Effect of Sugar Type and Flour Moisture on Surface Cracking of Sugar-Snap Cookies[1]

L. C. DOESCHER and R. C. HOSENEY[2]

Cereal Chem 62(4): 263–266

ABSTRACT

The effect of sugar type and flour moisture on the surface cracking pattern of sugar-snap cookies was studied. When moisture content of a standard cookie flour was adjusted, cookies baked from those flours showed differences in cracking pattern. Cookies baked from lower moisture flour cracked at each water level tested in the formula, whereas those baked from high-moisture flour did not crack. Flour moisture influenced cracking more than did the total water in the formula. Substitution of small levels of glucose, fructose, maltose, or high-fructose corn syrups for sucrose solids changed the cracking pattern. Cookies made with all fructose syrup or glucose syrup did not crack. Only cookies made with all granular sucrose or all dissolved sucrose exhibited surface cracking. The unique ability of sucrose to recrystallize at the cookie surface during baking appears to be responsible for the surface cracking pattern.

In 1974 the price of sugar increased dramatically. This caused production costs for cookie manufacturers to rise, and alternative sweeteners were sought to replace part of the sugar in their formulations. Currently high-fructose corn syrup (HFCS) is the most widely used sucrose substitute. However, substitution of small levels of HFCS for sucrose causes changes in the surface characteristics of baked cookies.

The use of time-lapse photography during baking showed that the outer surface of a cookie made with granular sucrose dried rapidly and cracked when it started to spread (Curley and Hoseney 1984). However, the surface of a cookie containing HFCS did not dry. Instead, it remained moist throughout the early stages of baking. The amount of water lost during baking did not significantly differ; thus, the rate of surface drying appeared to be controlled by internal water diffusion to the surface. Rate of water vaporization from the surface was a constant and depended upon oven conditions.

Curley and Hoseney (1984) proposed that two diffusion rates exist during the early stages of baking: the internal rate of water diffusion within the cookie dough and the rate of moisture loss at the surface during baking. The second is governed by the temperature and moisture in the oven and is the same for cookies made with different sweeteners.

When granular sucrose is used in cookie dough, a portion dissolves during mixing and the remainder dissolves during the early stages of baking (Abboud and Hoseney 1984). Curley and Hoseney (1984) proposed that the presence or absence of a discontinuous liquid phase controlled the diffusion rate within the cookie dough. Our objective in this study was to obtain evidence to support or reject this hypothesis and to determine what factors affect the surface cracking of sugar-snap cookies.

MATERIALS AND METHODS

Materials

Two shipments of a commercial soft wheat cookie flour from Mennel Milling Company, Fostoria, OH, were used. The flours had the following proximate analyses: flour A (9% protein, 16.2% moisture, and 0.44% ash), and flour B (8% protein, 13.4% moisture, and 0.41% ash). The sugar used was superfine pure cane sugar from Imperial Sugar Company, Sugar Land, TX. Anhydrous dextrose, D-fructose, and sorbitol were reagent grade. Maltose hydrate (stated to contain less than 2% maltotriose and less than 0.5% glucose) was from Sigma Chemical Company, St. Louis, MO. Isosweet 100 high-fructose corn syrup was donated by the A. E. Staley Manufacturing Company, Decatur, IL. It contained 71% solids and was composed of: 50% glucose, 42% fructose, and 8% higher saccharides. A commercial hydrogenated all-vegetable shortening, Crisco, from Procter & Gamble, Cincinnati, OH, was used.

Methods

Diffusion in cookie doughs. Cookie doughs were prepared using Micro Method III (Finney et al 1950), except leavening was omitted. For doughs prepared with dissolved sucrose, all of the formula sucrose was dissolved in the formula water. Cookie doughs containing HFCS were prepared by substituting 10% HFCS on a solids basis for sucrose. An appropriate amount of water was removed from the formula to account for water present in the syrup.

Cookie doughs were loaded into 5-cc plastic syringes with the tips removed. The plunger was inserted to seal the barrel, then 0.3 cc of dough was removed from the cut end of the syringe. Each syringe was mounted with the open end up and clamped in a ring stand. Durkee red food coloring (0.15 ml of water, propylene glycol, and artificial color) was deposited on the dough surface, the syringe barrels were sealed with Parafilm, and diffusion proceeded at room temperature. After 10 days, four measurements were taken of the diffusion band around the barrel of the syringe using a dial caliper (Mitutoyo Mfg. Co.). These tests were duplicated.

