Effect of Various Sugars on the Quality of Baked Cookies

SUKIE NISHIBORI[1] and SHUNRO KAWAKISHI[2]

Cereal Chem. 69(2):160-163

ABSTRACT

To study the quality of cookies baked with pentoses, hexoses, and di- and trisaccharides, cookie doughs prepared from wheat flour, eggs, butter, sugar, and sodium bicarbonate were heated at 150°C for 10 min in an electric oven. The baked cookies then were extracted with methanol-water (3:1, v/v), and the extracts were analyzed by high-performance liquid chromatography. A main peak from the cookie extracts containing pentoses was isolated and identified as furfural. The peaks from the cookies containing sugars other than pentoses were 2,3-dihydro-3,4-dihydroxy-5-acetylfuran (DDAF), 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one (DDMP), and 5-hydroxymethylfurfural (HMF). DDAF and DDMP appeared in batches that included hexoses. DDAF and DDMP produce sweetness and cookielike flavor; hexoses as sweeteners are thus useful in the formation of good cookie flavor. Results of the investigation on the physical properties of cookies—volume expansion, form, color, and surface condition—suggest that differences in cookies made with various sugars result from differences in melting point temperatures and solubility. The results also indicate that of all the baked cookies studied, those with fructose exhibit the most favorable physical properties and flavor.

We have previously reported the effects of dough materials on flavor formation in baked cookies (Nishibori and Kawakishi 1988). On the basis of data from ultraviolet (UV), nuclear magnetic resonance (NMR), fast atom bombardment mass spectral (FAB-MS), and electron impact mass spectral analyses, we identified the main roasted flavors during the baking of cookie doughs as 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one (DDMP) and 5-hydroxymethylfurfural (HMF) (Nishibori and Kawakishi 1990). As a model system for cookies, we isolated and identified 2,3-dihydro-3,4-dihydroxy-5-acetylfuran (DDAF) from the products in the reaction between D-fructose and β-alanine (Nishibori and Kawakishi 1991).

Hodge and Nelson (1961) and Hodge and Moser (1961) reported that maltol and isomaltol as trace constituents of bread may contribute to the fragrant aroma of freshly baked bread and to the final flavor of bread. Hodge et al (1972) reported that DDMP was odorless in a pure state at room temperature. However, the isolated and purified DDMP and DDAF in our laboratory produced a strong sweet aroma. DDMP and DDAF seem to be important in the development of a cookielike flavor in baked cookies.

Pentoses and hexoses are usually applied to processed foods for the improvement of qualities such as color, sweetness, and flavor. In the making of *chikuwa,* a Japanese processed seafood, xylose is used for the development of an appealing brownish color in a short heating time.

We discuss here the enhancement of physical properties of cookies, such as flavor, color, and condition of the surface, by baking with different sugars. Specifically, the formation of DDMP, HMF, and furfural in cookies baked at 150°C for 10 min is investigated. The difference in cookie quality with and without sodium bicarbonate also is discussed.

MATERIALS AND METHODS

Materials and Reagents

Commercial wheat flour (7.2% protein, Nisshin Milling Co., Tokyo, Japan), potato starch (Katakuriko, Hokuren Rural Organization, Sapporo, Japan), butter (Snow Brand Milk Co., Tokyo, Japan), and fresh eggs were used in the study. Reagent-grade sugars, furfural, and sodium bicarbonate also were used.

Sample Preparation

The cookie doughs were prepared from either wheat flour or potato starch (45%), eggs (10%), butter (25%), sugar (20%, one dough each made with pentoses, hexoses, and di- and trisaccharides), and sodium bicarbonate (0.5% by weight). The doughs were shaped into cookie form (5.0 × 30 mm in diameter) and baked in an electric oven at 150°C for 10 min. For UV and high-performance liquid chromatography (HPLC) analyses, 10 g of the baked cookies was crushed and extracted with 50 ml of methanol-water (3:1, v/v) for 30 min at room temperature.

