT**

Time-lapse photographs were taken to observe changes that occur in cookie diameter during baking. Cookie diameter is a function of the rate of spreading and the setting point of the cookie dough. Rate of spreading was greater and expansion time longer for good quality (soft wheat) cookie doughs compared to poor quality (hard wheat) cookie doughs. Compression tests showed that both doughs underwent a decrease in viscosity as temperature was raised. When compression was measured on doughs heated to a relatively low temperature (40°C), there was a large difference in force between doughs made from hard and soft wheat flours, with soft wheat dough exhibiting less resistance to compression.

Yamazaki (1950) developed a successful reconstitution procedure for cookie flours, which involved recombining all the fractions and mixing them into a dough, drying, and grinding the dough to produce a reconstituted flour. Using this technique, Yamazaki (1955) reported that the tailings fraction had a deleterious effect on cookie spread of reconstituted flours. A purified fraction from the tailings was highly hydrophilic; its deleterious effects on cookie spread were proportional to the amount added to a control flour. Addition to flour of similar hydrophilic materials from other sources also decreased spread to various degrees. Straight-grade flours from hard wheats contained more starch tailings than did straight-grade flours from soft wheats. This suggested that varietal differences in cookie flours might be attributable to quantitative differences in the tailings fraction. Low-grade flours that were rich in starch tailings give poor cookies (Sollars 1956). The purified tailings are rich in pentosans, and low in starch and nitrogenous compounds. However, no definite correlation could be established between chemical composition of tailings and cookie spread.

Sollars (1956) fractionated flour into four portions using an acid fractionation procedure and found that tailings had the most negative effect on cookie diameter and appeared to be the most important fraction in cookie quality. The water-soluble fraction had a small but consistent effect of decreasing spread; prime starch had only a slight effect, and the effect of gluten on spread was erratic.

Sollars and Bowie (1966) fractionated tailings into subfractions and reported that the pentosan-rich subfractions had greater diameter-decreasing effects than did the original tailings. Protein and enzymes appeared to have negligible effects, and lipids and small-granule starch had small diameter-reducing effects.

A major breakthrough in soft wheat flour quality research was made when Yamazaki (1956, 1959) used time-lapse photographs to study cookie expansion. His results showed that hard wheat cookie doughs stopped expanding sooner than those from soft wheat flours. These results emphasized the need for a test that could be conducted under baking conditions; therefore, the application of heat to physicochemical tests was researched. The heated mixograph, heated alkaline water retention capacity, and amylograph indicated that, after an initial decrease in viscosity, doughs from poor quality flours showed increased viscosity earlier (at lower temperature) than did doughs from better quality flours (Yamazaki 1956, 1959). In an attempt to clarify what actually happens during the baking process, Yamazaki (1962) used a vibrating probe viscometer that determined viscosity without mixing or stirring the sample. His results suggest that water movement at moderate dough temperature is a very important aspect of the mechanism of cookie baking. The objective of our study was to extend Yamazaki's work, using the resistance oven, Instron testing machine, and time-lapse photography, to better understand the basis for cookie flour quality.

## MATERIALS AND METHODS

The standard soft wheat flour (9.2% protein) used was a commercial cookie flour obtained from Mennel Milling Co., Fostoria, OH. The standard hard wheat was a low protein (9.7%) hard red winter milled at Kansas State University. Other flours and the cookie baking procedures used are described in a companion paper (Abboud et al 1985). The procedure for differential scanning calorimetry of cookie doughs is described in Abboud and Hoseney (1984).

