FUNCTIONALITY OF SUCRALOSE/MALTODEXTRIN: ISOMALT BLENDS IN
OATMEAL AND CHOCOLATE CHIP COOKIES

by

REBECCA JANE MCKEMIE

(Under the Direction of Ruthann Swanson)

ABSTRACT

Availability of reduced-in-sugar baked products with quality characteristics equal to their full-sugar counterparts may reduce simple carbohydrate and calorie consumption. In both oatmeal and chocolate chip cookies, a sugar alternative blend [Splenda® Granular (sucralose maltodextrin) and Isomalt] replaced 100% of the sugar. Control cookies were prepared with 100% granulated sugar. Using the multiple ingredient approach, three Splenda® Granular: Isomalt ratios were investigated: 30%:70%, 40%:60%, and 50%:50%. A trained descriptive panel evaluated sensory texture and flavors attributes. Physical/physicochemical tests included probing, color, water activity and cookie spread. Mixed model analysis of variance (p<0.05) revealed no flavor differences. Significant texture attributes were limited and varied with cookie type, with intensity differences within one scalar unit. Significant reformulation effects detected with physical/physiochemical techniques were within a narrow range. No consistent treatment effects were found. Overall, all blend ratios produced cookies with quality characteristics very similar to the controls. Sugar reduction was 30%; calorie, 4-7%.

INDEX WORDS: Cookies, High intensity sweetener(s), Sucralose, Isomalt, Flavor, Texture, Sensory evaluation, Instrumental Evaluation
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Chapter I
INTRODUCTION

Obesity is an epidemic in the United States that is affecting adults and children across all ethnic and gender groups. Nearly 1/3 of adult Americans and 17% of children are obese (Ogden et al, 2006). According to The Center for Disease Control’s (CDC) Behavioral Risk Factor Surveillance System (BRFSS) data, the prevalence of overweight and obesity has steadily increased across the lifespan from 1996 to 2006 (BRFSS, 2007a).

In 1996, 35.4% of the nation’s adult population was reported as being overweight whereas 16.8% was reported as being obese. By 2006, the number of adults who reported being obese had increased dramatically to 25.1%, whereas the number of people considered overweight had increased slightly to 36.5%. For adults, the BRFSS defines obese as having a BMI greater than or equal to 30 using the calculation of kilograms of weight divided by height in meters squared. Overweight is defined as a BMI of 25.0 to 29.9 using the same calculation (BRFSS, 2007b). The data that are collected by BRFSS is self-reported, so the incidence of overweight and obesity is probably higher than that reported (BRFSS, 2007b).

In a 2004 report in the Journal of the American Medical Association, researchers reported the incidence of childhood overweight (Hedley et al, 2004). For children, overweight is defined as at or above the 95th percentile of body mass index for age on the BMI-for-age-growth charts (Gordan et al, 2003). Using these criteria, 16% of children ages 6–19 were overweight, and 31% of the children in this age group were at-risk for being overweight. In 2008, the same
researchers evaluated data from four time-periods to look for possible trends. They determined, based on the 2000 CDC growth charts, that 31.9% of children were either overweight or at risk for being overweight (Ogden et al, 2008).

As the rates of overweight and obesity rise, so do associated health problems, such as diabetes, hypertension, hyperlipidemia, and heart disease. Recent reports from the American Heart Association estimate that nearly 1/3 American adults has hypertension. In 2003, 17% of American reported having high cholesterol (CDC, 2007b). Heart disease remains the number one cause of death in the United States. One in every three has some form of heart disease (Rosamond et al, 2008). Heart disease is the number one cause of death for American Indians, Alaska Natives, blacks, Hispanics, and whites (CDC, 2007b). Research recently reported that cardiovascular disease (CVD), another term for heart disease, caused 36.3% of deaths in 2004 and was mentioned as possible cause of death in 57% of deaths that year (Rosamond et al, 2008).

Hypertension is increasing among adults and children, particularly among African-American children (CDC, 2007a). In a 2004 study, researchers reported that African-American girls mean systolic blood pressure was 1.6mm Hg higher while the boys was 2.9mm Hg higher than any other ethnic group (Munter et al, 2004).

The American Diabetes Association states that nearly 8% of the American population has some form of diabetes with almost 1/3 of them not realizing they have it (CDC, 2008). The incidence of diabetes and obesity has increased over the last decade (Mokdad et al, 2001) in children and adults. Dietz (1998) reported that overweight or obese children have a greater risk of developing hyperlipidemia and diabetes. All of these associated health risks are serious and require attention from a doctor (Must et al, 1999).
The incidence of overweight and obesity can be largely attributed to the American diet, which is high in calories, fat, and sugar, and low in fruits, vegetables and dairy (Mokdad et al, 2001). Specific dietary factors that have influenced the obesity trend include increased portion size and caloric intake (Hedley, 2004). An improvement in nutrition and an increase in physical activity have been identified by CDC as the means to control the obesity epidemic (USDA, DHHS, 2005).

Trends suggest that consumption of foods high in sugars contribute to excess caloric intake and therefore, increased obesity and associated health risks (Henkle, 1999; Vermunt et al., 2003). In 2006, the USDA – ERS estimated that the average American consumed 138.9 pounds of added sugar per year. (USDA, ERS, 2008) USDA-ERS defines sugar as caloric sweeteners such as cane and beet sugar, corn sweeteners, edible syrups and honey. The most popular forms in which these calories are consumed are sugary drinks and sweets, such as pastries, cakes, and cookies.

A direct link between nutritive sweeteners and the development of chronic diseases has not been unequivocally established, with the exception of the development of dental caries (ADA, 2004). Excessive intake of sugary foods can be to blame for dental caries when coupled with poor oral hygiene (ADA, 2005). In addition, there is some evidence for a direct link between excess consumption of sugar and several chronic diseases. Excess consumption of sugar has been linked to the insulin resistance associated with diabetes (Brand-Miller, 2003) as well as an increase in serum triglyceride levels (Hellerstein, 2002), which is associated with an increased risk of coronary heart disease.
More recently, the potential effects of sugar intake on glycemic response has received increased attention (Vermunt et al., 2003). The glycemic effects on obesity as well as diabetes management have been suggested by some researchers (Bell and Sears, 2003) as the reason for the steady rise in both since the 1960’s. The glycemic effect of a food is defined as the rise in blood glucose 2 hours after consuming a food. The response is compared to that of white bread and expressed in the form of a percentage (Bell and Sears, 2003).

The current Dietary Guidelines recommends that a person’s sugar intake be limited and that sugar be consumed only as discretionary calories (USDA, DHHS, 2005). USDA defines discretionary calories as “the balance of calories remaining in a person’s energy allowance after accounting for the number of calories needed to meet recommended nutrient intakes through consumption of foods in low-fat or no added sugar forms.” (USDA, DHHS, 2005)

**Consumer Trends in the Marketplace and the Role of Cookies**

Cookies are one of America’s favorite desserts and snacks. Cookies are an indulgent food and traditional cookies are high in fat, calories, and sugar. The typical formulation for cookies in the United States is 30-75% sugar, 30-60% fat and 7-20% water on a flour-weight-basis (Pyler, 1988). One approach to addressing the obesity epidemic is to reformulate favorite foods to improve their nutritional profile (DHHS, 2004). This approach would allow consumers to retain favorite foods in the diet while reducing the feelings of deprivation often associated with the avoidance of the traditional counterpart (ADA, 2002). Cookies like cereals, cakes, and breads have been reformulated to have less added sugar. For example, in March of 2004, the Kellogg Company introduced a new variety of Apple Jack’s, Frosted Flakes, and Fruit Loops. These reformulated cereals contain 1/3 less sugar than their original formulations. Although the
full sugar cereal is still available, the 1/3 less sugar formulation offers consumers another way to reduce sugar and calorie consumption. Dietary incorporation of reformulated foods has been linked to a reduction in the chronic disease risk factors associated with obesity and improved weight management (ADA, 2004; CCC, 2005).

Recent reformulation efforts which have included cookies, reflect increased consumer awareness of sugar consumption and growing health concerns, such as obesity and diabetes. The use of low-calorie sweeteners in the food industry increased by 58.9% from 2003 to 2004 (Mintel, 2007). The cookie market appears to be rebounding from a low in 2005. The previous drop in sales was attributed to consumers being carbohydrate conscious and following low-carb diets, suggesting that consumers do make dietary changes in response to their health concerns, although they may not be maintained over time. The market now includes whole grains and portion control choices as well as low-fat and sugar-free choices. Some of the newer cookies on the market contain functional ingredients such as flax seed or additional dietary fiber. These products can help consumers meet the 2005 Dietary Guidelines recommendation to increase fiber consumption to 25g per day. Of the cookies purchased in the US in 2006, 11% were considered health-oriented cookies (Mintel, 2006). This market trend is expected to continue at least through the year 2011 with “health-oriented” cookies sales expected to increase by 5.2% in 2008. This is a broad product class. In this market analysis, health-oriented cookies were defined as cookies seen by consumers as being “good for you” (Mintel, 2006). However, continued growth in this market sector and retention of current consumers will depend on the availability of “health oriented cookies” with sensory characteristics that match those of the traditional product. This has not been the case to date for cookies formulated with sugar alternatives (Drewnowski et al, 1998).
Functional Role of Sugar in Cookies

Sugar performs multiple functional roles in cookies. The sweetness of sucrose is easily attainable through the incorporation of high intensity sweeteners (HIS). However, the other functions of sugar in cookies are more difficult to mimic. In addition to sweetness, sugar also provides bulk, influences texture, preservation, and browning, and affects appearance (Pyler, 1988; Davis 1995).