HPLC

HPLC analyses were performed using a Toyo Soda model HLC-803D pump (Tokyo, Japan). The conditions were as follows: column, Develosil ODS-5 (250 × 4.6 mm i.d.); mobile phase, water-methanol (6:1, v/v); flow rate, 0.8 ml/min; UV detection, 283 nm.

Spectrometric Analyses

NMR spectra were obtained on a JEOL GX-200 (Tokyo, Japan) (^{1}H, 200 MHz, and ^{13}C, 50 MHz). ^{1}H-NMR and ^{13}C-NMR were measured in D_2O as solvent. For NMR analysis, the extracts were prepared from the baked cookies with pentoses in the same way as for HPLC analysis and were separated by HPLC analysis. As a result, a main compound was isolated from the extracts. The main compound was sealed in a 4-mm-i.d. NMR tube. The compound was analyzed by FAB-MS after NMR analysis.

FAB-MS spectral analyses were performed on a JEOL DX-303. Glycerol was used as matrix for FAB-MS analysis.

To detect the browning color of cookies, the absorbance of methanol extracts from the baked cookies with various sugars was measured at 420 nm with a Hitachi model 200-10 spectrophotometer (Tokyo, Japan).

Expansion of Cookies

Cookie volumes were obtained by a rapeseed displacement procedure (Yamazaki and Donelson 1972). The measurement of the volumes was repeated five times, and the data were averaged. Expansion coefficients of the cookies baked with various sugars were calculated as the proportions of the volumes of the baked cookies to the volumes of the unbaked cookies shaped into 5- × 30-mm diameter forms. A formula for ratio of expansion is:

$$1 + \frac{\text{vols of baked cookies} - \text{vols of cookie doughs}}{\text{vols of cookie doughs}}$$

Sensory Evaluation

Sensory evaluation was conducted with texture and flavor profile methods (Caul 1957) by six panelists who were students and laboratory members from the Department of Food Science and Human Nutrition at the Women's College of Tokaigakuen. This profile panel acted in a combined independent-analysis and roundtable fashion. Before the data collection period, panelists were trained in sensory analyses and familiarized with test techniques and procedures. The panel members studied the evaluative terminology and the characteristics of the cookies to be evaluated. Panelists were instructed to refrain from drinking,

[1]Department of Food Science and Human Nutrition, Women's College of Tokaigakuen, Tenpaku-ku, Nagoya 468, Japan.
[2]Department of Food Science and Technology, Nagoya University, Chikusa-ku, Nagoya 464, Japan.

eating, or chewing gum for 30 min before the tasting session. Sensory tests were first conducted in a room with fluorescent lights and neutral gray walls, with partitions between each seat and table. Each panelist was given a tray with four samples of cookies baked with various materials and a glass of water for rinsing between samples. They were asked not to talk while tasting the cookies. Cookies were evaluated for spots, grain, wrinkles, and moistness. After the individual analyses, the panel leader conducted a roundtable discussion, with each member presenting his or her findings. All data were recorded.

RESULTS AND DISCUSSION

Flavor Compounds from Cookies Baked with Pentoses

The cookie doughs containing pentoses, such as ribose, xylose, and arabinose, were baked at 150°C for 10 min in an electric oven. The flavor compounds were extracted with methanol-water and analyzed by HPLC. The preparation from cookies containing ribose and xylose had a large quantity of furfural (Fig. 1). It exhibited maximum absorption at 279 nm in water, with a molecular weight of 96 (as determined by mass spectral analyses). The product was identified as furfural by comparing its spectrometric and HPLC data with those of an authentic sample. Furfural is pungent and sweet but does not have a cookielike, caramelic aroma; nonetheless, in cookies baked with pentoses, the formation of furfural seemed to enhance cookie quality with its slightly sweet aroma.