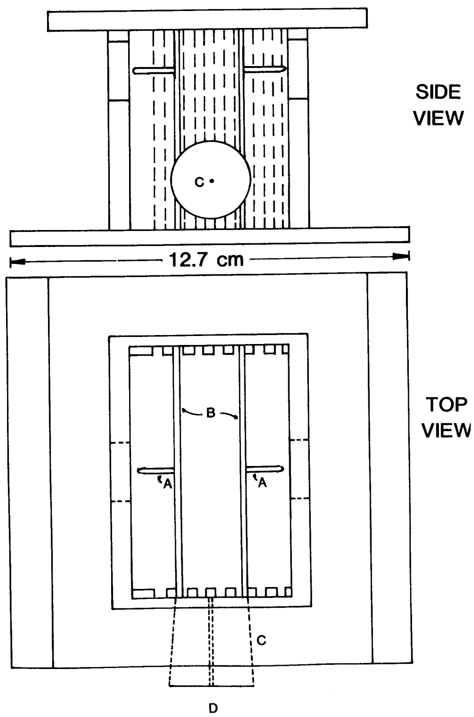


**Fig. 1.** Resistance baking oven (side view, **top**; and top view, **bottom**). **(A)** electrical connection, **(B)** stainless steel plates that can be placed in the different slots to change distance between plates, **(C)** rubber stopper, **(D)** hole to insert the thermocouple 1.52 cm from the bottom and parallel to the stainless steel plates.

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### Resistance Oven Baking

We used the resistance baking oven described by Baker (1939) and Junge and Hoseney (1981) to heat the dough uniformly. A cookie baking chamber was constructed from 0.635-cm Plexiglas (Fig. 1), with outside dimensions of 12.7 × 12.7 × 7.37 cm and inside dimensions of 6.35 × 8.89 × 6.35 cm. The electrical connections brought current to the stainless electrode plates.

Both distance between plates and voltage were adjusted to obtain the desired rate of heating. Approximately 60 g of cookie dough (complete dough except the leavening agent) was placed on one of the stainless steel plates. The dough was covered with the second plate, and the sandwich was then placed in slots 1.27 cm apart. A good contact between the dough and plate was thus maintained. The temperature of the dough was measured with a thermocouple inserted through a rubber stopper at a preselected location (1.52 cm from the bottom, Fig. 1).

### Compression Test

An Instron Universal Tester (model 1132) with a compression cell of 2-kg maximum load was used. The tester was adjusted to give a full-scale deflection of 250 g. The head speed was set at 5 cm/min. The cookie dough still in the resistance oven was placed on the tester, and the force required to press the probe 3 cm into the dough was taken as the compression force. The stainless steel probe was 4.2 cm long and covered with a 0.8-cm plastic tube attached to increase surface area (Fig. 2).

Cookie doughs were either heated to a temperature of 80° C and cooled to the test temperatures (40, 50, 60 or 70° C), or they were heated to approximate temperatures (50, 60, 70 or 80° C) and then cooled to a temperature of 40° C before testing. The compression test was run immediately upon reaching the desired temperature.

### Water Loss

Water losses were determined at 1-min intervals. Cookie doughs and a tared cookie sheet were weighed and placed in the oven, and baked for the desired time; then the cookie sheet was removed from the oven, and a petri dish of known weight was placed over each cookie to prevent moisture loss. After cooling, the cookie sheet, two cookie doughs, and the petri dish were weighed together. The moisture loss (weight) of the two cookies was calculated from these data.

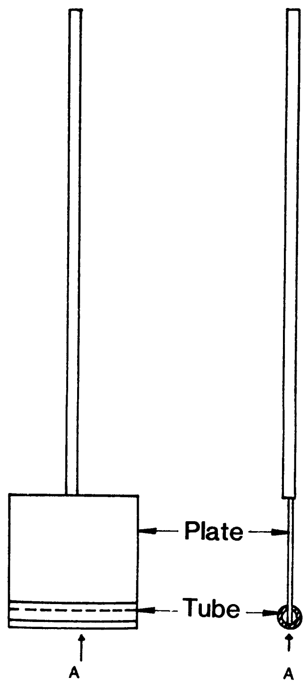


**Fig. 2.** A 16-cm long stainless steel probe with a 3.2 × 3.2 × 0.1 cm plate at the end. **(A)** 0.6-cm plastic tube attached to increase surface area of contact in compression test.

### Time-lapse Photography

Time-lapse pictures were taken by the procedure of Yamazaki (1956) with a slight modification. The cookies were cut to regular size (rather than the large cookies used by Yamazaki) and baked for 10 min, and a metal ruler was positioned at the center of the cookie sheet. Photographs were taken at 60-sec intervals.