High-intensity sweeteners (HIS) and low-calorie sweeteners are used in the formulation of reduced-in sugar or sugar-free products, including cookies. Many HIS are available in today’s market. They include but are not limited to aspartame, sucralose, saccharin, and acesulfame potassium (AceK). Although these compounds may provide calories, they are used at a very low concentration making their caloric contribution negligible. In addition to providing no calories, these sweeteners are considered safe for diabetics (ADA, 2004) and are non-cariogenic (Nelson, 2000). Limitations that exist when using HIS in cookies include no Maillard browning, no effect on water activity, no role in product structure and difficulty in dispersing the ingredient in the product. Further, some HIS exhibit bitter and/or lingering sweet aftertastes and are heat sensitive. In addition, these sugar alternatives do not provide the bulk contributed by sucrose when used alone. HIS have been used in combination with dextrose, polydextrose and maltodextrins. Fiber and sugar alcohols have also been used as bulking agents to overcome this functional limitation and to improve dispersibility (Alexander, 1998).

Low-calorie sweeteners, also known as polyols or sugar alcohols, provide an additional re-formulation option. These compounds, which are derived from various sugars, include mannitol, sorbitol, xylitol, erythitol, lactitol, maltitol, hydrogenated starch hydrolysates and isomalt. Caloric contributions range up to 2 calories per gram, varying with polyol selected.
These compounds like HIS are non-cariogenic and elicit a lower glycemic response than sucrose does. Sugar alcohols can provide bulk that is lost when using HIS without providing too much sweetness (Nelson, 2000). They are resistant to enzymatic and microbial activity while remaining heat stable. They are also used to lower water activity. However, like HIS they do not participate in Maillard browning (Deis, 2000).

When used alone, neither HIS nor polyols produce baked products with characteristics identical to those prepared with sucrose. A potential way to overcome some of these functional limitations is to use these ingredients in combination. This multiple ingredient approach allows formulation of products that better match the traditional gold standard than is possible with single alternative sweeteners (CCC, 2007). Factors to consider when blending a HIS with a low-calorie sweetener include the resulting sweetness profile and appearance and texture of the target product (Deis, 2000).

Sucralose is considered an all-purpose HIS. It is well-suited for sweetening drinks and is heat stable, so it has incorporation potential in baked products. Thus, sucralose offers a potential way to reduce the sugar content in sweet baked goods. This HIS is available to consumers as a blend of sucralose and maltodextrin, allowing some, but not all, of the functional limitations associated with sucralose alone to be overcome. This product is marketed as Splenda® Granular. Isomalt is a sugar alcohol that has a positive impact on the appearance and texture of baked products. It is less sweet than an equal quantity of sucrose allowing it to be combined with an appropriate HIS without an overpowering sweetness. Further, flavor transfer in foods is enhanced and shelf-life is improved. It does not exhibit the cooling effect characteristic of many other polyols (Nelson, 2000). However, consumption of high levels is associated with a laxative effect (Alonso and Setser, 1994).
Recently, Johnson and others (2006) studied various ratios of sucralose/maltodextrin to Isomalt as a 100% sugar replacement in cupcakes. A principal components analysis (PCA) revealed sensory attributes of the cupcakes prepared with 30% Splenda® Granular to 70% Isomalt were similar to the 100% sucrose control. An exact match was not found, and trends observed suggested that additional ratios should be investigated. Similar studies have not been conducted on cookie formulations.

Purpose and Hypothesis

The purpose of this experiment was to use the multiple ingredient approach to identify an alternative sweetener system that would produce lower calorie cookies, specifically chocolate chip and oatmeal, with the same sensory characteristics as the respective full–sugar traditional cookie. It was hypothesized that the 100% replacement of granulated sugar in the formulations by a ratio of 40% Splenda® Granular to 60% isomalt would produce cookies of both types with quality attributes most similar to the 100% granulated sugar control; the resultant cookies would exhibit a reduction in calories of 25% and a 100% reduction in carbohydrates contributed by granulated sugar.

Objectives of this study were:

1. To establish a product flavor and texture profile for each cookie type utilizing a trained descriptive sensory panel for each sucralose/maltodextrin: isomalt ratio investigated

2. To characterize each cookie prepared with each sucralose/maltodextrin: isomalt ratio from each cookie type using established non-sensory objective techniques: cookie spread, probing, color and water activity.
3. To determine the effects of product modification on macronutrient profile of each formulation from both cookie types.
REFERENCES


USDA, DHHS (United States Department of Agriculture, Department of Health and Human


Chapter II

REVIEW OF LITERATURE

Introduction

Cookies have been described as “small cakes made from a dough that is sufficiently viscous to permit the dough pieces to be baked on a flat surface.” Based on that definition, an infinite number of products of varying shapes, sizes, compositions, texture, color, and flavor would be classified as cookies. However, cookies are typically classified based on the industrial production manner employed: cutting machine, rotary moulded, bar, wire-cut, and deposit cookies (Pyler, 1988). Chocolate chip and oatmeal cookies can be classified as deposit cookies. Deposit batters tend to be somewhat fluid with the consistency like that of a thick cake batter.

Cookies are one of America’s favorite desserts and snacks. Sandwich-type cookies are the favorite with soft chocolate chip cookies being the second most popular type of cookie. Oatmeal cookies would be classified under other soft cookies by Mintel, the market analysis group, and they are ranked as the 6th most popular type of cookie. Sales data show that American consumers are more likely to purchase chewier cookies rather than their crisper counterparts (Mintel, 2007).

Cookies are an indulgent food, high in fat, calories, and sugar. Typical cookie formulations contain 30-40% sugar, 65-75% fat, and 15-25% egg when flour-weight equals 100% (Pyler, 1988). The traditional chocolate chip cookie formulation when flour equals 100% is typically 75% sugar, 60% fat, 7% egg, and 55% chocolate chips. These cookies contain both
granulated sugar and brown sugar. Traditional oatmeal cookies, when flour in a 50/50 oatmeal/flour ratio equals 100%, contain 50% shortening, 60% sugar, and 2% egg. (Pyler, 1988).

Reformulation of favorite foods, like cookies, to improve their nutritional profile allows these favorites to be retained in the diet while reducing the feelings of deprivation associated with the avoidance of the unmodified counterpart (ADA, 2002). Traditionally these modified products were targeted to individuals with specific dietary needs; however, these products are now targeted to the general consumer (Thomson, 2004). Currently, the CDC emphasizes the selection among available food products and portion control as key steps in the effort to help control the obesity epidemic and associated chronic health conditions (Newell et al, 2007). Thus, availability of foods reformulated to improve their nutritional profile, can help promote dietary choices consistent with current health recommendations. In response to Healthy People 2010, the food industry has introduced alternatives to popular food products with improved nutritional profiles (USDA, DHHS, 2005).

Over the last several years, the cookie market has adapted to increased consumer awareness of the diet-health link and associated health concerns. Of the cookies consumed in the US in 2007, 13.6% were considered health-oriented cookies (Mintel, 2007). Defined as cookies that are perceived by consumers as “being good for you,” this market segment includes organic, sugar-free, fat-free or low fat, low carb or no carb, no allergens, and added nutrients as well as whole grains and portion control choices.

Use of reduced-sugar foods and beverages formulated with sugar alternatives, as suggested by ADA (2004), has a positive impact on nutrient intake. Individuals who consume these modified products make dietary choices more consistent with dietary recommendations and have significantly higher micronutrient intakes (Sigman-Grant and Hsieh, 2005). However,
consumers want reformulated products with improved nutritional profiles that have the sensory characteristics of their unmodified counterparts (Kohn, 2000). The most popular of these products formulated with sugar alternatives are diet soft drinks (CCC, 2007b). Consumer perception of inferior sensory characteristics and doubt about the health benefits associated with consumption remain impediments to increased consumption of these products across a broad range of product classes (Sandrou and Arvanitoyannis, 2000).

**Cookie Formulations**

The key ingredients in cookies are flour, sugar, and fat. In the case of chocolate chip and oatmeal cookies, the key ingredients also include chocolate chips and oatmeal, respectively. Understanding the functional role of the targeted ingredient in cookie systems and its interaction with other food ingredients is necessary when trying to reformulate each cookie to improve its nutritional profile.

**Role of Sugar**

Sucrose, a disaccharide, is the sweetener that serves as the gold standard in food products. It is a white crystalline product derived primarily from sugar cane and sugar beets that is characterized by a clean, sweet taste with a rapid onset of relatively short duration. In cookies, it provides multiple functional roles. In addition to sweetness, sugar also provides bulk, and influences spread, texture, preservation, appearance and browning (Pyler 1988, Davis 1995). It is relatively easy to replace the sweetness provided by sugar. However, the other functional roles of sugar are more difficult to successfully mimic (Bullock et al., 1992).

**Sweetness**

The sweetness intensity of sucrose, which is assigned a value of 100, serves as the standard against which all other sweeteners are compared. The response to a solution’s sweetness
and its concentration are linear. As the perceived sweetness of a sucrose solution increases, so does its concentration (Alexander, 1998). The same is not true of other sweeteners. Sweeteners also differ in the time of sweetness onset post-ingestion, as well as the length of its duration. Further, unlike sucrose, some sweeteners are associated with bitterness (Nelson, 2000).

**Bulk**

Bulk contributed by sugar makes a major contribution to the total ingredient volume in a cookie system. Sugar also functions to dilute the other ingredients present, influencing their interaction and therefore the resultant texture of the baked cookie. It is also easily dispersed within the system (Pyler, 1988). When bulk contributed by sugar is not present, the resulting cookies will be hard and will exhibit a great deal of surface cracking (Doescher and Hoseney, 1985).

**Spread**

Cookie spread reflects the final product dimensions, both height and width, and is generally considered to be an overall indicator of cookie quality. Several studies (Curley and Hoseney, 1984; Doescher and Hoseney, 1985; Doescher et al, 1987a) demonstrated that increasing the amount of sugar in a formulation increases cookie spread. As the cookie bakes, the sugar melts and turns into a liquid making the batter more viscous and creating spread. In addition, sugar increases the temperature needed to gelatinize starch and denature proteins, delaying product set (Alexander, 1997). Sugar additionally affects spread by competing with the flour for water; increased flour hydration is associated with increased gluten development which limits spread (Doescher et al., 1987a).

**Texture**
Gluten is “a protein complex formed when water is kneaded with wheat flour. In cookies, the goal is to have very little gluten formation. If too much gluten develops, the cookies will be tough (Faridi, 1994). Sugar tenderizes the cookies by reducing gluten formation by competing with the protein for the limited amount of water in the cookie system.

