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Role of Various Sugars in the Quality Characteristics of Sugar-Snap Cookies

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Abstract

The effects of sucrose, lactose, maltose, fructose, glucose, and malt syrup on the quality characteristics of the sugar snap cookie were investigated. The reduced viscosity of cookie dough with sugars caused different spreading ratios although densities have remained almost consistent. The water activity values of the cookies were within the range of 0.36 to 0.44. Both lactose and glucose raised the viscosity of the cookie dough, expecting the unnecessary gluten development during increased mixing. The crystallization properties of the disaccharides caused harder/crisper cookies. The influence on the gelatinization temperature of the wheat starch was almost negligible. Typical cracking patterns in cookie surfaces were observed with sucrose, lactose, and maltose while the non-crystallizing and hygroscopic properties of fructose and glucose resulted in no cracking. Despite the product name "snap cookie", cookies with a neat and mild brown surface, a soft and flexible texture less cracking, and a sweeter taste were preferred by sensory evaluation of the products.

Key words: sugar, cookie, surface crack, snap cookie, quality

Introduction

The demand for bakery products like cookies and breads are increasing as dietary habits in Korea become westernized and simplified. With the exception of the United States, biscuits are classified into the two categories of crackers and cookies (Hoseney, 1990). Crackers are thin, crisp biscuits that are often eaten with cheese. However, cookies, which are derived from the Danish word "Koekje" (Wade, 1988) meaning a small, sweet cake, have a dry and crispy texture with a closer grain and a sweeter taste (Francis, 2000).

In general, cookies are products made from varieties of soft wheat and are characterized by a formula high in sugar (30-75%) and shortening (30-60%) and relatively low in water (7-20%) (Perry et al., 2003).

Sugar, one of the major ingredients, not only acts as a sweetener but also effects some functional properties, such as spreading and wetting of the dough, starch swelling and gelatinization, final browning color formation of the crust, and product softness, flavor, humectant effects, and shelf-life after baking (Wade, 1988; Cauvain & Young, 2000; Bean & Setser, 1992). As much as 20 to 60% (w/w) (Nip, 2006) of sugar is found in ordinary sugar-added food products. Use of a reduced volume of high-sweetness sugar additives, rather than normal sugars, in processed foods makes use of appropriate additives to compensate for changes in textural changes advantageous. Therefore, depending on the quantity and kind of sugar, the physical and sensory properties of the final products are substantially affected. As the cookie dough is heated in the oven, the surface color, the spreading ratio, the softness, and the flavor of the final product are affected (Hoseney & Rogers, 1996). Sugar can also retard the hydration of gluten and gelatinization of starch. As a hardening agent, sugar also produces crunch cookies in the course of crystallization during cooling (Olewink, 1984).

The gelatinization temperature of a cereal starch in cookie dough is largely governed by the source of the starch, the moisture content, the pH, and the variety and concentrations of salts and/or sugar (Hoseney, 1990; Fennema, 1996). For example, high concentrations of sugar of more than 20-50% can depress starch gelatinization in the decreasing order of sucrose > glucose > fructose although this effect is negligible at low concentrations (Kim, 1988). The final diameter of the cookie following the set of cookie starch is dependant on the spreading rate (amount of flow) of the cookie dough and the heating time (Miller & Hoseney, 1997a; Miller & Hoseney, 1997b; Abboud et al., 1985; Miller, 1997).

Sugar also affects the crunchiness of the bite, which is so called 'snap' of the cookie product (Hoseney, 1990; Curley &

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Heseney, 1984). In many cases, cookies have a cracking pattern on the surface. This phenomenon is caused by rapid moisture loss from the surface of the cookie during baking. As baking proceeds, sucrose is concentrated with the loss of moisture and tends to crystallize at the surface of the cookie. Thus, the surface cracks as the cookie expands during baking. Sucrose as either granules or in solution can easily cause this phenomenon. However, small amounts of other sugars can interfere with sucrose crystallization, completely eliminating this cracking ability (Hoseney & Rogers, 1996; Hoseney, 1990). For example, substitution of glucose, fructose, maltose, high-fructose corn syrup, or certain other sugars as dilute as 10% can interfere with sucrose crystallization and eliminate the cracking pattern (Hoseney, 1990). Accordingly, the substitution of other sugars for sucrose is limited to a range of 10-30%, for hard cookies and 60-75%, for soft cookies. Moisture also affects the cracking of the cookie surface within a range of 9.2-16.2% of the moisture content while the effect is mitigated at more than 16.2% (Campbell, 1992).