## RESULTS AND DISCUSSION

### Model for Cookie Formation

Cookie dough is a mixture of flour, sugar, and shortening, along with small quantities of sodium bicarbonate, ammonium

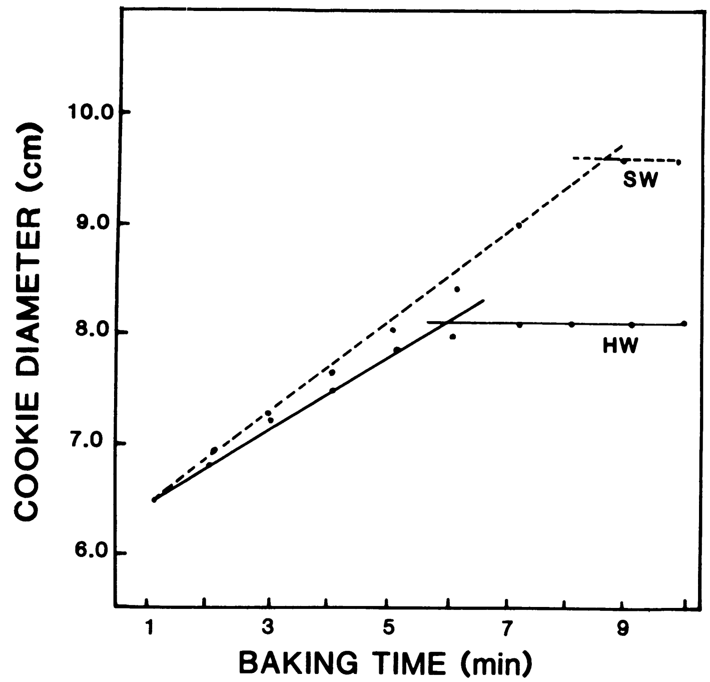


**Fig. 3.** Changes in cookie diameter during baking: HW = hard wheat, SW = soft wheat.

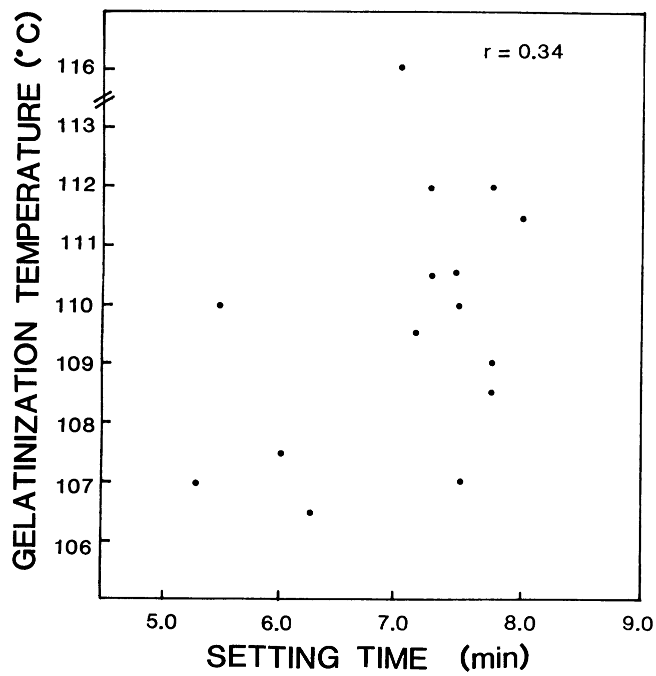


**Fig. 4.** Setting time vs. gelatinization temperature in 15 flours chosen from several wheat classes.

bicarbonate, salt, milk solids, and sufficient water to give the proper handling consistency. During baking, the cookie dough changes to a solid structure. The transition from semi-fluid dough to solid cookie is the least understood phase of cookie baking.

Time-lapse photography was used to record the changes that occurred during baking. Cookie diameter increased linearly with baking time in the early and middle stages of baking. After a certain time, however, the diameter was fixed and underwent no further change.

When cookie diameter was plotted against baking time, the data did not produce one single pattern, but gave various plots (Fig. 3). All doughs started expanding at the same time, but the rate of spreading was greater for good quality cookie doughs. Also, expansion continued longer for the soft wheat doughs than for hard wheat cookie doughs. Final cookie diameter was a result of spreading rate and setting time. These results agree with those reported by Yamazaki (1956, 1959).