The amount of sugar in a system is a major contributor to the cookies final crispness and hardness. The higher the sugar content of a product, the more crisp and hard it will be (Faridi, 1994). As the sugar in a system begins to harden or crystallize after being removed from the oven, the product begins to develop fractuability. As the cookie ages and recrystallizes, it becomes more fracturable, it develops snap (Curley and Hoseney, 1984). With the partial replacement of the sugar in a system with high-fructose corn syrup, the cookies tended to bend before breaking (Curley and Hoseney, 1984), indicating reduced fracturability. Products containing less sucrose or sugar tend to be softer and chewier (Alexander, 1994).

**Appearance and Browning**

Sugar contributes to cookie color as a reactant in the Maillard browning reaction. Maillard browning occurs through a series of reactions that requires an amine group, a reducing sugar, and water (Daniel et al., 2007). Although granulated sugar or sucrose is not a reducing sugar, it can be hydrolyzed to its respective components of glucose and fructose which are reducing sugars. These reducing sugars can then react with amino acids that are present. Three stages of the Maillard reaction are typically described. In the initial phase the condensation or glycation reaction yields glycosylamine. The glycosylamine can undergo an irreversible Amadori rearrangement that yields a derivative of 1-amino-1-deoxy-D-fructose. In the intermediate phase of this reaction, the Amadori product degrades. In the final phase, melanoidins which are the compounds primarily responsible for the resulting brown color, are
produced (Oliver et al., 2006). These compounds are largely responsible for the surface browning found in baked products; they also contribute to the characteristic flavor.

**Preservation**

Sugar functions as a preservative through an effect on water activity. Because nutritive sweeteners bind water in food systems, they lower water activity (Alexander, 1998). Most cookie formulations contain three to five percent water or liquid. The low percentage does not present a problem regarding cookie preservation. According to Fontana (2000), cookies containing three to five percent moisture generally have a water activity around 0.3.

**Sugar replacement**

A way to reduce the amount of added sugar consumed is to formulate a cookie with a high-intensity sweetener (HIS) or sugar replacer (CCC, 2007b). Many HIS are available in today’s market. Sucralose is considered an all-purpose HIS that is heat stable. Thus, sucralose offers a potential way to replace the sweetness contributed by sugar in baked products (CCC, 2007a). Sugar replacers are also known as polyols or sugar alcohols. Most are less sweet than sugar and offer anywhere from 0.2 kcals/g to 3 kcals/g (CCC, 2007d). Isomalt is a sugar replacer that can be measured cup-for-cup like sugar on either a volumetric or weight basis.

**Sucralose**

Sucralose is a high-intensity non-caloric sweetener (HIS) that is 600 times as sweet as sucrose. Sucralose was first seen on the market in 1976 in England. It was initially developed by Tate and Lyle and Queen Elizabeth College in London. Sucralose entered the US market in 1999, when it obtained FDA approval as a “general-purpose sweetener” (Nelson, 2000). Sucralose that is available to US consumers is sold as Splenda®, a sucralose/maltodextrin blend. Until 2006, it was exclusively sold by McNeil Nutritionals in the US in cooperation with Tate
and Lyle. Portions of the patent for Splenda® expired in 2006 allowing generic versions of it to be available to consumers. However, Tate and Lyle in association with McNeil Nutritionals own the rights to Splenda® until 2020.

Sucralose is manufactured beginning with sugar which is processed to selectively replace three OH groups with chlorine. It is with this replacement that sucralose is formed. Sucralose is heat stable and can survive baking, pasteurization, and extrusion. Because it can survive such processes, it is considered a good alternative to sucrose in many foods. Sucralose is not soluble in fats or oils, and its solubility in water increases as heat increases. Its sweetness can also be maintained over a wide pH range, although its sweetness profile differs from sucrose (Nelson, 2000).

Sucralose is available to consumers as Splenda® Granular which is a blend of sucralose and maltodextrin. The Code of Federal Regulations (2008) defines maltodextrin as a “nonsweet nutritive saccharide polymer that consists of D-glucose units linked primarily by α-1-4 bonds with a dextrose equivalent (D.E.) of less than 20. It is prepared as a white powder or
concentrated solution by partial hydrolysis of corn starch, potato starch, or rice starch with safe and suitable acids and enzymes.” It is the addition of maltodextrin to the sucralose that enables Splenda® Granular to be measured cup for cup like granulated sugar. Maltodextrin functions as a bulking agent, a key role of sugar in baked products including sugar. Although the maltodextrin may function as a bulking agent by contributing volume, it does not contribute a great deal of weight to the overall product, therefore substitutions are made on volume rather than weight basis.

Other potential limitations of sucralose use as a sugar alternative include no Malliard browning, and no effect on water activity. Sucralose does not participate in Malliard browning because it is not a reducing sugar nor does it breakdown into reducing sugars. Sucralose also does not affect a system’s water activity. In a traditional cookie system, sucrose binds water reducing the amount of water in a system and thus lowering water activity (Burrington, 1998). When sucrose is not present, this does not happen and an environment suitable for microbial growth may be created. Further, the rate of chemical and biochemical reactions that impact shelf-life may be altered (Fontana, 2000).

**Isomalt**

Isomalt, a sugar alcohol, is manufactured starting with sucrose which is made into isomaltulose. The isomaltulose is then hydrolyzed into the final product Isomalt. The isomalt intermediate, isomaltulose, obtained FDA GRAS approval November 1, 2005. However, Isomalt itself has not obtained FDA GRAS approval, although a petition has been filed to have its status affirmed GRAS (CCC, 2007e). FDA is still in the process of reviewing submitted materials. The World Health Organization’s Joint Expert Committee on Food Additives
(JECFA) reviewed the safety of isomalt and placed it in the safest possible category (CCC, 2007e).

Isomalt is 45 to 60% as sweet as granulated sugar or sucrose. Isomalt offers 2 kcals/g whereas sucrose offers 4 kcals/g. Because one cup of granulated sugar weighs 200 grams and one cup of isomalt weights 198 grams, isomalt can be substituted for sugar on either an equal weight- or volume-basis.

![Conversion of sucrose to isomalt](Palatinit, 2007)

Isomalt is non-cariogenic, which means it will not cause cavities like sucrose can (Franz et al, 2002). Gostner and colleagues (2005) suggest that Isomalt could be a prebiotic. In this study, volunteers were asked to consume 30g of Isomalt per day in a variety of foods ranging from biscuits to jam to chocolate and the impact of consumption on metabolism and gut function.
when volunteers followed a Western diet was investigated. Although volunteers participating in this study reported an increase in stool frequency, it did not affect the study’s outcome. Because a person consuming a Western diet may suffer from chronic functional constipation, the mild laxative effect may be beneficial to consumer health and well-being (Gostner et al., 2005). An earlier study suggested high Isomalt consumption caused a laxative effect in study volunteers (Marteau and Flourie, 2001).

Currently, Isomalt is being used primarily in confections like hard candies, chocolates, and chewing gums. According to Palatinit (2007), the main manufacturer of Isomalt, in a ratio of 1:1, Isomalt can replace sugar in confectionery and other foods to produce products that are low in calories, and are low glycemic or tooth friendly. Isomalt has a low hygroscopicity, which means it does not readily attract water. Due to this property, it serves as an appropriate alternative in confections. Of sugar alcohols, it is the least soluble (Kuntz, 1996). Isomalt also exhibits a synergistic effect when combined with HIS (Alonso and Setser, 1994)

**Sugar replacement in cookies**

Zoulias et al (2000) tested the effect of sugar replacement on cookies. Cookies were prepared with various alternative sweeteners, including a single HIS, Ace-K, and the sugar alcohols, maltitol, lactitol, sorbitol, xylitol, and mannitol, and Ace-K in combination with each sugar alcohol individually (0.037 HIS to 200g sugar replacer). The cookies prepared with mannitol alone were thicker and harder than the other cookie formulations in the study. They also showed no line spread and exhibited low water activity. The addition of AceK did not improve the quality of cookies prepared with mannitol, although a bitter flavor note was introduced. Thus, this HIS/sugar alcohol combination did not produce an acceptable reduced
sugar product. For all other blends, Ace-K successfully supplied the missing sweetness of the sugar alcohols. Some differences in texture and cookie spread were found with blend incorporation. This study did not utilize Isomalt or sucralose.

More recently, Cardello (2003) tested the descriptive sensory aspects of two types of cookies, which had been prepared using an Ace-K and Splenda® Granular blend. In this study, 50% of the granulated sugar was substituted with a blend of AceK and Splenda® Granular. The research indicated no significant effect on flavor for either type of cookie, oatmeal or chocolate chip. However, upon instrumental textural analysis using the probing technique, each cookie treatment was found to differ from its sucrose control (Cardello, 2003). When compared to the controls, the modified oatmeal cookies were less fracturable and less cohesive. The modified chocolate chip cookies were less cohesive, fracturable, rough, hard and chewy than their respective sucrose control. Cardello’s (2003) study and work done by Zoulias and others (2000) indicates the potential of the multiple ingredient approach. The multiple ingredient approach (CCC, 2007c) allows formulation of products that better match traditional gold standard than is possible with single alternative sweeteners (CCC, 2007c).

Johnson and others (2006) studied various ratios of sucralose/maltodextrin to Isomalt as 100% sugar replacement in cupcakes. With a 30% Splenda® Granular to 70% Isomalt replacement, Principal Components Analysis revealed cupcake sensory attributes were similar to the 100% sucrose control. An exact match was not found. This combination of sweeteners allowed sucralose to contribute sweetness whereas Isomalt contributed bulk. Similar studies in cookies have not been reported.
**Cookie Quality Assessment**

**Physicochemical and Physical Analysis**

Numerous physical and instrumental analyses can be utilized to determine the characteristics of foods. Physical or physicochemical tests that apply to cookie quality include cookie spread, water activity, color analysis and the puncture test. It can be expected that replacing sugar with alternative sweeteners will have an effect on cookie quality.