In this study, we have assessed the effects of various sugars in cookie products on dough preparation and quality attributes of the final products. The instrumental measurement data obtained from the six kind of cookies with different sugars were finally compared with the sensory panel rankings of the cookie quality parameters in order to asses the practical acceptance of the final products by consumer.

Materials and Methods

Raw materials

Commercial soft wheat flour (CJ Co., Seoul, Korea) with a moisture content of 13.5%, protein 8.7%, ash 0.2%, and fat 1.1% (as supplied by the manufacturer) was used for cookie preparation. The sugars used were: sucrose (CJ Co.), lactose (Duksan Chemical Co., Seoul, Korea), maltose (Junsei Chemicals Co., Ltd., Tokyo, Japan), glucose (Samyang Genex Corp., Seoul, Korea), fructose (Samyang Genex Corp.), and starch syrup (Shindongbang Co., Seoul, Korea).

Dough preparation and baking

Sugar snap cookies were prepared according to the Approved Method 10-52 (AACC, 1995) with modification. The cookie formula is shown in Table 1. Sugar, butter, and baking powder were creamed in a mixer (Model K45SS, KitchenAid Inc., St. Joseph, MI, USA) equipped with a wire whip beater set at the 4th-speed setting for 3 min. Then, wheat flour, egg, and vanilla flavor powder were added to the mix using a flat beater with intermittent scraping of the creamed mass every 1 min. Salt dissolved in water was added over a period of 1 min to the creamed mass during mixing at low-speed setting of the machine. The completed cooked dough was equilibrated in a refrigerator at 4°C for 2 hr. The dough was rolled with a rolling pin to gently flatten to a 1-cm thick sheet. The dough sheet was then divided into appropriately sized dough pieces by cutting with a cookie cutter (6 cm, i.d.). Excess dough was discarded. The dough pieces were placed on a lightly buttered baking sheet in an equally portioned pattern approximately 5 cm apart. The dough pieces were then baked for 10 min in a pre-warmed oven (GOR-22M3B, Tong Yang Magic Co., Seoul, Korea) at 205°C and then cooled at room temp for 1 hr. The cookie samples were removed from the baking sheet and placed in a zippered plastic bag for analysis. The baked cookies contained on average 6.1% moisture, 8.5% crude protein, 14.3% crude fat, 1.2% ash, and 59.9% carbohydrate as obtained by the AOAC official methods (1995). Carbohydrate content was calculated as the difference from 100%.

Table 1. Formulation of cookie containing various kinds of sugars

Ingredients	Formulation (g)
Wheat flour	100
Sugar[1)]	40
Butter	30
Baking powder	3
Egg	40
Salt	1
Vanilla flavor powder	1
Water	70

[1)]Sucrose, lactose, maltose, fructose, glucose, malt syrup.

Dough consistency

To determine dough consistency, cookie dough was tightly sealed in a polyethylene bag and was maintained for 2 hr at room temperature to equilibrate the inner moisture. A 15-g portion of the dough was then placed in a mini-Kramer cell (2.5×2.5×3.0 cm) (Stable Microsystems, Surrey, UK) with no void space. Cookie samples loaded in the mini-Kramer cell attached to a Texture Analyzer (TA-XT2, Stable Microsystems) were pressed to 50% (1.5 cm) of the original height while half of the dough squeezed out from the bottom slit of the cell. Dough consistency was determined as the resistance force (kg) against the compression. A minimum of three cookie dough samples were measured for each treatment.