Set time, the point at which expansion of cookies stopped, was without exception earlier for cookies prepared from hard wheat flours than for cookies prepared from soft white spring, soft white winter, or club wheat flours. An obvious question is, What makes the cookie stop expanding? To investigate this, starch gelatinization and water loss were studied. Flour samples (15) were chosen to represent hard, soft white spring, soft white winter, and club wheats. Cookie doughs were made from those flours, and a sample of each dough was run in the differential scanning calorimeter. The data showed no consistent relationship between gelatinization temperature (Abboud and Hoseney 1984) and setting time (Fig. 4). This might be expected, as the starch has been shown to be ungelatinized in baked cookies (Abboud and Hoseney 1984). The second phenomenon studied was dough water loss. Because cookie doughs lose water during baking, we thought it important to see if the water loss was related to the setting time. The water loss was quite similar for both cookie flours (Fig. 5).

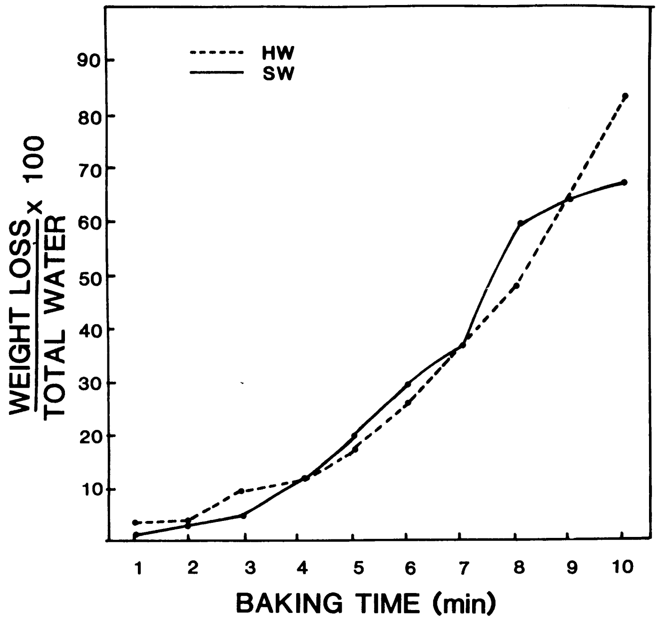


**Fig. 5.** Water loss from cookies during baking: HW = hard wheat, SW = soft wheat.

**Resistance Oven**

The resistance oven has been described as a way of uniformly heating bread dough (Junge and Hoseney 1981). A similar oven was used in the present study to obtain uniform heating of cookie doughs. To obtain a heating rate similar to that found in conventional cookie baking, sample thickness was varied; at about 1.27 cm a heating rate similar to that reported (Yamazaki 1959) for cookies was obtained.

Obvious differences exist between the resistance oven and conventional oven. Heating is uniform in the resistance oven, whereas in the conventional oven it is different at the bottom, sides, and surface of the dough. In the early phases of cookie baking, surface evaporation tends to cool the cookie. The bottom of the dough is not cooled and is influenced more by the heat transferred through the metal sheet. At the same time, the cookie begins to expand, and movement of the dough occurs. During this period, the bottom temperature is higher than the interior of the dough, and well-defined temperature gradients from the bottom and edges to the center are established.

Temperature changes inside a soft wheat cookie dough during baking in the resistance oven are shown in Figure 6. The temperature increase was essentially linear until the temperature exceeded the boiling temperature of water. The results are in good