**Cookie Spread**

Cookie spread is considered an indication of overall cookie quality, although this quality assessment was originally designed for cookie flour quality (Doescher et al, 1987a). Cookie spread is determined by obtaining the average width and thickness of six randomly selected cookies. The ratio of cookie width to cookie thickness is then calculated, after correcting for barometric pressure at the time of baking (AACC 10 – 50D, 2000). Cookie spread is influenced by formulation, and type of sugar used (Matz, 1992), along with baking conditions and humidity (Pyler, 1988). Morrow and others (1974) also demonstrated that atmospheric pressure does influence cookie spread. The more humid it is, the greater the spread.

The volume and granulation of sugar will affect cookie spread. When the volume of sugar is decreased, gluten formation increased and decreased cookie spread results (Matz, 1992). The specific sugar used in the formulation will influence spread through an effect on the time to product set. Doescher and others (1987b) illustrated that cookies prepared with glucose and fructose set faster, therefore making them notably smaller and thicker than were the control cookies prepared with sucrose. It is expected that the cookies prepared with a blend of Splenda® Granular and Isomalt will spread less than the 100% sucrose control cookies.
**Water Activity**

Water activity is defined as a measure of the energy status of the water in a system and its availability to act as a solvent and participate in chemical and biochemical reactions and growth of microorganisms. A product’s water activity is different from the moisture content of a food. Water activity measures the amount of free water present a system, whereas moisture content is the total amount of water available. It’s important to know a food’s water activity in order to determine its safety and shelf stability (Fontana, 2000). Water activity can be measured one of two ways, measuring the dew point or the relative humidity. Both methods have been validated.

Knowing water activity is crucial in product development. Most food products have a water activity between 0.2 and 1.0. A food product with high water activity, over 0.9, will support the growth of bacteria, while food products with water activity over 0.6 will support the growth of molds and yeasts. No microbial activity takes place at or below 0.6. According to Fontana (2000), cookies containing three to five percent moisture generally have a water activity around 0.3. The water activity of a product may also change the rate at which chemical and enzymatic reactions that occur.

Water activity becomes a concern with sugar replacement because of the potential of sugar to interact with the water in the system. While the product may need to stay moist for consumer acceptability, it should not compromise the product’s shelf-life and safety. By replacing sucrose with sugar alternatives, there will be a reduction in the amount of solute within the system, even when it is replaced on a volumetric basis by bulking agents. When the amount of solute is reduced, so is the system’s osmotic pressure. This creates an environment that is potentially susceptible to microbial growth (Penfield and Campbell, 1990, Vandell, 1998).
Information regarding water activity and sugar alternatives is limited, but it has been noted that since the quantity of sucralose used in a product is small, it is unlikely it interferes with the water in a system (Chapello, 1998). Because of that, there is an increased potential of microbial growth within a system when high intensity sugar alternatives are utilized (Nelson, 2000). Little is known about how Isomalt specifically affects a cookie system. However, sugar alcohols may be incorporated into products to help control water activity (Deis, 2000).

Water activity will also affect the texture of food (Fontana, 2000). If the water activity of a system is low, the product may be viewed as being tough, hard, dry, crisp, or crunchy. However if the water activity is higher, the product may be seen as chewy or soggy. Hardness is an attribute that has been linked to water activity in modified cookie systems. Perry and others (2003) demonstrated this with reduced-in-fat-and-sugar cookies. They showed that as hardness declined, the water activity of the system increased. Additionally, water activity affects the stability of the fat within the system. When water activity is in an intermediate range, 0.2 to 0.8, lipid oxidation is limited. However, when water activity is very low, 0 to 0.19, or very high, 0.81 to 1.0, lipid oxidation increases (Fontana, 2000). The water activity for traditional crisp cookies is 0.30, putting them out of the danger zone for lipid oxidation. When the sucrose of the system is replaced, the water activity is impacted, and potential issues of shelf stability may be created. HIS and sugar replacers do not absorb water like sucrose, this leaves more “free” water within the system creating an environment for microbial growth, and potentially impacting shelf stability.

**Color Analysis**

Consumers assess foods in many ways, appearance, flavor, texture, and nutritional value. Of those, appearance may be in most important. Consumers eat with their eyes first. They are
unlikely to purchase or consume products that are visually unappealing (Setser, 1984). If consumers believe the color is off, they will not purchase the item because color can be a sign of off-flavors or spoilage. The connection between color and food safety, acceptability and preference are learned associations. Color has been shown to affect the taste thresholds of sweet, sour, and bitter. It also affects the perception of sweetness. It can serve as an important clue to flavor identification for foods that lack distinctive textural cues, such as sherbets and soft drinks (Clydesdale, 1993). Color is assessed visually with the eye and instrumentally using colorimeters and spectrophotometers (Mabon, 1993). The spectrophotometers give values for L*, a*, and b*. L* is a measure of lightness that ranges from 0 to 100, where 0 is dark and 100 is white; a* is a measure of redness or greenness, and b* is a measure of yellowness or blueness. Positive a* values mean the product is more red, while negative values mean the product is more green. Positive b* values indicate more yellow, whereas negative values indicate more blue.

Product modification can affect a products’ appearance. To determine the affect of the modification, instrumental color analysis is done. Kane and others (2003) used a color spectrophotometer successfully to assess cookie color of reduced-calorie chocolate chip and oatmeal cookies.

**Puncture Test**

The puncture test, also known as a probing, tests and records characteristics of the food product from the top outside of the product through its matrix. This is done by measuring the force it takes to push a round probe into a sample (Bourne, 1975). Probing with a texture analyzer is done by placing the food sample on a baseplate that in the case of cookies has a hole to receive the probe as it passes completely through the sample. The arm of the texture analyzer, which holds the probe, slowly penetrates the surface of the product at a set rate and continues a
set distance, while measuring the force to overcome the resistance produced by the cookie. A computer program then generates a curve depicting the force required to penetrate the cookie’s surface and the changes in force that are required to push the probe through the product. The diameter of the hole in the baseplate that receives the probe, the diameter of the probe itself, the location of assessment on the cookie surface and the closeness of the multiple assessment points on a single cookie can all influence the results (Gaines, 1994). Several measurements can be obtained from probing. They include firmness (Bourne, 1975), hardness (Gaines, 1994), and toughness (Sanchez and others, 1995). Probing in this manner has been done successfully with a variety of products, including both crisp, and soft and chewy cookies (Gaines et al 1992a, Gaines et al 1992b, Perry et al, 2003, Cardello 2002).

Historically researchers’ instrumentally assessed cookie texture using a 3-beam approach rather than puncture testing. The 3-beam approach is done by placing a cookie on 2-beams a set distance apart. The third beam is lowered down onto the cookies and the force it takes to break the cookie is determined. This technique is most useful when assessing crisp cookies. When used with softer cookies, the cookie will bend instead of snapping causing an inaccurate reading of force. Gaines (1994) introduced the probing or puncture method as a way to assess texture of cookies, stating it was more reliable and accurate. The method requires less product than the 3-beam technique and provides better estimates of texture.

**Sensory Analysis**

Sensory analysis is an important process in product development process. It is needed to fully characterize the food product (Meilgaard et al., 1999). Sensory evaluation can be described as measuring, analyzing, and interpreting reactions to characteristics of foods as perceived by the five senses (Penfield and Campbell, 1990). Trained descriptive panels are used to detect the
presence and intensity of specific texture or flavor attributes like chewiness or sweetness. The group of people who serve as panelists are chosen based on their sensitivity to attributes and descriptive ability as well as reasoning ability. Trained panelists, when presented with stimuli, rate their perception on line scales. They are asked to rate the intensity of the stimuli. Trained panels do not rate product acceptability. To determine product acceptability, a panel of targeted consumers is utilized (Meilgaard et al., 1999).

The Spectrum® Method is one of several approaches to descriptive sensory analysis. The Spectrum® approach allows all aspects of a product to be assessed, generating a profile of each product (Murry et al., 2001). Panelists use standard references to identify which individual attributes are present as well as their intensity on each attribute scale. After determining the attributes that are present in a product class, panelists determine the order in which those attributes are perceived. Through scaling practice with an array of samples characteristic of a product class, the panelists are calibrated to assess the intensity of the attributes present. Thus, they function as a human analytical instrument (Lawless and Heymann, 1998). Throughout the training process, individual panelist’s performance is assessed statistically to determine discriminating ability, consistency and reliability and to determine the focus of subsequent training (Powers, 1984). Panelists’ training for a specific product typically requires about 50-60 hours when using this approach to descriptive analysis. In addition, the attribute list generated by the panel initially may be revised to remove duplication during the training process. Ultimately, the test samples are evaluated under controlled conditions on a 15-point linescale. The resulting data are analyzed statistically to identify attributes that differ significantly among the samples evaluated as well as identify the intensity of the each attribute present and generate a product profile for each formulation (Meilgaard et al., 1999).
REFERENCES


Chapter III

METHODS

Experimental Design

Effects of sugar replacement (Table 3.1) were investigated in two cookie types: chocolate chip and oatmeal; the study was blocked on cookie type. For chocolate chip cookies, the factorial design included 4 formulations, 3 samples and 4 replications for cookie color, water activity, and cookie spread. The design for probing included 5 punctures/penetrations on each of 6 cookies for each treatment. The descriptive sensory design involved 4 formulations, with 4 replications and evaluations by 8 panelists. The factorial design for the oatmeal study was identical to that used for the chocolate chip cookies except data were collected from 3 rather than 4 replications.