Gelatinization temperature

A Differential Scanning Calorimeter (DSC-2010, TA Instruments, Twin Lakes WI, UK), calibrated with indium for temperature and enthalpy was used to analyze the phase transition peak temperature (T_p) and the enthalpy (ΔH) during the transition in cookie dough due to added sugars. Approximately 15 mg of homogenized (Ultra-Turrax T25, Janke & Kunkel Ika-Labortechnik, Staufen, Germany) mixture of wheat flour, sugar, and water (10:4:7) was sealed in an aluminum sample pan. A thermogram plot of differential heat flow as a function of temperature was obtained at a heating rate of 5°C/min from 30°C to 120°C.

Spread ratio and density

Seven selected cookies were placed edge to edge and their diameters were measured using a Vernier caliper (TESA SA, Renens, Switzerland). Cookies were rotated 90° and the measurement was repeated. The mean values were used to obtain the width of a cookie (Preston et al., 2005). For thickness measurement (Preston et al., 2005), the geographical center point of the cookie height was measured from the bottom using the same caliper for the same cookies. Practically, two measurements were obtained and averaged by stacking the cookies, then reversing the order. The spreading ratio of the cookie was determined as the ratio of the spread to the thickness. The volume of the cookie as measured by the seed displacement method using rapeseed (Hoseney & Rogers, 1996) was divided by the weight to determine cookie density for each of the 7 measured cookies.

Water activity

The water activity of cookies was measured using a water activity meter (Thermoconstanter model TH200, Novasina AG, Zurich, Switzerland) with 1 g of powdered cookie sample. A minimum of seven cookies was measured for each treatment.

Surface color

A colorimeter (CR-400 Minolta colorimeter, Konica Minolta Sensing, Inc., Tokyo, Japan) was used to measure the color parameters of the cookie surface including Hunter colorimetric L (lightness), a (redness), and b (yellowness) values. Seven measurements were made for each treatment. The colorimeter was calibrated using a standard white plate with L, a, and b values of 94.6, 0.313, and 0.32, respectively.

Hardness and brittleness

Baked cookies tempered at room temperature for 24 hr were analyzed for textural hardness and brittleness (Bourne, 1978; Kim & Kim, 2004; Gaines et al., 1992) using a Texture Analyzer with conditions as shown in Table 2. Measurements were made 5 times to obtain average and standard deviation values for each treatment.

Hardness was determined according to the method of Gaines et al. (1992) with modification. The force (kg) against compression with a spherical probe (5 mm, diameter) for penetration 3 mm inward from the geometrical center of the cookie surface was expressed as the hardness. A 'snapping test' using a 'three point bending rig' apparatus attached to a Texture Analyzer was used to determine brittleness. A cookie sample was placed 20 mm from the two supporting arms and was bent from the center with an upper blade until it snapped. The compression force (kg) required for the upper blade to snap the cookie was used as the brittleness of the cookie.

Sensory evaluation

A sensory evaluation was conducted by a 15-member panel of trained evaluators who were senior or graduate students at the Department of Food Engineering, Dankook University. Before the data collection period, panelists were trained in sensory analyses and familiarized with test techniques and procedures. Sample evaluations were made for color, appearance, taste, softness, and overall acceptance on a 0-7

Table 2. Operation condition of texture analysis for cookies

Item	Condition
Instrument	Texture Analyzer, model TA-XT2
Probe/Attachment	Dough consistency: mini-Kramer shear cell Hardness: Φ5 mm Spherical probe Brittleness: three point bending rig, needle probe
Mode	Measure force in compression
Test speed (pre- and post-)	1 mm/sec (5 mm/sec, each)
Travel distance	Dough consistency: 15 mm Hardness: 3 mm Brittleness: 10 mm (three point bending rig), 5 mm (needle probe)

scale (Lim et al., 1989).

Statistical analysis

Data were evaluated using the analysis of variance (ANOVA) and correlation analysis procedures of the Statistical Analysis System (SAS Institute, Cary, NC, USA), and differences among the means were compared using Duncan's Multiple Range Test.