Cookie baking. All cookies were baked according to Micro Method III (Finney et al 1950). A minimum of two trials were baked for each treatment. For a portion of this study, some of the formula sucrose was omitted from the cream and added to the dough before the last 5 sec of mixing, either in granular form or as a syrup. When high-fructose corn syrup, maltose syrup, or sorbitol syrup were used to replace some of the sucrose solids, formula water was adjusted to compensate for water present in the syrup.

Syrups were used in place of granular sucrose in some trials. When sucrose, glucose, or fructose syrups were used, an alternate leavening system syrup was used: 60% sugar solids, 1% sodium chloride, and 0.75% ammonium bicarbonate were dissolved in the formula water. Fructose and glucose syrups were neutralized with 0.1 *N* sodium hydroxide for some trials.

Glucose and fructose syrups were prepared at the same molar concentration as the sucrose control. Enough water was added to make the total amount of solution equal to the sucrose control; this was calculated using the volume displacement factor for each sugar from tables in the CRC Handbook of Chemistry and Physics (Weast and Astle 1982).

Flour A was dried to different moisture levels by spreading it thinly on cookie sheets while a fan set at low speed passed air over the surface. Flour moistures were determined by the air-oven method (44-15A, AACC 1976). When cookies were baked from the flour of varying moisture content, a constant amount of formula water was used. In other trials, enough formula water was used to

[1]Contribution 85-195J, Department of Grain Science and Industry, Kansas Agricultural Experiment Station, Manhattan 66506. Submitted as a portion of a doctoral dissertation, Kansas State University.
[2]Graduate research assistant and professor, respectively.

© 1985 American Association of Cereal Chemists, Inc.

make the total water in the cookie system equivalent across flour moisture levels.

Heating stage microscopy. Glucose and sucrose syrups were prepared by dissolving 24 g of solids in 8.9 ml of water. This is the concentration used in the cookie formula.

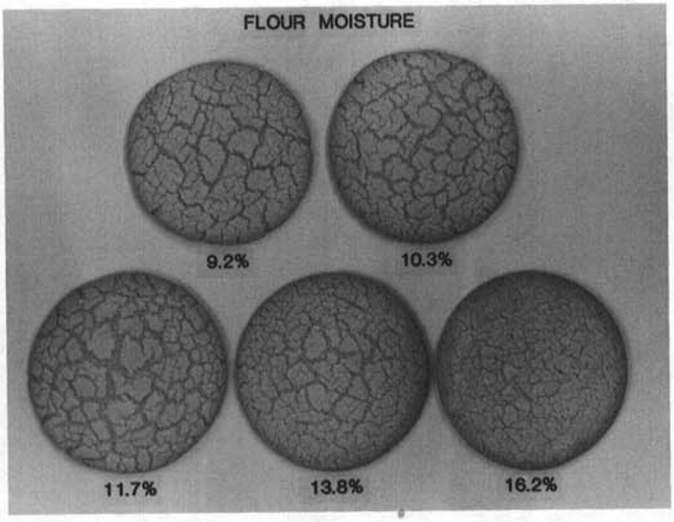

Fig. 1. Effect of flour moisture on the surface cracking pattern of cookies.

Several drops of sucrose syrup, glucose syrup, and a mixture of the two syrups were mounted on separate microscope slides. The slides were placed on the stage of a heating stage microscope without cover slips. The samples were heated, and changes during the heating period were noted.

RESULTS AND DISCUSSION

Diffusion in Cookie Dough

The rates of diffusion of the food coloring in cookie doughs made with completely dissolved sucrose, crystalline sucrose, or with 10% HFCS replacing 10% sucrose solids were not significantly different. However, the rate of diffusion was faster for the high-moisture flour (Table I). This difference existed whether sucrose was crystalline or dissolved.

Thus, the diffusion rate cannot be used to explain the differences in cracking patterns between the control cookie and those containing low levels of HFCS syrup. However, it may explain why cookies having different flour moistures have different cracking patterns.

Baking

Role of flour moisture. Cookies baked from flours of different moisture but with a constant amount of added formula water showed differences in cracking pattern (Fig. 1). As flour moisture increased, the degree of cookie symmetry increased. The number of islands on the cookie surface decreased and the cracks between the islands became larger as flour moisture increased. No cracking was present in cookies made with the 16.2% moisture flour.