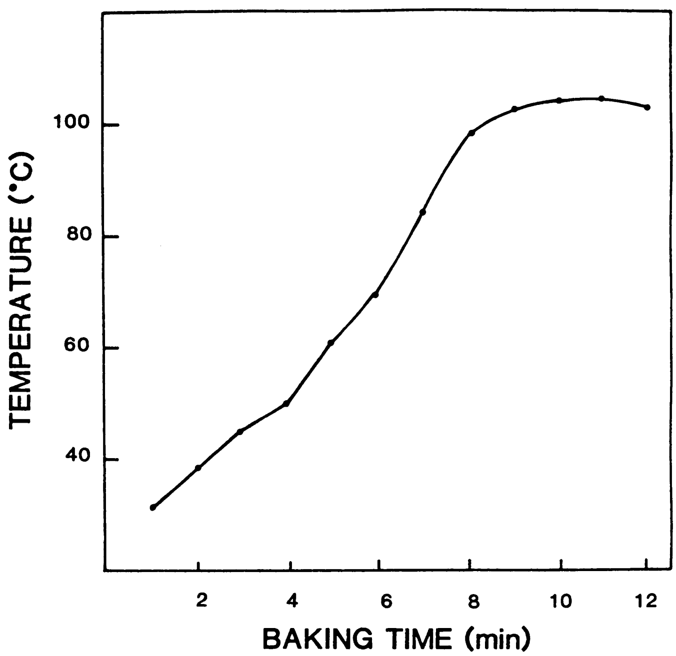


**Fig. 6.** Temperature of soft wheat cookie dough during baking in the resistance oven.

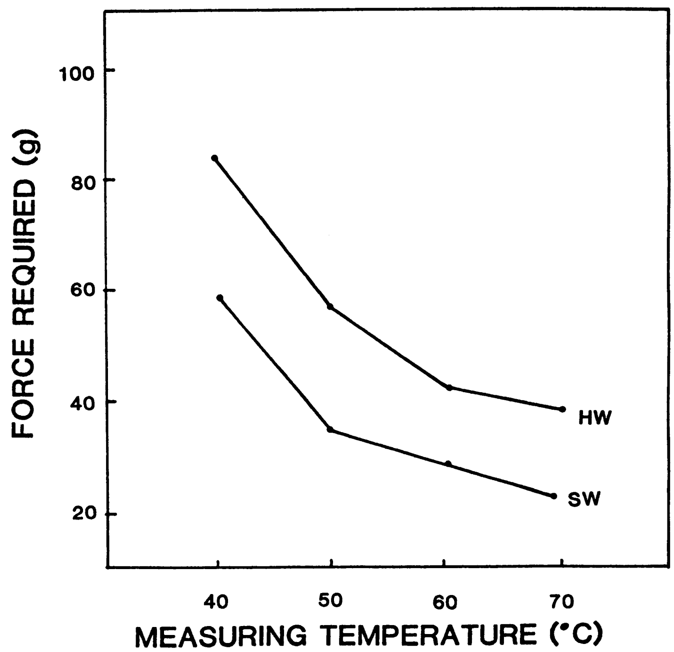


**Fig. 7.** Effect of measuring temperature upon force required to compress cookie doughs made from hard and soft wheat flours. All doughs were heated to 80° C and then cooled to the measuring temperature: HW = hard wheat, SW = soft wheat.

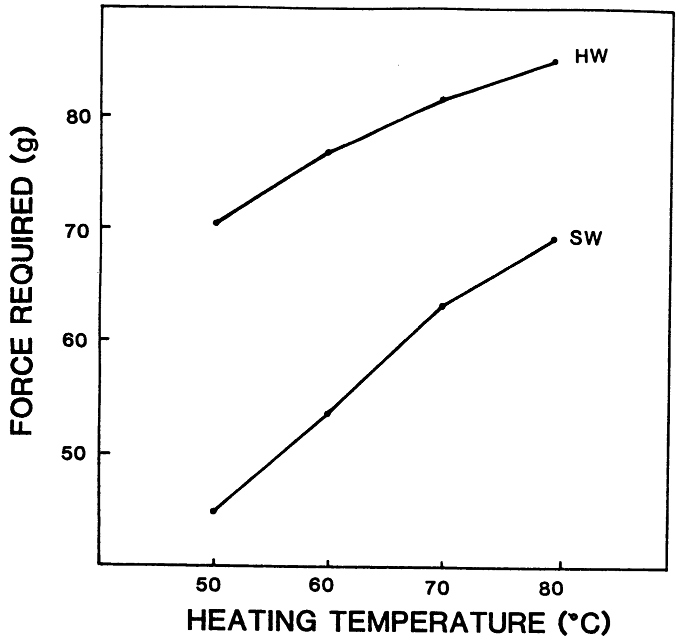


**Fig. 8.** Force required to compress cookie doughs made from hard and soft wheat flours. All measurements were made after cooling to constant temperature (40° C): HW = hard wheat, SW = soft wheat.