Flavor Compounds from Cookies Baked with Hexoses

The main compounds in the cookies baked with hexoses (such as mannose, fructose, and glucose) were DDAF, DDMP, and HMF (Fig. 2). In the cookies baked with mannose, HMF was a major component. In the cookies containing fructose, DDAF and DDMP were generated in large quantities, although the formation of HMF was slight. When glucose was added, flavor compounds were similar to those when fructose was added, although the amount of DDAF and DDMP were slightly lower than with fructose. HMF is bitter and has a burnt odor, while DDAF and DDMP have a sweet aroma and cookielike flavor. These compounds are well known as important precursors of isomaltol and maltol, respectively (Hodge et al 1972). In this study we found that fructose was the favored additive for the generation of the sweet flavor preferred as the cookie aroma.

Flavor Compounds from Cookies Baked with Di- and Trisaccharides

When maltoses were added to the cookie dough, slight amounts of DDAF and DDMP and high amounts of HMF and an unknown compound were generated (Fig. 3). The formation of HMF with the addition of cellobiose was slight; no HMF formed with sucrose. Only a trace amount of DDMP was formed in the cookies with cellobiose and sucrose.

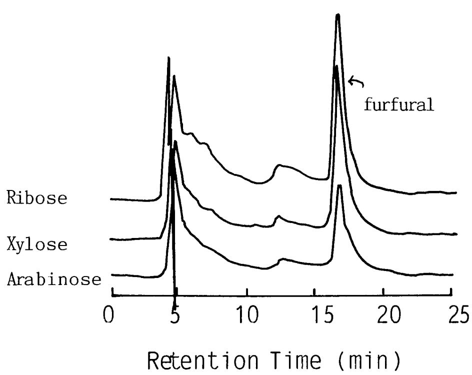

Fig. 1. High-performance liquid chromatograph of extracts from cookies baked with various pentoses at 150°C for 10 min. Chromatographic conditions: column, Develosil ODS-5, 250 × 4.6 mm i.d.; mobile phase, H_2O-MeOH (6:1, v/v); flow rate, 0.8 ml/min; UV detection, 283 nm.

The HMF formation was high in the cookies baked with mannose, maltose, and raffinose. Furfural formation was observed only in cookies with pentoses. DDAF and DDMP were formed in the cookies containing hexoses.

Effects of Glucose, Fructose, and Sucrose on the Quality of Baked Cookies

Sucrose, glucose, and fructose are generally used in the making of cookies. As shown in Tables I and II, wheat flour cookies made with glucose, fructose, and sucrose differed in texture, form, and color. Specifically, cookies made with glucose differed from those with fructose or sucrose in texture, expansion, and spots and wrinkling on the cookie surface. Cookies with glucose expanded vertically (which is preferable to lateral spreading), but the surfaces were more wrinkled than those with fructose and sucrose (Figs. 4 and 5). Also, cookies with glucose were the softest and most moist among the three kinds. These physical properties are undesirable for cookie texture.

Cookies baked with fructose spread laterally, and their form was similar to that of cookies with sucrose. The texture was dry and exhibited shortness similar to that of cookies with sucrose. Shortness means the condition in which foods, such as cookies, pies, and pastries, fall or crumble easily into pieces. These properties are considered favorable for cookie texture.

When potato starch is used in place of wheat flour in the cookie dough containing glucose, wrinkling of the cookie surface does not occur. Several workers (Seguchi and Matsuki 1977, Johnson and Hoseney 1979, Kissell and Yamazaki 1979, Gaines and Donelson 1985) have reported that Cl_2-treated flours and certain ingredients, such as eggs, citric acid, calcium chloride, and aluminum sulfate, inhibit gluten formation and consequently improve cookie quality. Nagao et al (1977) observed that protein content directly affects the quality of baking products and that lower contents of protein were favorable in confectionery products. In the same way, Gaines and Donelson (1985) have shown that the protein content of flour significantly affects the tenderness and vertical expansion of angel food cake.