<table>
<thead>
<tr>
<th></th>
<th>Cookie Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chocolate Chip</td>
</tr>
<tr>
<td><strong>Instrumental/Physiochemical Tests</strong></td>
<td></td>
</tr>
<tr>
<td>Water Activity</td>
<td>4x3x4</td>
</tr>
<tr>
<td>Probing</td>
<td>4x6x4x5</td>
</tr>
<tr>
<td>Cookie Spread</td>
<td>4x3x4</td>
</tr>
<tr>
<td>Cookie Color</td>
<td>4x3 x4</td>
</tr>
<tr>
<td><strong>Sensory Test</strong></td>
<td></td>
</tr>
<tr>
<td>Descriptive Panel</td>
<td>4x4x8</td>
</tr>
</tbody>
</table>

Cookie Formulations and Procedures

The control formulas and ingredient sources are found in Table 3.2. The multiple ingredient approach (CCC, 2007) was used in the development of the modified formulas.
Table 3.2: Chocolate Chip and Oatmeal Cookie Formulations  (1 chocolate chip cookie = 17.5 g; yield = 43 cookies; 1 oatmeal cookie = 12.4g; yield = 45 cookies)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Chocolate Chip Control (g)a</th>
<th>Oatmeal Control (g)b</th>
<th>Product Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>All – Purpose Flour</td>
<td>308.3</td>
<td>222.6</td>
<td>The White Lily Foods Co., Knoxville, TN</td>
</tr>
<tr>
<td>Baking Soda</td>
<td>3.0</td>
<td>3.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Salt</td>
<td>5.5</td>
<td>2.8</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Old-fashion Oats</td>
<td>160.0</td>
<td></td>
<td>The Quaker Oats Co., Chicago, IL</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>1.1</td>
<td>1.1</td>
<td>McCormick and Co., Inc., Hunt Valley, MD</td>
</tr>
<tr>
<td>Ground Cloves</td>
<td>0.3</td>
<td></td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Ground Nutmeg</td>
<td>0.6</td>
<td></td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Granulated Sugar</td>
<td>150.0</td>
<td>100.0</td>
<td>Dixie Crystals, Savannah, GA</td>
</tr>
<tr>
<td>Splenda® Granularc</td>
<td></td>
<td></td>
<td>McNeil Specialty Foods, New Brunswick, NJ</td>
</tr>
<tr>
<td>Isomaltc</td>
<td></td>
<td></td>
<td>PALATINIT, Mannheim, Germany</td>
</tr>
<tr>
<td>Brown Sugar</td>
<td>109.0</td>
<td>165.0</td>
<td>Dixie Crystals, Savannah, GA</td>
</tr>
<tr>
<td>Vanilla</td>
<td>4.0</td>
<td>2.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Butter</td>
<td>227.2</td>
<td>26.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Egg</td>
<td>114.0</td>
<td>85.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Shortening</td>
<td></td>
<td>125.0</td>
<td>The JM Sumucker Co., Orrville, OH</td>
</tr>
<tr>
<td>Mini Chocolate Chips</td>
<td>200.0</td>
<td></td>
<td>Nestle USA, Solon, OH</td>
</tr>
</tbody>
</table>

a Combine flour, salt, and soda in separate bowl; blend butter, sugar, light brown sugar, and vanilla for 1 min at speed 1, with a Kitchen Aid Mixer (Kitchen Aid, Model K5SS, St. Joseph, Michigan. Add egg; blend 1 min at speed 1. Gradually add flour mixture over 2 min period at speed 2. Add the chocolate chips over 1 min at speed 1. Scoop with #70 (approx. 17.5 grams), flatten with 1.3 cm dough guides. Bake in rotary oven (National Mfg. Co., Lincoln, NE) at 190°C for 10 min for the control and 9 min for each Splenda® Granular/Isomalt blend. (AACC Method 10 – 50D, 2000)
b Blend flour, soda, salt, oatmeal, sugar, lt. brown sugar, cinnamon, cloves, and nutmeg for 2 min at speed 1. Incoporate shortening, butter, egg, and vanilla for 1.5 min at speed 1. Portion with #60 scoop (approx. 12.4 grams) and flatten with 1.3cm dough guides, Bake in rotary oven at 190°C for 11 min for the control and 10 min each Splenda® Granular/Isomalt blend. (AACC Method 10 – 50D, 2000)
c For each cookie type, the following sugar replacement ratios were used for 100% of the sugar: 30% Splenda® Granular to 70% Isomalt, 40% Splenda® Granular to 60% Isomalt, and 50% Splenda® Granular to 50% Isomalt. Ratios were determined on a volumetric basis.: per cup Splenda® Granular weighed 24.7g, Isomalt weighed 198g.
Three ratios of Splenda® Granular to Isomalt replaced 100% of the granulated sugar in each formulation. The following ratios of Splenda® Granular to Isomalt were evaluated: 30% Splenda® Granular to 70% Isomalt, 40% Splenda® Granular to 60% Isomalt, and 50% Splenda® Granular to 50% Isomalt. The Splenda® Granular and Isomalt were substituted for the granulated sugar in the cookies on a volumetric basis; sugar was the only variable ingredient. Sugar weighed 200g per cup whereas Splenda® Granular weighed 24.9g and Isomalt weighed 198g (Table 3.3).

**Table 3.3 – Splenda® Granular : Isomalt Substitutions**

<table>
<thead>
<tr>
<th></th>
<th>Chocolate Chip</th>
<th>Oatmeal</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Splenda®</td>
<td>Isomalt</td>
<td>Splenda®</td>
<td>Isomalt</td>
</tr>
<tr>
<td>Granular (g)</td>
<td>Granular (g)</td>
<td>Isomalt</td>
<td>Granular (g)</td>
<td>Isomalt (g)</td>
</tr>
<tr>
<td>30% Splenda® Granular to 70% Isomalt</td>
<td>5.56</td>
<td>103.95</td>
<td>3.71</td>
<td>69.30</td>
</tr>
<tr>
<td>40% Splenda® Granular to 60% Isomalt</td>
<td>7.41</td>
<td>89.10</td>
<td>4.94</td>
<td>59.40</td>
</tr>
<tr>
<td>50% Splenda® Granular to 50% Isomalt</td>
<td>9.27</td>
<td>74.25</td>
<td>6.18</td>
<td>49.50</td>
</tr>
</tbody>
</table>

All the dry ingredients (Table 3.2) were purchased in bulk from the same lot or were thoroughly combined to account for variation among lots. Fresh ingredients, eggs and butter, were purchased from the same lot the day before baking. The eggs and butter were held at room temperature for 45 minutes prior to use. Eggs in the quantity needed for each replication were thoroughly combined and aliquots drawn as needed. The baking order was randomized within each cookie type. All cookies were mixed in a Kitchen Aid mixer (model K5SS, St. Joseph, MI) and baked in rotary oven (National Manufacturing Co. Inc., Lincoln, NE). Chocolate chip cookies (17.5 g) were scooped with a #70 scoop and oatmeal cookies (12.4g) were scooped with
a #60 scoop. Cookies were deposited 4 across in five rows on a 41.9cm by 30.5cm half sheet pan lined with pan-release paper (Papercon, Atlanta, Georgia). The modified cookies were baked for one minute less than the control following manufacturing instructions for cooking time. After removing the cookies from the oven, the cookies were allowed to cool on the sheet pan for 2 minutes before being removed to wire cooling racks where they cooled for 2 hours under ambient conditions. After the cookies were completely cooled they were placed in individual zip-top bags (8.2cm x 16.5cm x 29.2µm; Kroger Corp., Cincinnati, OH) for holding until evaluation the next day. All individually bagged cookies from each formulation were then sealed in a large zip-top bag (26.8cm x 27.3cm x 29.2µm; Kroger Corp., Cincinnati, OH) and stored flat until testing.

**Nutrient Analysis**

Nutrient analysis for the cookie treatments was determined with ESHA Food Processor SQL (Salem, Oregon). Isomalt values, which were obtained from BENO – Palatinit (Morris Plains, New Jersey), were entered in the database. These values were based on 1 cup weighing 198g where total calories equaled 396, all of which are contributed by sugar alcohols. Calorie contribution made by the sugar alcohols are included in total carbohydrates.

**Instrumental Analysis of Cookies**

Instrumental tests included measuring cookie spread, cookie height, probing, water activity, and color. All instrumental analyses, except cookie spread, occurred on the same day as the descriptive sensory analysis, 20 hours post-bake. Cookie spread was determined 2 hrs post-bake.
Cookie spread was determined on the day of baking using AACC method 10 – 50D (2000), after the cookies had cooled completely. Six cookies per treatment were used for each assessment for this non-destructive test. Cookie height and width were determined; the spread ratio which was corrected for the barometric pressure on the day of baking was calculated. Barometric pressure for Athens GA was obtained from the National Weather Service (NOAA) on each bake day.

Probing was done with a 50-kg capacity TA.XT2 Texture Analyzer (Stable Micro Systems, Haslemere, Surrey, England) equipped with *Texture Expert Exceed Software (version 2.61)*. The 0.3 cm probe was attached to the cross-arm that traveled at a speed of 5mm/second with a trigger force of 10 grams (Bourne, 1965, Gaines et al, 1992, Perry et al, 2003, Cardello 2003). A 0.6cm hole in the baseplate received the probe as it completely punctured each cookie. The probe punctured each cookie five times in a bull’s-eye pattern. (Fig. 3.1) The outer 15% of the cookie (shaded area) was avoided due to hardness and textural changes (Gaines et al, 1992). The output was given in the form of a time/force curve. The measurements of maximum force to penetration, slope, and area under the curve defined by end of the down stroke were extracted from the curve to characterize the cookies. In previous studies (Perry, 2001, Cardello, 2003), these curve parameters have been used to instrumentally characterize textural attributes of cookies. Data were collected on six cookies per treatment.
Fig. 3.1 – Bull’s-eye pattern for data collection in the probing test

Time Intensity Curve

Fig. 3.2 – Typical force/time curve obtained from probing a cookie. Data extracted were: Force to initial surface penetration (A), slope to maximum force (B), and total area under the curve (box), and time and distance to initial penetration (C)
Water activity was measured using the Aqua Lab (Decagon Devices, Pullman, WA); the instrument was calibrated with distilled water. Six cookies from each treatment were ground using a mini-food processor for 25 seconds (Cuisinart Mini – Prep Processor, DLC-1, East Windsor, NJ). Three aliquots were drawn from the composite sample (Curley and Hoseney, 1984) for each treatment for the water activity assessment.