Results and Discussion

Dough consistency

The consistency of cookies is directly related to the efficiency of dough mixing during preparation (Armbrister & Setser, 1994). Viscous cookie dough is related to gluten development due to the increased work requirement for dough mixing. As a result, the contour of the final cookie products differed in length, thickness, and density. Water solubility and the crystal-forming characteristics of the sugar affected the spreadability of the cookie dough due to changes in viscoelasticity (Armbrister & Setser, 1994). This phenomenon is especially important in cookie dough preparation with a wire cut machine where no mould is used to divide dough into individual pieces without distortion.

Except for glucose syrup, most of the sugar syrups with carbohydrates have similar viscosities. The consistency variations of the cookie dough according to added sugars are shown in Table 3. Great contributions of lactose and glucose to the consistency of the dough were observed. Lactose (21.6 kg·s) caused a dough mass approximately two (9.0 kg·s, maltose) to four times (3.9 kg·s, sucrose) more viscous than dough with other sugars, except glucose (14.9 kg·s). The higher consistency-increasing effect of sucrose rather than glucose in case of the high-methoxyl pectin gel (1%, w/w) as reported by Yoo et al. (2003) was contrary to the above result. The role of lactose as a consistency builder in the cookie dough is not completely understood. Excess mixing can result in unnecessary gluten development during dough preparation that may results in hard cookies. Accordingly, use of sugars like lactose or glucose that results in the increased dough consistency needs special considerations because it will adversely affect cookie texture through vigorous mixing of the viscous dough.

Table 3. Consistency of cookie dough baked with various kinds of sugars by mini-Kramer cell test[1,2)]

Sugar	Consistency (kg·s)
Sucrose	3.9 ± 0.3^{d}
Lactose	21.6 ± 1.4^{a}
Maltose	9.0 ± 0.5^{c}
Fructose	5.0 ± 0.2^{d}
Glucose	14.9 ± 1.2^{b}
Malt syrup	5.2 ± 0.8^{d}

[1)] Mean±SD (n=7)
[2)] Values with different superscripts were significantly different by Duncan's multiple range test ($p<0.05$).

Gelatinization temperature of the cookie dough

The presence of sugar in the cookie dough is known to affect the gelatinization temperature of the starch at sugar concentrations as high as 20-50% or more (Miller, 1997). At the same sugar concentration, the gelatinization temperature of wheat flour was increased in the descending order of sucrose > glucose > fructose, as reported by Miller et al. (1997).

The influence of added sugars on the gelatinization temperature of the starch system in wheat flour, the key ingredient of cookies, as measured by DSC (Differential Scanning Calorimetry), is shown in Table 4. No noticeable alterations in the starch system (wheat flour-sugar, 10:4) were noted in DSC thermograph showing gelatinization temperature patterns. Addition of malt syrup caused increases in both the start of gelatinization and peak temperatures of the starch system from 2 to 3°C. This phenomenon is probably attributable to impurities in the malt syrup rather than to differences in the sugars.

Spread ratio and density

When cookie dough is heated in an oven, the leavening system in the dough becomes active and causes the cookie to expand in all directions. At the same time, undissolved crystalline sugars melt into the dough causing an increase in the volume and fluidity of the mass until the dough sets with passage of time. The SR (spreading ratio) values of the cookie

Table 4. Gelatinization temperature and enthalpy of wheat starch added with various kinds of sugars

Sugar	T_0 (°C)[1)]	T_p (°C)[2)]	ΔH (J/g)[3)]
Sucrose	60.10	67.29	1.21
Lactose	60.36	66.90	1.02
Maltose	59.93	66.43	1.26
Fructose	59.53	66.52	1.33
Glucose	60.04	67.01	1.44
Malt syrup	62.58	70.35	1.50

[1)] T_0: onset temp
[2)] T_p: maximum peak temp
[3)] ΔH: crystal melting enthalpy

products according to the added sugars are shown in Table 5.