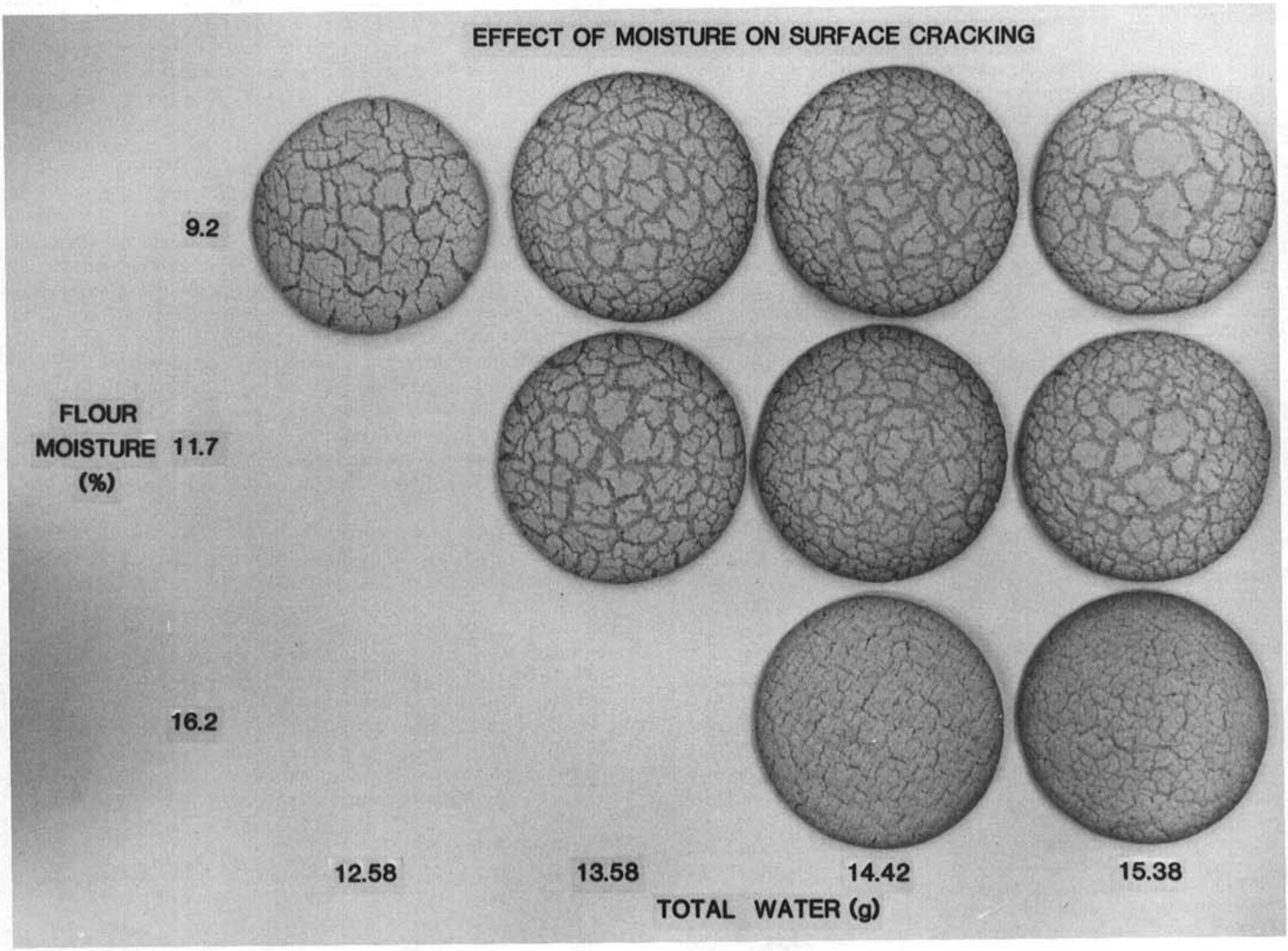

Fig. 2. Effect of moisture on surface cracking pattern of cookies. Rows have the same flour moisture; columns have the same amount of water in the system.