Color of the cookie surface for each treatment was evaluated using a Minolta Color Spectrophotometer (Minolta Corp. Instrument Division, Ramsey, NJ, Model CM-508d) with a viewing area of 8mm. The F6 illuminant was used with specular component excluded (SPE setting), due to the presence of inclusions (Mabon, 1993). The instrument was calibrated prior to data collection with a white calibration cap (CM – A70). Color measurements included whiteness (L*), redness (a*), and yellowness (b*) on 3 cookies from each treatment. Each of the cookies was analyzed for color at single point on the cookie surface. For each color assessment, the spectrophotometer took five readings and averaged the three most similar measurements to generate a single value subsequently used in data analysis.

**Trained Descriptive Sensory Analysis**

The chocolate chip cookies and oatmeal cookies were assessed by a trained sensory panel, which functions as a human analytical instrument. The trained descriptive sensory analysis took place at the Richard B. Russell USDA – ARS Center in Athens, Georgia. Members of this descriptive sensory panel, which had been in existence for approximately 12 years, received compensation for their skills and time. The panelists, who had been screened for smell and taste sensitivity, utilized a Spectrum®-like (Meilgaard, et al, 1999) approach. This approach to descriptive analysis begins with the establishment of a frame of reference for the product
Panelists were presented a wide range of cookies from both cookie types. Chocolate chip and oatmeal cookie lexicons previously established by the panel (Perry, et al., 2003; Cardello, 2003) were reviewed for appropriateness. The panel agreed on the inclusion of the basic tastes (sweet, salty, sour, bitter), 10 textural attributes (manual hardness, manual facturability, roughness, oral fracturability, cohesiveness, oral hardness, oily, chewiness, residual particles, and oily mouthcoat) for both cookie types. Flavor attributes and aftertaste/feel specific to each cookie type were included. The flavor attributes were developed through the evaluation of laboratory-baked cookies in which specific ingredients and their levels were manipulated (Appendix C).

For chocolate chip cookies, 6 flavor attributes (brown sugar/caramelized, chocolate, white wheat flour, butter, pure vanilla, and baking soda) were determined to characterize the product category. For oatmeal cookies, the 6 flavor attributes included were: cinnamon/woody spice, brown sugar/caramelized, grainy/oatmeal, butter, pure vanilla, and baking soda. The aftertaste attribute bitterness was included for chocolate chip cookies. For oatmeal cookies, the afterfeel attribute astringency was evaluated. Attribute identity and intensity were established using standard references (Table 3.4 and 3.5).

Panelists reviewed evaluation techniques and food reference that covered a 0 – 15 point range of intensities for each texture attributes (Table 3.5). Flavor attributes were reviewed across the 0 – 15 point intensity range using aromatic references and basic taste solutions with intensities 0, 5, 10, 15 points (Table 3.4). Practice sessions allowed panelists to fine-tune their assessment techniques; panelist performance was checked using blind replicate sample testing and analysis of ata obtained during the practice sessions with Senstools v. 3.3.2 software (OP&P Product Research BV, Utrecht, The Netherlands). Panel training typically takes 50 to 60 hours.
Because the panel had previously evaluated similar products, training for the evaluation of these products required 16 hours.

All products were evaluated in individual sensory booths under low-pressure sodium vapor lights (CML-18, Trimble House, Norcross, GA). The panelists profiled four treatments of each cookie type. Aromatic references were provided for use as needed during product evaluation; panelists opened and immediately closed the jars after sniffing the reference material (Tables 3.6 and 3.7) as needed during evaluation. Panelists were presented a warm-up cookie sample to allow self-calibration followed by the cookie treatments. All samples were coded with 3-digit random numbers and presented monadically. A randomized order of presentation was used for the treatment samples. After evaluating each sample, panelists were given a 15-min break to prevent taste fatigue and eliminate lingering aftertastes. A total of five samples were evaluated in one session. After evaluating each sample, panelists were asked to cleanse their palates with distilled water and one or more of the additional palate cleansers available (carrot sticks, apple slices, and unsalted top saltine crackers).

Data were collected using CompuSense *five* version 4.8 software (Compusense Inc., Ontario, Canada). Panelists marked their responses on a 15-point line (0=not perceptible, 15=high intensity) scale that appeared on their computer screen using a computer mouse to rate the intensity of a specific attribute. Attributes were arranged in 3 phases for cookie evaluation (Table 3.6). Flavor attributes were evaluated in the order in which the panelists perceived the flavor notes during training. Basic tastes were evaluated in a separate phase of testing. The texture attributes hardness, fracturability and roughness were evaluated manually. Four texture attributes were evaluated throughout mastication (cohesiveness, oral hardness, oiliness, chewiness). The aftertaste/afterfeel attributes were evaluated 1 minute post-swallow. The
descriptive sensory analysis helped determine which formulation was most like the respective 100% sucrose control cookie.

**Statistical Analyses**

All data that were collected from the instrumental and sensory tests were analyzed using SAS version 9.1 for Windows (SAS, Inc., Cary, NC). Normality plots were generated with PROC UNIVARIATE to verify normal distribution of the data and equal variance; logs were used for data transformation, when appropriate. Significant differences (p<0.05) attributable to formulation were identified with mixed model analysis of variance (PROC MIXED). The random effects statement within PROC MIXED included replication and the interaction between replication and interaction. PDIF was used for LS-means separation. Standard errors were generated. The descriptive sensory data were also plotted on a radar graphs which allowed a visual means to examine the variability due to formulation by attribute.
Table 3.4: Descriptive Sensory Flavor and Basic Tastes Attributes: Lexicon, Definitions and References

<table>
<thead>
<tr>
<th>Phase I: Flavor</th>
<th>Attribute</th>
<th>Definition</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Chocolate Chip</strong></td>
<td></td>
<td>The following was used as a universal 0-15 point line scale which was applied to all flavor attributes:</td>
</tr>
<tr>
<td></td>
<td>Brown Sugar/Caramelized</td>
<td>Aromatic associated with brown sugar/caramelization</td>
<td>Soda note in Saltine crackers (2) (Nabisco)</td>
</tr>
<tr>
<td></td>
<td>Chocolate</td>
<td>Aromatic associated with chocolate</td>
<td>Grape note in Grape Kool-Aid (5)</td>
</tr>
<tr>
<td></td>
<td>White Wheat Flour</td>
<td>Aromatic associated with white wheat flour</td>
<td>Orange note in Orange juice (Minute Maid) prepared from concentrate (7)</td>
</tr>
<tr>
<td></td>
<td>Butter</td>
<td>Aromatic associated with butter</td>
<td>Grape note in Welch’s grape juice (10)</td>
</tr>
<tr>
<td></td>
<td>Vanilla</td>
<td>Aromatic associated with vanilla</td>
<td>Cinnamon note in Big Red gum (12)</td>
</tr>
<tr>
<td></td>
<td>Soda</td>
<td>Aromatic associated with soda</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Oatmeal</strong></td>
<td></td>
<td>Same universal flavor scale used for the oatmeal cookies.</td>
</tr>
<tr>
<td></td>
<td>Cinnamon/woody spice</td>
<td>Aromatic associated with cinnamon and non-specific spices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brown Sugar/molasses</td>
<td>Aromatic associated with brown sugar/molasses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grainy/oatmeal</td>
<td>Aromatic associated with non-specific grain/oatmeal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Butter</td>
<td>Aromatic associated with butter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanilla</td>
<td>Aromatic associated with vanilla</td>
<td></td>
</tr>
<tr>
<td>Soda</td>
<td>Aromatic associated with soda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Phase II: Basic Tastes – Chocolate Chip and Oatmeal**

<table>
<thead>
<tr>
<th>Taste</th>
<th>Description</th>
<th>Solution (w/v) in water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>Basic taste on the tongue stimulated by sugars and high potency sweeteners</td>
<td>Sucrose solution (w/v) in water</td>
</tr>
<tr>
<td>Salt</td>
<td>Basic taste on the tongue stimulated by sodium salt, especially sodium chloride</td>
<td>NaCl solution (w/v) in water</td>
</tr>
<tr>
<td>Sour</td>
<td>Basic taste on the tongue stimulated by acids</td>
<td>Citric acid solution (w/v) in water</td>
</tr>
<tr>
<td>Bitter</td>
<td>Basic taste on the tongue stimulated by solutions of caffeine, quinine, and certain other alkaloids.</td>
<td>Caffeine solution (w/v) in water</td>
</tr>
</tbody>
</table>

**Phase III: Aftertaste/Afterfeel**

<table>
<thead>
<tr>
<th>Aftertaste</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chocolate Chip</td>
<td>Basic taste on the tongue stimulated by solutions of caffeine, quinine, and certain other alkaloids.</td>
</tr>
<tr>
<td>Oatmeal</td>
<td>Feeling of drying of the linings of the mouth</td>
</tr>
</tbody>
</table>

*All flavor definitions were determined by the in-house panel (USDA–ARS, Sensory Evaluation Laboratory, Athens, GA). Basic taste definitions were obtained from Civille and Lyon (1996) and basic taste references were obtained from Meilgaard et al. (1999).*
Table 3.5: Descriptive Sensory Texture Attributes for Chocolate Chip and Oatmeal Cookies: Lexicon, Definitions and References