On the other hand, Fujii and Danno (1988) and Fujii et al (1990) report the formation of gluten from gliadin and glutenin in wheat protein by the addition of water and the formation of the sticky material from the pentosan of wheat when the cookie

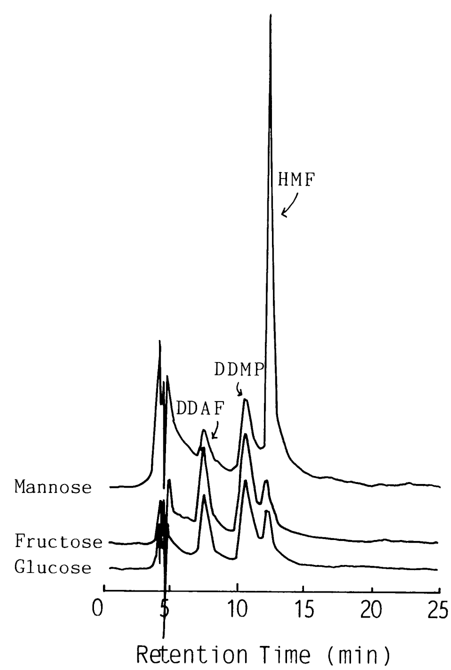

Fig. 2. High-performance liquid chromatograph of extracts from cookies baked with various hexoses at 150°C for 10 min. DDAF = 2,3-dihydro-3,4-dihydroxy-5-acetylfuran, DDMP = 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one, HMF = 5-hydroxymethylfurfural.

dough was prepared. The formation of these secondary materials afforded adhesive and wet properties to cake tissue. These studies suggested that gluten formed in the dough prepared with wheat flour and glucose inhibits the lateral spreading of the cookie and contributes to surface wrinkling. Moreover, the adhesive material from pentosan produced moistness in the cookies.

A significant difference ($P < 0.001$) in the physical properties, especially height, grain, wrinkles, and texture, of cookies made with glucose and with fructose might be dependent on the melting point of sugars, which is 146.5°C for glucose and 102–104°C for fructose. On the other hand, the difference between glucose and sucrose may be dependent also on their solubilities in water, which for sucrose is 203 g/100 g and for glucose 46 g/100 g at 20°C. Abboud and Hoseney (1984), Curley and Hoseney (1984), Doescher and Hoseney (1985), and Doescher et al (1987) report that when sugar-snap cookies are baked with sucrose, the surface becomes dry during the early stages of baking and cracks when it starts to spread. Cookie doughs with sucrose (Abboud and Hoseney 1984) and fructose spread laterally more rapidly than cookies with glucose for high solubility and low melting point, and the surface of cookies with sucrose and fructose quickly spread more than cookies with glucose. As a result it is thought that the moisture in cookies with sucrose or fructose rapidly decreases, and the products become more dry and brittle than the cookies with glucose. Because of the high melting point and low solubility of glucose, cookies baked with glucose may spread scarcely at all in the initial stage of heating and may expand only a little in the final stage. Thus, it seems likely that the surface wrinkling and the moist condition of the cookie are caused by the heating of the cookie dough. This result, however, does not agree with the baking data for cookies produced with glucose and fructose syrups as reported by Doescher and Hoseney (1985). They showed that the cookie dough containing sucrose had a much greater spread than doughs containing either glucose or fructose. Clearly, the cookies made with sugar syrup differ from those made with crystalline sugar like ours. The effect of the low solubility of glucose on the spread of the cookies does not appear in the case of sugar syrups.

TABLE I
Effect of Wheat Flour and Potato Starch on the Surface Condition of Cookies Containing Various Sugars, with or without Sodium Bicarbonate

Sugar	Materials and Sample Number[a]	Surface Spots[b]	Surface Wrinkles
Glucose	Wheat flour (1)	−	+
	Wheat flour + $NaHCO_3$ (2)	+++	+++
	Potato starch	−	−
	Potato starch + $NaHCO_3$	+++	−
Fructose	Wheat flour (3)	−	−
	Wheat flour + $NaHCO_3$ (4)	+++	−
	Potato starch	−	−
	Potato starch + $NaHCO_3$	+++	−
Sucrose	Wheat flour (5)	−	−
	Wheat flour + $NaHCO_3$ (6)	−	−
	Potato starch	−	−
	Potato starch + $NaHCO_3$	−	−

[a]Samples 1–6 correspond to samples 1–6, respectively, in figures 4 and 5.
[b]+++ = Prominently present, + = barely present, − = not present.