The highest ratio for baked cookies was caused by sucrose, with a decreasing ranking of malt syrup > fructose > glucose > lactose > maltose. The SR values of the highest value group (sucrose, malt syrup, and fructose) were significantly different ($p<0.05$) from the rest of the sugars. Sucrose cookies were thinner than others due to the very low consistency of the dough. As cookie dough enters into the oven and starts to heat, the sugar melts and dough fluidity decreases and allows the dough to spread as a function of gravity (Hoseney, 1990). Accordingly, the higher the consistencies of the dough, the lower the SR values of the cookies were shown although no proportional relationships were existing. It indicates that as the solubility of the sugar increased, the SR value decreased. The retarded thermal set of the wheat starch in the cookie dough probably contributed to the increased spread of the baked cookie. Thus, control of the final shape of a cookie product can be partially achieved by proper sugar selection during preparation.

In contrast to bread, the effect of the moisture content on the final volume of the baked cookie is limited because cookie dough is naturally low in moisture content. Because the same amount of water was added to all samples (Table 1), the effect of leavening by water vapor was more or less limited and the density of the cookie was almost consistent among samples although SR value of the cookie was different. The overall density values of the cookies were in the range 0.19-0.22 g/cm^3, with no significant outliers ($p<0.05$) (Table 6). Sucrose and maltose cookies, which exhibited the highest (SR, 2.25) and the lowest spreadability values (SR, 1.38), resulted in similar density values because the final volume of each cookie was minimally affected by the added sugars in this experiment.

Water activity

The water activity (a_w) of food, which is defined as the ratio of the vapor pressure of water in a food to the saturated vapor pressure of water at the same temperature, is directly dependent on the concentration of dissolved solute, particularly salts and sugars in the water (Armbrister & Setser, 1994). Thus, dissolved sugars in the cookie will affect the water activity of the product in different ways according to the solubility and molecular weight of each sugar, which should affect the storage stability and the Maillard browning reaction of the cookies.

Cookies are naturally low in moisture content and have a long preservation period at room temperature as long as proper moisture-proof packaging is used. The water activity value of cookies based on added sugars is shown in Table 6. All values were within the narrow range of 0.36 to 0.44 in the ascending order of glucose < malt syrup < maltose < fructose < lactose < sucrose. These values are far below the lower limit of 0.80 for most enzyme activity and growth of most fungi. Even the water activity value for the maximum velocity of the Maillard browning reaction which is 0.65 in most food (Fellows, 1988) is significantly greater than the measured values.

The osmotic pressure of a food is also related to the sugar

Table 5. Spread ratio of cookies containing various kinds of sugars[1,2)]

	Sugar					
	Sucrose	Lactose	Maltose	Fructose	Glucose	Malt syrup
Width	37.58±0.77	33.40±1.17	32.65±0.95	35.03±1.06	33.66±1.08	38.88±0.56
Thickness	16.61±1.16	23.72±1.75	23.73±0.99	22.18±1.14	22.73±0.94	20.03±0.77
Spread ratio	2.25±0.37^{a}	1.42±0.13^{de}	1.38±0.08^{e}	1.59±0.13^{c}	1.48±0.10^{d}	1.94±0.09^{b}

1)Mean±SD (n=7)
2)Values with different superscripts were significantly different by Duncan's multiple range test ($p<0.05$).

Table 6. Density, water activity and Hunter's color value of cookies containing various kinds of sugars[1,2)]

Sugar	Density (g/mL)	Water activity (a_w)	Hunter's color value		
			L	a	b
Sucrose	0.20±0.03^{a}	0.44±0.05^{a}	82.68±0.60^{a}	-3.26±0.14^{e}	30.81±0.47^{c}
Lactose	0.21±0.00^{a}	0.44±0.01^{a}	81.91±0.52^{b}	-0.67±0.27^{c}	28.69±0.99^{d}
Maltose	0.20±0.02^{a}	0.39±0.01^{bc}	78.90±0.46^{c}	-1.10±0.17^{d}	31.38±0.62^{c}
Fructose	0.19±0.02^{a}	0.43±0.03^{ab}	75.47±0.91^{d}	2.14±0.72^{b}	33.10±0.94^{b}
Glucose	0.22±0.03^{a}	0.36±0.01^{c}	73.72±0.88^{d}	3.14±0.68^{a}	36.21±0.29^{a}
Malt syrup	0.21±0.04^{a}	0.38±0.03^{bc}	82.78±0.12^{a}	2.24±0.27^{b}	27.08±0.22^{e}