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Definition</th>
<th>References (numeric intensity on a 15-point scale)&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase I: Evaluated by breaking with fingers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual Hardness</td>
<td>Manual force required to break or separate the sample into two pieces</td>
<td>Pringle (4) Ginger Snap (10)</td>
</tr>
<tr>
<td>Manual Fracturability</td>
<td>Force with which the sample breaks</td>
<td>Graham cracker (4) Ginger Snap (8) Peanut brittle (13)</td>
</tr>
<tr>
<td><strong>Phase II: Evaluated surface characteristics with lips</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roughness</td>
<td>Amount of particles in the surface as detected by the lips</td>
<td>Gelatin (0) Pringle (8) Rye Wafer (10)</td>
</tr>
<tr>
<td><strong>Phase III: Evaluated at first bite with front teeth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral Fracturability</td>
<td>Force with which the sample breaks at the first bite with the front teeth</td>
<td>Graham cracker (4) Ginger Snap (8) Peanut brittle (13)</td>
</tr>
<tr>
<td><strong>Phase IV: Evaluated at first chew with molar teeth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>Degree to which the sample deforms rather than crumbles, cracks, or breaks at first chew with molar teeth</td>
<td>Corn bread (1) Raisin (10) Chewing gum (15)</td>
</tr>
<tr>
<td>Oral Hardness</td>
<td>Force required to bite through the sample at first chew with molar teeth</td>
<td>American cheese (4) Peanuts (9.5) Lifesavers (14.5)</td>
</tr>
<tr>
<td><strong>Phase V: Evaluated during chewdown</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oiliness</td>
<td>Amount of oil in the sample</td>
<td>Saltine (0) Tuna in oil (11)</td>
</tr>
<tr>
<td>Chewiness</td>
<td>Amount of work to chew the sample to the point of swallow</td>
<td>Rye bread (1.5) Gum drop (8.5) Tootsie Roll (13)</td>
</tr>
<tr>
<td><strong>Phase VI: Evaluated after swallow</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual Particles</td>
<td>Amount of particles in the mouth after swallowing</td>
<td>Nabisco Oatmeal Cookies (~5)</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Oily Mouthcoat</td>
<td>Amount of oily coating in the mouth after swallowing</td>
<td>Keebler Chips Deluxe Soft and Chewy (~5)</td>
</tr>
</tbody>
</table>

\* All texture definitions and references were obtained from Meilgaard et al. (1999), except the references for manual hardness, manual fracturability, chewiness, which were established by the in-house panel (USDA–ARS, Sensory Evaluation Laboratory, Athens, GA).

\^ 15-point line scale, where 0= not perceptible and 15 = high intensity.
Table 3.6: Aromatic reference standards for Chocolate chip cookies\textsuperscript{a}

<table>
<thead>
<tr>
<th>Aromatic Sensation</th>
<th>Amount (g)</th>
<th>Product Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown sugar/caramelized\textsuperscript{b}</td>
<td>4.5</td>
<td>Dixie Crystals Inc., Savannah, GA</td>
</tr>
<tr>
<td>Chocolate\textsuperscript{b}</td>
<td>18</td>
<td>Nestle USA, Inc., Solon, OH</td>
</tr>
<tr>
<td>White Wheat Flour\textsuperscript{b}</td>
<td>3</td>
<td>The White Lily Foods Co., Knoxville, TN</td>
</tr>
<tr>
<td>Butter\textsuperscript{c}</td>
<td>5.5</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Pure Vanilla\textsuperscript{d}</td>
<td>2 drops</td>
<td>McCormick and Co., Inc., Hunt Valley, MD</td>
</tr>
<tr>
<td>Baking Soda\textsuperscript{b}</td>
<td>8</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Each panelist received a set of reference standards. Each sample was held in a closed screw-top 3.5oz jar. Panelists opened and immediately closed the jars after sniffing as needed during evaluation.

\textsuperscript{b} Samples were prepared once and then used for subsequent training and replications.

\textsuperscript{c} Butter samples were refrigerated after each session. New samples were prepared after 5 storage days. Samples were removed from the refrigerator 10 minutes prior to evaluation.

\textsuperscript{d} Vanilla samples were prepared just prior to each sensory evaluation session. Cotton ball served as carriers of the vanilla. Samples were allowed to air-out for 5 minutes prior to closing the jars.

Table 3.7: Aromatic reference standards for oatmeal cookies\textsuperscript{a}

<table>
<thead>
<tr>
<th>Aromatic Sensation</th>
<th>Amount (g)</th>
<th>Product Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinnamon/woody spice\textsuperscript{bc}</td>
<td>1.1 cinnamon</td>
<td>McCormick and Co., Inc., Hunt Valley, MD</td>
</tr>
<tr>
<td></td>
<td>0.3 cloves</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td></td>
<td>0.6 nutmeg</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Brown sugar/caramelized\textsuperscript{d}</td>
<td>4.5</td>
<td>Dixie Crystals Inc., Savannah, GA</td>
</tr>
<tr>
<td>Grainy/oatmeal\textsuperscript{e}</td>
<td>6.5</td>
<td>The Quaker Oats Co., Chicago, IL</td>
</tr>
<tr>
<td>Butter\textsuperscript{d}</td>
<td>5.5</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Pure Vanilla\textsuperscript{e}</td>
<td>2 drops</td>
<td>McCormick and Co., Inc., Hunt Valley, MD</td>
</tr>
<tr>
<td>Baking Soda\textsuperscript{e}</td>
<td>8</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Each panelist received a set of reference standards. Each sample was held in a closed screw-top 3.5oz jar. Panelists opened and immediately closed the jars after sniffing as needed during evaluation.

\textsuperscript{b} Spices (cinnamon, cloves, nutmeg) were combined according to the amounts as specified in the original formula. Aliquots were taken from a composite sample and given to panelists.

\textsuperscript{c} Samples were prepared once and then used for subsequent training and replications.

\textsuperscript{d} Butter samples were refrigerated after each session. New samples were prepared after 5 storage days. Samples were removed from the refrigerator 10 minutes prior to evaluation.

\textsuperscript{e} Vanilla samples were prepared just prior to each sensory evaluation session. Cotton ball served as carriers of the vanilla. Samples were allowed to air-out for 5 minutes prior to closing the jars.
REFERENCES


CHAPTER IV

FUNCTIONALITY OF SUCRALOSE/MALTODEXTRIN AND ISOMALT BLEND IN

CHOCOLATE CHIP AND OATMEAL COOKIES
Abstract

Availability of reduced-in-sugar baked products with quality characteristics equal to their full-sugar counterparts may reduce simple carbohydrate and calorie consumption. In both oatmeal and chocolate chip cookies, a sugar alternative blend [Splenda® Granular (sucralose maltodextrin) and Isomalt] replaced 100% of the sugar. Control cookies were prepared with 100% granulated sugar. Using the multiple ingredient approach, three Splenda® Granular:Isomalt ratios were investigated: 30%:70%, 40%:60%, and 50%:50%. A trained descriptive panel evaluated sensory texture and flavors attributes. Physical/physicochemical tests included probing, color, water activity and cookie spread. Mixed model analysis of variance (p<0.05) revealed no flavor differences. Significant sensory texture attributes were limited and varied with cookie type, with intensity differences typically within one scalar unit. Significant reformulation effects detected with physical/physicochemical techniques were within a narrow range. No consistent treatment effects were found. Overall, all blend ratios produced cookies with quality characteristics very similar to the controls. Sugar reduction exceeded 35%; calorie, 5–8.5%.

Introduction

In the United States, obesity is an epidemic that is affecting adults and children, across all ethnic and gender groups. For adults over the age of 20, obesity is defined as having excess body fat and a body mass index greater than 30 kg/m² (Ogden et al, 2002). According to the National Center for Health Statistics, more than 1/3 of adult Americans are obese (Ogden et al, 2007). Further, obesity is associated with a higher risk of developing chronic health conditions such as cardiovascular disease, diabetes, and hypertension. Dietary factors influencing the obesity trend include increased portion size and calorie intake (Hedley et al, 2004).
Although a direct link between nutritive sweeteners and the development of chronic
diseases has not been established (ADA, 2004), trends suggest that consumption of foods high in
sugars contribute to excess caloric intake and therefore, obesity and associated health risks
(Henkle, 1999; Vermunt et al., 2003). In 2006, the average American consumed 138.9 pounds of
added sugar with sugary drinks and grain-based sweets, such as pastries, cakes, and cookies the
major sources (USDA, ERS, 2008).

In the United States, the typical cookie formulations contain 30-40% sugar, 65-75% fat,
and 15-25% egg when flour-weight equals 100% (Pyler, 1988). Soft chocolate chip cookies are
America’s favorites, while oatmeal cookies are its sixth favorite (Mintel, 2007). The gold
standard for chocolate chip cookies is 75% sugar, 67% fat, 17% water, and 55% chocolate chips.
The standard for oatmeal cookies is 60% sugar, 54% fat, and 15% water. These ratios yield
cookies that are sweet and soft rather than crisp. Both crisp and soft as well as chewy cookies
from both types are available in the marketplace. In 2006, of all the cookies consumed 43% were
soft chocolate chip (Mintel, 2007).

The functional role of sugar in cookies is not only to provide sweetness, but also bulk,
texture, preservation, appearance and browning. (Pyler 1988, Davis 1995) The sweetness of
sucrose is easily attainable through high intensity sweetener (HIS) incorporation, however, the
other functions of sugar are more difficult to replicate. The use of a bulking agent helps
overcome many of the limitations associated with the use of HIS alone. HIS have been used in
combination with dextrose, polydextrose, and maltodextrins (Alexander, 1998). Fiber and sugar
alcohols have also been used as bulking agents. Sugar alcohols are particularly well-suited for
this role as they also impart many of the other functional roles of sugar, although the specifics
vary with the specific sugar alcohol selected (Nelson, 2000). Use of this multiple-ingredient
approach when reformulating products to reduce sugar content, allows products with quality attributes more similar to the full-sugar traditional product to be developed (Nabors, 2002).

Availability of favorite foods formulated with sugar alternatives (ADA, 2004) can help promote dietary choices consistent with current health recommendations (Sigman-Grant and Hsieh, 2005). Indeed, the use of low-calorie sweeteners in the baking industry increased by 58.9% from 2003 to 2004, and these development efforts are expected to continue (Mintel, 2007). Despite recent increases in sales (Mintel, 2007), continued consumer selection of “health oriented cookies,” which includes lower sugar formulations, will require that the sensory characteristics match those of the traditional full sugar product. However appropriate selection among possible alternative ingredients is critical to achieve the desired results.