Effects of Addition of Sodium Bicarbonate on Cookie Dough

Sodium bicarbonate usually is added to the cookie dough to obtain good expansion of the cookie material. The addition of

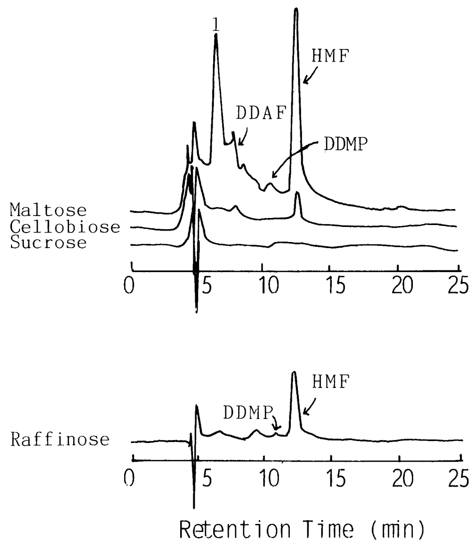

Fig. 3. High-performance liquid chromatograph of extracts from cookies baked with various di- and trisaccharides at 150°C for 10 min. Peak 1 was an unknown product. DDAF = 2,3-dihydro-3,4-dihydroxy-5-acetylfuran, DDMP = 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)-pyran-4-one, HMF = 5-hydroxymethylfurfural.

TABLE II
Effect of Addition of Various Sugars on the Physical Properties of Baked Cookies Containing Sodium Bicarbonate

Sugar[a]	Ratio of Expansion[b]	Height (mm)	Surface Spots[c]	Surface Grain	Surface Wrinkles	Texture[d]	Color[e] Optical Density (420 nm)
Pentose							
Xylose	1.70	6.70	+++	Coarse	−	D/H	0.193
Ribose	1.73	6.73	+++	Coarse	−	D/H	0.354
Arabinose	1.65	12.55	+++	Fine	+	W/S	0.163
Hexose							
Galactose	1.84	6.84	+++	Coarse	−	D/H	0.153
Glucose (1)	1.68	12.68	+++	Fine	+	W/S	0.042
Mannose	1.81	6.81	+++	Coarse	−	D/H	0.264
Fructose (3)	1.72	6.72	+++	Coarse	−	D/H	0.160
Disaccharide							
Cellobiose	1.70	12.70	++	Fine	+	W/S	0.032
Lactose	1.94	6.94	++	Coarse	−	D/H	0.052
Maltose	1.71	6.81	++	Coarse	−	D/H	0.015
Sucrose (5)	1.70	6.80	−	Coarse	−	D/H	0.013
Trisaccharide							
Raffinose	1.62	12.62	−	Fine	+	W/S	0.078

[a]Samples 1, 3, and 5 correspond to samples in figure 4.
[b]Based on dough shaped into 5- × 30-mm diameter cookies. Ratio of expansion $= 1 + \frac{\text{vols of baked cookies} - \text{vols of cookie doughs}}{\text{vols of cookie doughs}}$
[c]+++ = Prominently present, ++ = clearly present, + = barely present, − = not present.
[d]W/S = Wet and soft, D/H = dry and hard.
[e]Extract from 10 g of the baked cookie with 50 ml of methanol-water (3:1, v/v).