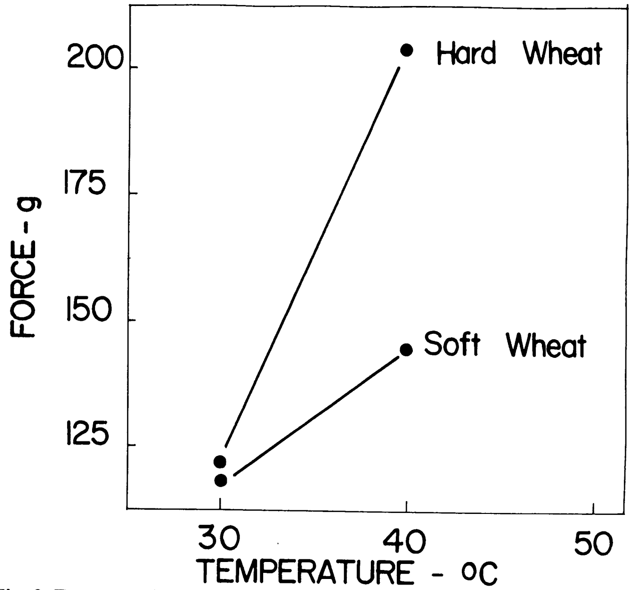


**Fig. 9.** Force required to compress cookie doughs made from hard and soft wheat flours. All measurements were at 27° C after heating to the indicated temperatures.

agreement with those obtained by Yamazaki (1959) using the conventional oven.

**Cookie Dough Compression**

The reason for differences in the rate of spreading of cookie doughs deserves investigation. We used the resistance oven and Instron universal testing machine to heat the dough uniformly and to measure the force required to move a probe through the dough at certain temperatures.

Results obtained at temperatures above 80° C were inconsistent, probably because the dough expanded rapidly at that temperature. Therefore, cookie doughs were not heated above 80° C.

Once the power was discontinued the dough temperature dropped rapidly, therefore, each cookie dough was cooled at least 10° C before measuring the force. Cookie doughs were heated to 80° C and cooled to 70, 60, 50, or 40° C for compression measurement. Immediately upon reaching the desired temperature, compression was tested. The force required to compress cookie doughs made from hard and soft wheat flours was compared. The results indicated that more force was required for doughs prepared from hard wheat flours than for doughs prepared from soft wheat flours at all temperatures measured (Fig. 7). These results showed that as the system was heated, the compression force of a cookie dough made from good quality flour was lower than that of a dough made from a poor quality flour. This resulted in a high rate of spreading for the dough made from soft wheat flour.

When cookie doughs were heated to 50, 60, 70, or 80° C and cooled to the same temperature (40° C, Fig. 8), it is clear that as the temperature of the cookie dough was raised, the force required to compress the dough increased.

However, it was not clear if the differences between hard and soft wheat were caused by the heating or were inherent in the unheated doughs. Thus, doughs were prepared and measured at 30° C with little heating (Fig. 9). The force required was similar. Heating the doughs to 40° C, cooling to 27° C, and then measuring the force gave a large difference between hard and soft wheat flour doughs. Thus, the difference between the flours becomes obvious only after heating to relatively low temperatures (40° C).

## CONCLUSIONS

When heated, cookie doughs flow (increase in diameter) at a constant rate until a certain point is reached. At this point the viscosity of the cookie dough is great enough to offset the gravity force that is causing the dough to flow. Thus, the set time of cookie doughs is controlled by a temperature-mediated change in viscosity. As shown here (Fig. 7), the force for compression decreased as the temperature was increased; at the same time changes were occurring in the dough that increased the force for compression (Fig. 8). Over the same time span, during baking, the cookies were losing water (Fig. 5), which also increased the force of compression. Both the loss of water and the decrease in force of compression as a function of temperature are approximately equal for hard and soft wheat flour doughs. However, the change in force of compression for the hard wheat flour dough was much greater at low temperature than was the change for soft wheat flour. Therefore, it appears that this low temperature change is the factor that makes the hard wheat flour set at a lower temperature than does the soft wheat flour. Further work is required to determine what is changed during low temperature heating.

The second factor that determines the final size of the cookie is the rate of flow. The slope of the line shown in Figure 3 is clearly important.

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