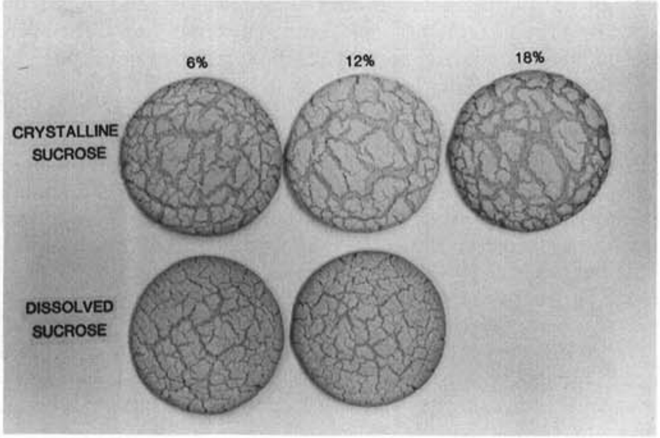

Fig. 3. Effect of formula sucrose added to a control dough late in the mixing period.

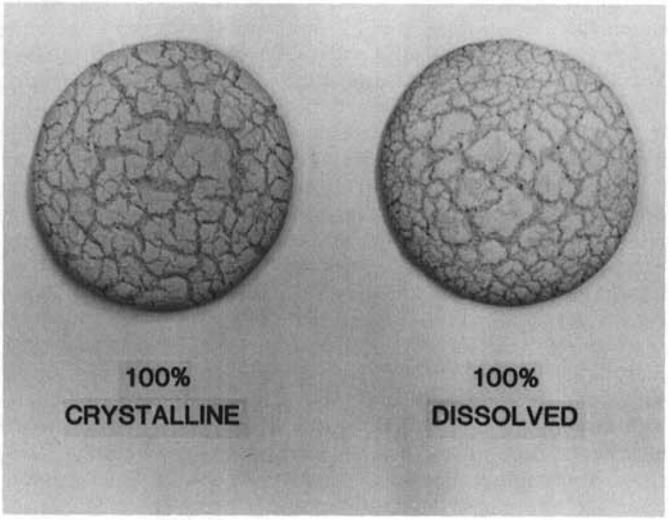

Fig. 4. Comparison of surface cracking pattern of cookies with all crystalline and all dissolved sucrose.

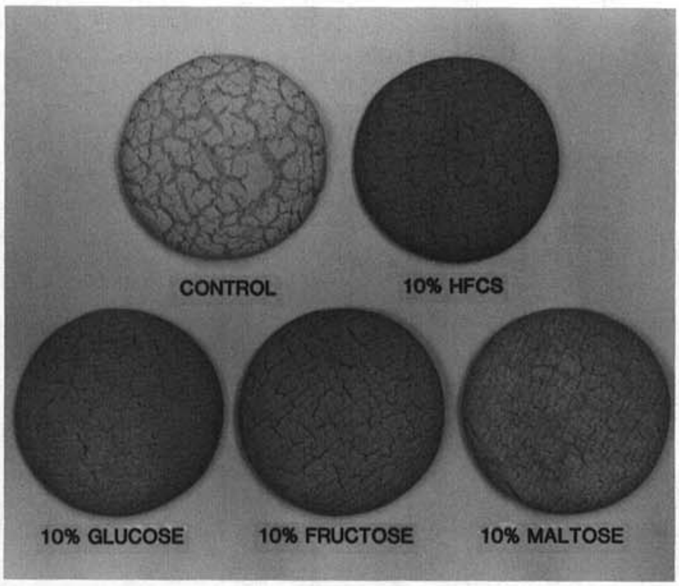

Fig. 5. Effect of syrups on the surface cracking pattern of cookies. HFCS = high-fructose corn syrup.

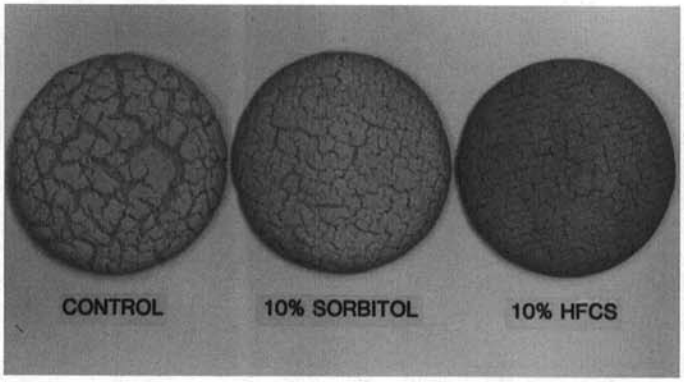

Fig. 6. Effect of sorbitol on the surface cracking pattern of cookies. HFCS = high-fructose corn syrup.