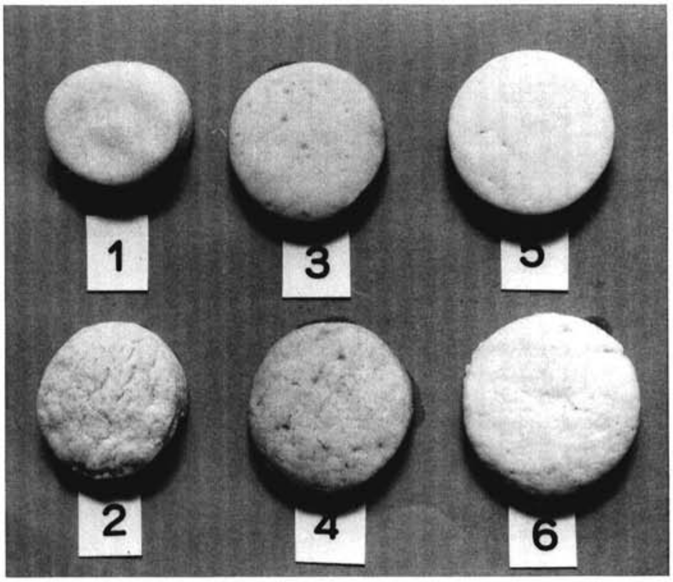

Fig. 4. Surface of cookies baked with various sugars with or without $NaHCO_3$ at 150°C for 10 min. 1, Glucose; 2, glucose and $NaHCO_3$; 3, fructose; 4, fructose and $NaHCO_3$; 5, sucrose; 6, sucrose and $NaHCO_3$.

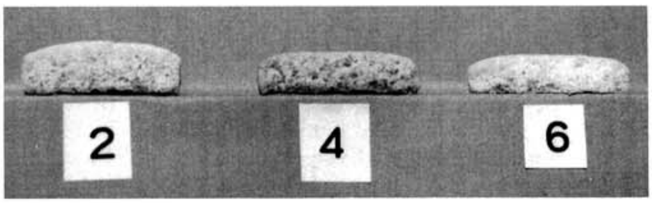

Fig. 5. Cross sections of cookies baked with various sugars and $NaHCO_3$ at 150°C for 10 min. 2, glucose and $NaHCO_3$; 4, fructose and $NaHCO_3$; 6, sucrose and $NaHCO_3$.

sodium bicarbonate to the dough increases a small portion of DDMP (Nishibori and Kawakishi 1990) and affects markedly the development of color and brown spots on the cookie surface (Figs. 4 and 5). The brown color of the cookies baked with fructose was the darkest among three types of cookies. The cookies with sucrose had the lightest brown coloring. During baking, brown spots developed on the surface of cookies made with fructose or glucose, but not on those made with sucrose. Cookies baked with glucose and sodium bicarbonate expanded upward the most among the three types of cookie with sodium bicarbonate (Fig. 5), and they wrinkled more than cookies without sodium bicarbonate (Fig. 4 and Table I). Cookies with fructose or sucrose spread the most and expanded (a behavior that is very favorable in cookies).

Effects of Starch on Brown Spots in Cookies Baked with Sugar

Since brown spots were observed on cookies with added sodium bicarbonate and either fructose or glucose, the effects of the potato starch used in place of wheat flour were investigated (Table I). It was found that spots developed in cookies baked when either wheat flour or potato starch was used in cookie dough with added sodium bicarbonate and fructose or glucose. These results suggested that neither wheat flour nor potato starch participated in the formation of the spots. On the other hand, the formation of wrinkles on the surface of the cookies with glucose was markedly depressed when potato starch was used, regardless of whether or not sodium bicarbonate was added.

Effects of Various Sugars on Cookie Quality

Since the brown spots in the cookies were due to the kinds of sugars added to the cookie doughs and wrinkles developed only when glucose and wheat flour were used, the effect of different sugars on the development of spots and wrinkles was investigated (Table II). It was found that pentoses, hexoses, and disaccharides, but not sucrose, caused spots. When pentoses and hexoses were added to the doughs, many spots were observed in the baked cookies. Given that sucrose and raffinose did not produce brown spots, it would seem that formation of the spots is due to the presence of reducing sugars. This reaction is the so-called Maillard reaction. The formation of wrinkles occurred with the addition of arabinose, glucose, cellobiose, and raffinose. In this study, the differences between the mono- and disaccharides were not significant ($P < 0.05$) in the formation of the wrinkles. As described previously, it can be assumed that the wrinkles result from the sugars having a high melting point and low solubility.