1)Mean±SD (n=7)
2)Values with different superscripts were significantly different by Duncan's multiple range test ($p<0.05$).

content. The osmotic pressure of sugar is inversely related to the molecular weight of the material, as seen from the high osmotic pressures in low molecular weight sugars (Bean & Setser, 1992). The presence of high osmotic materials removes moisture from the food, resulting in a lower water activity, as evidenced by the lower water activity of glucose cookies. However, the fructose cookie, in spite of the low molecular weight of the added sugar, exhibited a water activity value similar to others cookies containing disaccharides.

Surface color

Under oven heating conditions, the surface color of cookies is governed by added sugar through the non-enzymatic Maillard browning reaction of reducing sugars and the caramelization reaction of sugars that are heat unstable. The internal temperature of cookies during the later part of baking directly affects the degree of these reactions. The color characteristics of the cookie surface according to added sugars are shown in Table 6.

Hunter colorimetric lightness values (L) were in the range of 73.72-82.78, indicating relatively light tones. Based on Maillard browning, the presence of reducing sugars like fructose and glucose influences the surface color by lowering the lightness values while non-reducing sugars like lactose and maltose result in original colors with lighter surfaces. Hunter colorimetric redness (a) values were diverse with values from 3.26 to 3.14. The reducing sugars involved in Maillard browning reactions caused the glucose and fructose cookies to become red while cookies with non-reducing sugars were affected a little.

Hunter colorimetric yellowness (b) values were also diverse, scattered from 27.08 (malt-syrup) to 36.21 (glucose). The yellowness was also affected by the Maillard browning reaction. Shin et al. (1999) reported that cookies with sucrose and malt syrup (non-reducing) were less affected by the browning color changes. We also experienced the cookie with reducing sugars like sucrose, lactose, and malt syrup was affected a little degrees in colorimetric yellowness values in relation with browning reaction.

Texture

Textural properties of cookies are one of the prime quality factors in the final product. The overall quality of cookies, including flavor, are generally assessed by sensory evaluation techniques, while both instrumental and sensorial testing tools can be used for texture measurements (Charun, 2000; Sanchez et al., 1995; Chung et al., 2003).

Among numerous methods and instruments applicable to the measurement of cookie texture, 'probing testing' has the most use in cereal products like cookies and crackers. This method measures the integrated forces of a cylindrical probe required for penetration a predetermined distance into a sample. Results can be expressed as firmness, toughness, tenderness, ripeness, and hardness (Szczesniak, 1977).

The effect of added sugars on the hardness of cookies is shown in Table 7. In descending order of strength, lactose > maltose > sucrose > glucose > fructose > malt syrup, the use of different sugars affected the hardness of cookies. In general, cookies containing the disaccharides lactose (6.21 kg), maltose (3.94 kg), and sucrose (3.33 kg) were significantly harder than cookies with fructose (2.03 kg), glucose (2.31 kg), and malt syrup (1.70 kg) ($p<0.05$), although no significant differences were found within the latter group ($p<0.05$).

Lactose had an especially pronounced effect on cookie hardness, which could be correlated to greater consistency of cookie dough (Table 3). The high crystallization tendency of lactose probably influences the hardening of cookies because cookie hardness was measured by penetration of a cylindrical probe to a depth of 3 mm from the surface, where most sugar crystallization is assumed to occur (Hoseney, 1990).