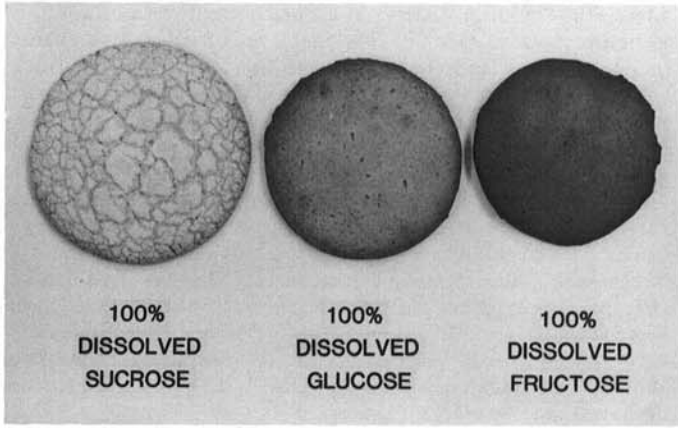

Fig. 7. Effect of the type of sweetener on surface cracking pattern of cookies.

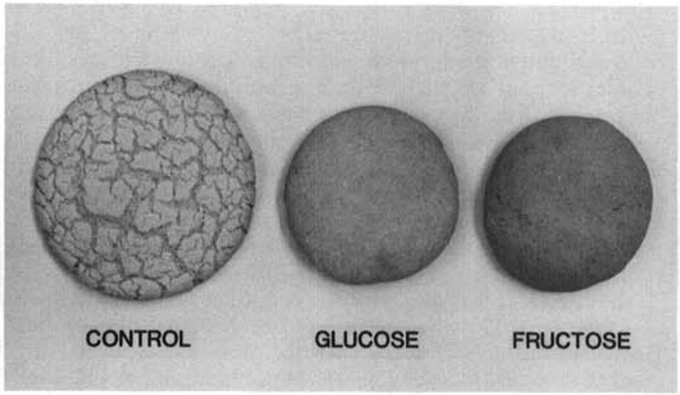

Fig. 8. Surface characteristics of cookies having an equal molar amount of sweetener and an equivalent amount of total solution.

TABLE I
Effect of Flour Moisture on Diffusion Rate

Flour Moisture (%)	Sucrose	Diffusion Band (mm)	SD
9.2	Crystalline	4.31	0.19
	Dissolved	3.80	0.15
12.2	Crystalline	4.71	0.43
	Dissolved	4.64	0.75
16.2	Crystalline	5.54	0.57
	Dissolved	6.42	0.62

To determine the role of flour moisture, flour A (16.2% moisture) was dried to 9.2 and 11.7% moisture. In some trials cookies were baked from each flour with a constant amount of formula water. In other trials, enough formula water was added to make the total amount of water in each cookie system equivalent.

Flour A dried to 9.2% moisture gave cookies with cracks and islands even when the total water level was high (Fig. 2). The same flour dried to 11.7% moisture gave cookies with cracking and islanding at each water level tested. When no formula water was added to the 16.2% moisture flour, the surface was bumpy and had only hairline cracks. Cookies with a typical cracking pattern could not be produced with the 16.2% moisture flour, which shows that flour moisture is more important than total moisture in determining surface cracking.

Effect of presence of crystalline sucrose. It is a common practice in the cookie industry to add crystalline sucrose late in the mixing of cookie doughs to induce surface cracking. Crystalline sucrose and dissolved sucrose were added late in the mixing using flour A dried to 11.7% moisture. Withholding 6, 12, or 18% of the formula sucrose and adding it with the flour changed the cracking and islanding pattern (Fig. 3). As the level of crystalline sucrose increased, the islands became larger and fewer, and the cracks widened; but the same levels of dissolved sucrose added late in the mixing had no significant effect on cracking. In this study, late addition of 6–75% of the formula sucrose had no effect on surface cracking for the 16.2% moisture flour. Neither mixing time after addition (5–25 sec) or sucrose granulation had an effect on surface cracking when the 16.2% moisture flour was used.

The pattern of surface cracking was not different for cookies baked with 100% crystalline sucrose or 100% dissolved sucrose (Fig. 4). This explains why no difference between the two doughs was found in rate of diffusion. However, the question still remains why cookies with 10% of the sucrose replaced with HFCS do not show surface cracking, whereas those with 100% dissolved sucrose do have a surface cracking pattern.