The intensity of brown color of cookies baked with various sugars is shown in Table II. The addition of ribose browned cookies the most, followed by mannose. Pentoses generally increased the brown color of cookies more than hexoses. Cookies baked with sucrose exhibited the lightest brown color. For the development of a favorable color to cookies, the addition of pentoses and hexoses, except glucose, will produce a desirable effect.

LITERATURE CITED

ABBOUD, A. M., and HOSENEY, R. C. 1984. Differential scanning calorimetry of sugar cookies and cookie doughs. Cereal Chem. 61:34.
CAUL, J. F. 1957. The profile method of flavor analysis. Adv. Food Res. 7:1.
CURLEY, L. P., and HOSENEY, R. C. 1984. Effects of corn sweeteners on cookie quality. Cereal Chem. 61:274.
DOESCHER, L. C., and HOSENEY, R. C. 1985. Effect of sugar type and flour moisture on surface cracking of sugar-snap cookies. Cereal Chem. 62:263.
DOESCHER, L. C., HOSENEY, R. C., and MILLIKEN, G. A. 1987. A mechanism for cookie dough setting. Cereal Chem. 64:158.
FUJII, T., and DANNO, G. 1988. Properties of sponge cakes made with wheat starch. Nippon Shokuhin Kogyo Gakkaishi 35:684.
FUJII, T., KUYAMA, S., and DANNO, G. 1990. Rheological properties of sponge cakes made with wheat starch. Nippon Shokuhin Kogyo Gakkaishi 37:619.
GAINES, C. S., and DONELSON, J. R. 1985. Effect of varying flour protein content on angel food and high-ratio white layer cake size and tenderness. Cereal Chem. 62:63.
HODGE, J. E., and MOSER, H. A. 1961. Flavor of bread and pastry upon addition of maltol, isomaltol, and galactosylisomaltol. Cereal Chem. 38:221.
HODGE, J. E., and NELSON, E. C. 1961. Preparation and properties of galactosylisomaltol and isomaltol. Cereal Chem. 38:207.
HODGE, J. E., MILLS, F. D., and FISHER, B. E. 1972. Compounds of browned flavor derived from sugar-amine reactions. Cereal Sci. Today 17:34.
JOHNSON, A. C., and HOSENEY, R. C. 1979. Chlorine treatment of cake flour. II. Effect of certain ingredients in the cake formula. Cereal Chem. 56:336.
KISSELL, L. T., and YAMAZAKI, W. T. 1979. Cake-baking dynamics: Relation of flour-chlorination rate to batter expansion and layer volume. Cereal Chem. 56:324.
NAGAO, S., ISHIBASHI, S., IMAI, S., SATO, T., KANBE, T., KANEKO, Y., and OTSUBO, H. 1977. Quality characteristics of soft wheats and their utilization in Japan. III. Effects of crop year and protein content on product quality. Cereal Chem. 54:300.
NISHIBORI, S., and KAWAKISHI, S. 1988. Changes in baking products of cookie dough composed of different materials. Nippon Shokuhin Kogyo Gakkaishi 35:235.
NISHIBORI, S., and KAWAKISHI, S. 1990. Effects of dough materials on flavor formation in baked cookies. J. Food Sci. 55:409.
NISHIBORI, S., and KAWAKISHI, S. 1991. Formation of 2,3-dihydro-3,4-dihydroxy-5-acetylfuran in the reaction between D-fructose and β-alanine. Agric. Biol. Chem. 55:1159.
SEGUCHI, M., and MATSUKI, J. 1977. Studies on pan-cake baking. II. Effect of lipids on pan-cake qualities. Cereal Chem. 54:918.
YAMAZAKI, W. T., and DONELSON, D. H. 1972. The relationship between flour particle size and cake-volume potential among eastern soft wheats. Cereal Chem. 49:649.

[Received May 29, 1991. Accepted October 25, 1991.]