The brittleness of cookies according to a 'snapping test' (Gaines et al., 1992) and a 'needle probing test' (Doescher & Hoseney, 1985) is shown in Table 7. The influence of sugars on the brittleness of cookies was in a decreasing order of lactose > maltose > fructose > glucose > sucrose > malt syrup, as measured by the 'snapping test' and maltose > lactose > sucrose, malt syrup > fructose > glucose, as measured by the 'needle probing test' (Table 7). As a whole, disaccharides had a greater influence for increasing the brittleness. Cookies containing monosaccharides developed less of the porous structure due to limited expansion and were considered to be

Table 7. Hardness and brittleness of cookies baked with various kinds of sugar by probing test[1,2]

Sugars	Hardness (kg)	Brittleness (kg·s)	
		Snapping test	Needle probing test
Sucrose	3.33±0.29^{b}	0.61±0.04^{bc}	12.1±1.4^{b}
Lactose	6.21±1.05^{a}	1.60±0.48^{a}	13.0±1.5^{b}
Maltose	3.94±0.75^{b}	1.52±0.17^{a}	15.7±2.7^{a}
Fructose	2.03±0.85^{c}	0.91±0.06^{b}	11.9±2.7^{b}
Glucose	2.31±0.44^{c}	0.88±0.12^{b}	10.6±2.1^{b}
Malt syrup	1.70±0.11^{c}	0.42±0.07^{c}	12.1±1.8^{b}

[1)]Mean±SD (n=5)
[2)]Values with different superscripts were significantly different by Duncan's multiple range test ($p<0.05$).

less brittle.

Surface pattern

Certain cookies, gingersnaps for example, develop a characteristic cracking pattern on the surface during cooking (Hoseney, 1990). As cookies are heated at a fast rate in an oven, this phenomenon occurs due to expansion of the cookie surface and breaking of the recrystallized sugar that has already lost moisture and is no longer moldable. This is unique with sugars that crystallize easily, such as sucrose. In comparison, the presence of sugars that do not easily crystallize interferes with the crystallization of other sugars. For example, glucose and high fructose corn syrup (HFCS) cause cookies to lose this surface cracking property and, consequently, result in a soft and chewable texture instead of a 'snap' property (Fellows, 1988).

Cracking patterns on the surface of the cookies according to different kinds of sugar are shown in Fig. 1. Typical cracking patterns were seen on cookies with the added disaccharides like sucrose, lactose, and maltose while cookies with added glucose, fructose, and malt syrup lacked cracking patterns. The cracking rate on the surface of cookies was influenced in the descending order of sucrose > lactose > maltose, according to the recrystallization of sugars. In contrast, glucose and fructose did not contribute to surface cracking due to poor recrystallization and the moisturizing effect that maintained the flexibility of the cookie surface. These results are in agreement with results of another study (Doescher & Hoseney, 1985) in which an absence of cracking patterns was noted with fructose- and glucose syrup.

Sensory properties

Cookies produced with six different sugars were ranked for color, appearance, taste, softness, and overall acceptance by sensory panelists. Individual panelists ranked those parameters with mean scores of 4.5-5.6 (color), 4.6-5.8 (appearance), 2.8-6.0 (taste), 3.0-5.6 (softness), and 3.1-6.0 (overall acceptance) points on a 1-7 scale for desirability.

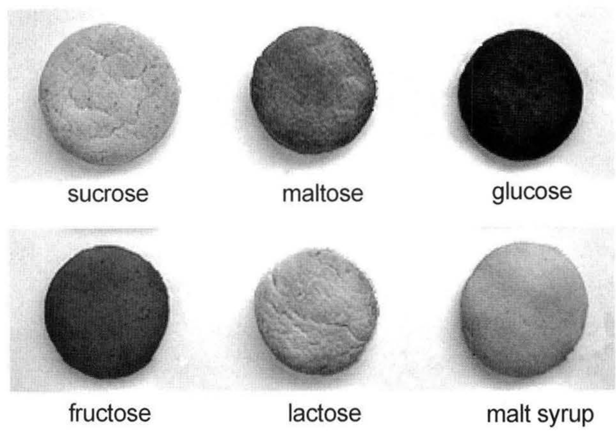

Fig. 1. Surface of cookies baked with various sugars.