Role of syrups. To determine the effect of syrups on surface cracking, 10% glucose, fructose, or maltose syrup was substituted for sucrose solids. Each of the syrups had the same effect on surface cracking as did the 10% HFCS (Fig. 5). The syrups had low pH and thus produced cookies with a pH significantly lower than the control. If pH of the syrup affects surface cracking, then neutralization of the syrup should eliminate the differences. When cookies were baked with each of the neutralized syrups, the surface pattern was the same as with the unneutralized syrup.

Because sucrose and maltose have the same molecular weight, the osmotic pressure should be the same. Cookies baked with sucrose syrup had a cracking pattern, whereas those baked using maltose syrup did not crack. Therefore, differences in osmotic pressure do not explain the difference in top grain between cookies containing sucrose and cookies prepared with the other syrups.

The monosaccharides, glucose and fructose, along with the disaccharide, maltose, also produced cookies that did not crack. However, the disaccharide, sucrose, produced cookies with a cracked surface. Thus, the size of the sugar is not responsible for the difference in cracking pattern.

Cookies without surface cracks resulted whenever a reducing sugar was present in the formula. When a nonreducing sugar, sucrose, was used, cracks resulted. To determine whether the nonreducing property of the sugar was responsible for the cracking pattern, sorbitol was used. Sorbitol is a straight chain, six carbon, nonreducing compound. Substitution of 10% sorbitol syrup for 10% of the sucrose solids produced cookies that had only a few cracks on the surface and no islanding pattern (Fig. 6). Therefore, the unique nonreducing property of the sugar does not explain the differences in cracking pattern.

When low levels of nonsucrose syrup were substituted for sucrose solids, two different sweeteners were present in the cookie. However, the control cookie and the cookie baked with dissolved sucrose contained only one sweetener. If cracking was the result of the presence of only one sweetener, then cookies baked using 100% dissolved glucose or 100% dissolved fructose would crack as well. Cookies baked from 100% fructose and 100% glucose did not crack (Fig. 7). Therefore, a single sweetener was not responsible for surface cracking.

Cookies prepared with glucose and fructose contained approximately twice as many moles of sugar as did the sucrose cookie. When the sugars were substituted on an equal molar basis, no cracking resulted (Fig. 8).

In earlier work, it was found that the cracking and islanding pattern of cookies was influenced by the introduction of crystalline sucrose late in the mixing period. Shanot (1981) stated that recrystallization of sucrose during baking was responsible for surface cracking, but he provided no evidence to support his statement.

The ability of sucrose and glucose syrups to recrystallize when heated was tested using a heating stage microscope. During heating the sucrose syrup recrystallized. Glucose syrup did not recrystallize in spite of a longer heating period and excessive moisture loss. A combination of approximately equivalent amounts of glucose and sucrose syrups also did not recrystallize. Whenever sucrose was used as the sole sweetener in cookies, cracking resulted, but mixtures of sweeteners produced cookies without a cracking pattern. The presence of a second sugar could serve as an interfering agent so that recrystallization of sucrose could not occur.

Recrystallization of sucrose occurs more readily than recrystallization of glucose or fructose. Sucrose may give up its water readily, whereas glucose and fructose are quite hygroscopic. This would explain the differences in surface cracking pattern when glucose, fructose, or sucrose was used as the sole sweetener. Only cookies containing sucrose had a surface cracking pattern. Based upon these findings, the ability of sucrose to recrystallize at the cookie surface during heating appears to be responsible for the surface cracking in sugar-snap cookies.

LITERATURE CITED

ABBOUD, A. M., and HOSENEY, R. C. 1984. Differential scanning calorimetry of sugar cookies and cookie dough. Cereal Chem. 61:34.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1976. Approved Methods of the AACC. Method 44-15A, approved October 1975. The Association: St. Paul, MN.

CURLEY, L. P., and HOSENEY, R. C. 1984. Effects of corn sweeteners on cookie quality. Cereal Chem. 61:274.

FINNEY, K. F., MORRIS, V. H., and YAMAZAKI, W. T. 1950. Micro versus macro cookie-baking procedure for evaluating the cookie quality of wheat varieties. Cereal Chem. 27:42.

SHANOT, M. A. 1981. Sweeteners: Functionality in cookies and crackers. AIB Res. Dept. Tech. Bull., Vol 3, No. 4. Am. Inst. Baking: Manhattan, KS.

WEAST, R. C., and ASTLE, M. J., eds. 1982. Pages D-238, 239, D-270 in: CRC Handbook of Chemistry and Physics, 63rd ed. CRC Press, Inc.: Boca Raton, FL.

[Received December 17, 1984. Revision received February 11, 1985. Accepted February 11, 1985.]