For color, the maltose cookie (5.56) with a mild brown color and the sucrose cookie (5.18) with a light color tone as determined by instrumental color measurement were favored, although there was no apparent trend to indicate an overwhelming preference for any specific surface color. However, it was evident that cookies with darker surfaces resulting from too much browning (glucose and fructose sugars at 4.50 each) were less favored.

In appearance, the panelists preferred malt syrup cookies (5.75), with a mid-brown neat surface free of cracking patterns. Judging from the higher appearance preferences for cookies with malt syrup (5.75), sucrose (5.50), and fructose (5.31) with cracking patterns (sucrose) and without (malt syrup and fructose), the cracking pattern was not a critical influencing factor for cookie appearance.

Cookie taste resulted in a characteristic preference. Malt syrup (2.88) and lactose (2.75) cookies lacking a sweet taste were least favored in comparison with cookies (4.06-6.00) ($p<0.05$) with a relatively high sweetness value.

Soft and flexible cookie textures lacking advanced sugar

Table 8. Sensory evaluation score for the characteristics of cookies baked with various kinds of sugars[1,2)]

Sensory characteristic	Sugar					
	Sucrose	Lactose	Maltose	Fructose	Glucose	Malt syrup
Color	$5.18\pm1.07^{1)a}$	4.56 ± 1.92^{b}	5.56 ± 1.72^{a}	4.50 ± 1.60^{b}	4.50 ± 1.85^{b}	4.56 ± 2.09^{b}
Appearance	5.50 ± 1.31^{ab}	4.69 ± 1.91^{b}	4.75 ± 1.49^{b}	5.31 ± 1.87^{ab}	4.63 ± 1.69^{b}	5.75 ± 1.39^{a}
Taste	5.63 ± 1.69^{a}	2.75 ± 0.89^{c}	4.06 ± 1.15^{b}	5.81 ± 0.65^{a}	6.00 ± 0.53^{a}	2.88 ± 0.83^{c}
Softness	4.50 ± 1.67^{b}	3.13 ± 1.55^{c}	4.13 ± 1.36^{b}	5.50 ± 1.30^{a}	5.63 ± 1.30^{a}	3.00 ± 1.20^{c}
Overall acceptance	5.56 ± 0.82^{a}	3.88 ± 13.73^{b}	4.25 ± 1.28^{b}	5.88 ± 0.69^{a}	6.00 ± 0.76^{a}	3.13 ± 0.99^{c}

7: like extremely - 1: dislike extremely
[1)]Mean±SD (n=15)
[2)]Values with different superscripts were significantly different by Duncan's multiple range test ($p<0.05$).

crystallization were generally preferred with glucose (5.63) and fructose (5.50) cookies favored over lactose and malt syrup cookies. The lowest mean panel scores for softness of the malt syrup cookies were contrary to the results of the instrumental probe test (Table 8) in which the malt syrup cookie attained the lowest hardness value. This implies that the palate discriminating ability of the human sense that leads to sensory evaluation result is not always replaced by the simple result of instrumental probe measurement (probe resistance values) (Gaines et al., 1992) because human senses the collaborative outcome of the many influencing factors.

In the overall preference for cookie products, glucose (6.00) and fructose (5.88) cookies again were judged to be best, while lactose (3.88) and malt syrup cookies (3.13) received the lowest scores ($p<0.05$). The typical 'surface cracking' of the sugar snap cookie had no consistent influence on the overall desirability of the product.

In conclusion, cookies baked with various common sugars that are ordinary employed in food industry resulted in diverse products with different physical and organoleptic properties. Although typical surface cracking and Maillard browning were obviously indicated according to added sugars, cookies with bright color, instead of brown one and soft texture, rather than crunch one were more favored by the organoleptic evaluations although both of the quality attributes are obtainable from different sugar sources. Optimization of appropriate sugars in different mixing ratios to satisfy consumer's preferences and its evaluation will be the further research needs to be continued.

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