Zoulias et al (2000) evaluated cookies prepared with a single HIS, Acesulfame potassium (Ace-K), the sugar alcohols, maltitol, lactitol, sorbitol, xylitol, and mannitol, and Ace-K in combination with each sugar alcohol individually. The cookies prepared with mannitol alone were thicker and harder than the other cookie formulations in the study. They also showed no line spread and exhibited low water activity. The addition of AceK did not improve the quality of cookies prepared with mannitol, although a bitter flavor note was introduced. Thus, this HIS/sugar alcohol combination (0.037 HIS to 200g sugar replacer) did not produce an acceptable reduced sugar product. Ace-K successfully supplied the missing sweetness of the sugar alcohols in other combinations. Sugar alcohols, except mannitol, have potential in combination with Ace-K as a sugar alternative blend, although some differences in texture and cookie spread were found. Recently, Johnson and others (2006) studied the suitability of the HIS sucralose in combination with the sugar alcohol Isomalt as a potential replacer for 100% of the granulated sugar in a yellow cake. Various ratios of Splenda® Granular, a sucralose/maltodextrin blend
available commercially to consumers, to Isomalt were investigated. A principal component analysis (PCA) revealed sensory attributes were most similar to the control cake when a 30% Splenda® Granular :70% Isomalt blend replaced the sucrose on a volumetric-basis. All other ratios evaluated were lower in Splenda® Granular and higher in Isomalt (Johnson et al, 2006).

Sucralose, the HIS in Splenda® Granular, is a popular high-intensity sweetener that offers no energy. It is 600 times sweeter than sucrose. The maltodextrin in Splenda® Granular, functions as a bulking agent, a key role of sugar in baked products. In addition, it dilutes the sweetness of the sucralose and facilitates its incorporation into the product (Kuntz, 1997).

However, this sweetener blend does not deliver all of the functional roles of sucrose and its sweetness profile differs from sucrose (Wiet, 1992).

Isomalt, a low-energy bulk sweetener, is a sugar alcohol derived from sucrose. It provides 2 kcal/g. Isomalt is 45 to 60% as sweet as sucrose and its sweetness is retained with heating, although it does not participate in browning reactions typical of sugar. Unlike other sugar alcohols, it does not exhibit a cooling sensation. (Zumbe, et al, 2007; Nabors, 2002). When this combination of sweeteners in a 30% Splenda® Granular to 70% Isomalt ratio was used to replace 100% of the sucrose, it inapplicably appears to overcome many of the functional limitations of using the sucralose/maltodextrin blend alone as well as the lower sweetness intensity of the Isomalt (Johnson et al, 2006).

Consumers desire high quality products that are healthy and convenient. Increasing the quality of a variety of reduced-in-sugar products may facilitate better consumer choices and positively impact health. In this study, the multiple ingredient approach was used to characterize the nutritional and functional effects of sucralose/maltodextrin and isomalt blends on cookie quality. Effects on both chocolate chip and oatmeal cookies were investigated and compared to
the full-sugar cookie, which served as the control. Objectives were to: (1) profile cookie flavor, and texture for each cookie type with descriptive sensory analysis; (2) to determine the effects of substitution on overall cookie quality (cookie spread and water activity), and on cookie color and texture with physical and physicochemical techniques, and (3) to determine the effects of sugar replacement on the total calorie and sugar levels of the reformulated cookies.

Materials and Methods

Materials

A control and three modifications were prepared for oatmeal and chocolate chip cookies. (Table 4.1). Isomalt and Splenda® Granular in the following ratios were substituted for the granulated sugar in the cookies on a volumetric basis: 30% Splenda® Granular to 70% Isomalt, 40% Splenda® Granular to 60% Isomalt, and 50% Splenda® Granular to 50% Isomalt. The cookie prepared with 100% granulated sugar served as the control.

Methods

All the ingredients, expect the eggs and butter, were purchased from the same lot at the beginning of the study. Eggs and butter were purchased from the same lots for each replication. All dry ingredients and vanilla were weighed one day prior to baking. The eggs and butter were measured the day of baking. Prior to mixing, the eggs and butter were held at room temperature for 45 minutes.

All cookies were mixed in a Kitchen Aid mixer (model K5SS, St. Joseph, MI) and baked in a rotary oven (National Manufacturing Co. Inc., Lincoln, NE). Cookies were deposited 4 across in 5 rows on a 41.9cm x 30.5cm half sheet pan lined with pan-release paper (Papercon, Atlanta, Georgia). Baked cookies cooled for 2 min on the half-sheet pan before removal to cooling racks for two hours at ambient temperatures. Cookie spread and color was assessed prior
to bagging for storage on the day of baking. Individual cooled cookies were sealed in zip-top bags (8.2cm x 16.5cm x 29.2µm; Kroger Corp., Cincinnati, OH). All individually bagged cookies from each formulation were then sealed in a large zip-top bag (26.8cm x 27.3cm x 29.2µm; Kroger Corp., Cincinnati, OH) and stored flat until sensory, water activity and probing assessments one-day post-bake.

**Table 4.1: Chocolate Chip and Oatmeal Cookie Formulations**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Chocolate Chip Control (g)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Oatmeal Control (g)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Product Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>All – Purpose Flour</td>
<td>308.3</td>
<td>222.6</td>
<td>The White Lily Foods Co., Knoxville, TN</td>
</tr>
<tr>
<td>Baking Soda</td>
<td>3.0</td>
<td>3.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Salt</td>
<td>5.5</td>
<td>2.8</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Old-fashion Oats</td>
<td>—</td>
<td>160.0</td>
<td>The Quaker Oats Co., Chicago, IL</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>—</td>
<td>1.1</td>
<td>McCormick and Co., Inc., Hunt Valley, MD</td>
</tr>
<tr>
<td>Ground Cloves</td>
<td>—</td>
<td>0.3</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Ground Nutmeg</td>
<td>—</td>
<td>0.6</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Granulated Sugar</td>
<td>150.0</td>
<td>100.0</td>
<td>Dixie Crystals, Savannah, GA</td>
</tr>
<tr>
<td>Splenda®&lt;sup&gt;c&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>McNeil Specialty Foods, New Brunswick, NJ</td>
</tr>
<tr>
<td>Isomalt&lt;sup&gt;c&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>PALATINIT, Mannheim, Germany</td>
</tr>
<tr>
<td>Brown Sugar</td>
<td>109.0</td>
<td>165.0</td>
<td>Dixie Crystals, Savannah, GA</td>
</tr>
<tr>
<td>Vanilla</td>
<td>4.0</td>
<td>2.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Butter</td>
<td>227.2</td>
<td>26.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Egg</td>
<td>114.0</td>
<td>85.0</td>
<td>Kroger Co., Cincinnati, OH</td>
</tr>
<tr>
<td>Shortening</td>
<td>—</td>
<td>125.0</td>
<td>The JM Sumucker Co., Orrville, OH</td>
</tr>
<tr>
<td>Mini Chocolate Chips</td>
<td>200.0</td>
<td>—</td>
<td>Nestle USA, Solon, OH</td>
</tr>
</tbody>
</table>

<sup>a</sup> Combine flour, salt, and soda in separate bowl; blend butter, sugar, light brown sugar, and vanilla for 1 min at speed 1, with a Kitchen Aid Mixer (Kitchen Aid, Model K5SS, St. Joseph, Michigan). Add egg; blend 1 min at speed 1. Gradually add flour mixture over 2 min period at speed 2. Add the chocolate chips over 1 min at speed 1. Scoop with #70 (approx. 17.5 grams), flatten with 1.3 cm dough guides (AACC Method 10 – 50D, 2000). Bake in rotary oven (National Mfg. Co., Lincoln, NE) at 190°C for 10 min for the control and 9 min for each Splenda® Granular/Isomalt blend.

<sup>b</sup> Blend flour, soda, salt, oatmeal, sugar, light brown sugar, cinnamon, cloves, and nutmeg for 2 min at speed 1. Incorporate shortening, butter, egg, and vanilla for 1.5 min at speed 1. Portion with #60 scoop (approx. 12.4 grams) and flatten with 1.3 cm dough guides (AACC Method 10 –
Bake in rotary oven at 190°C for 11 min for the control and 10 min each Splenda® Granular/Isomalt blend.

For each cookie type, the following sugar replacement ratios were used for 100% of the sugar: 30% Splenda® Granular to 70% Isomalt, 40% Splenda® Granular to 60% Isomalt, and 50% Splenda® Granular to 50% Isomalt. Ratios were determined on a volumetric basis: per cup, Splenda® Granular weighed 24.7g, Isomalt weighed 198g.

Instrumental Analysis of Cookies

Cookie spread was measured in triplicate on the day of baking (AACC Method 10 – 50D, 2000). Six cookies from each formulation were randomly selected to determine the width, thickness, and width-to-thickness ratio.

Instrumental analysis of texture occurred on the same day as the descriptive sensory analysis. A 50-kg capacity TA.XT2 Texture Analyzer (Stable Micro Systems, Haslemere, Surrey, England) equipped with Texture Expert Exceed Software (version 2.61) was used to probe each cookie five times in a bull’s-eye pattern (Fig. 4.1). The 0.3 cm probe, which traveled at a speed of 5mm/second with a trigger force of 10 grams (Bourne, 1965; Gaines et al, 1992; Perry et al, 2003; Cardello 2003), passed through a 0.6 cm hole in the baseplate. The outer 15% of the cookies (shaded area) was avoided (Gaines et al, 1992). Six cookies were probed for each formulation per replication. The data were recorded in the form of a force time curve. The data that were extracted from the curve were: force to surface penetration, slope to maximum force, total area under the curve, and tine and distance to surface penetration.
Water activity was measured using the Aqua Lab (Decagon Devices, Pullman, WA). Six cookies were ground (Cuisinart Mini–Prep Processor, DLC-1, East Windsor, NJ) for 25 seconds and aliquots were drawn from the composite sample. (Curley and Hoseney, 1984) Three samples were tested for each treatment from each cookie type per replication.

Cookie color was evaluated with a Minolta Spectrophotometer (Minolta Corp. Instrument Division, Ramsey, NJ, Model CM-508d) calibrated with white calibration cap number CM–A70; the F6 illuminant was used with specular component excluded (SPE). The surface color of three cookies for each variation was assessed for each cookie type. The three most similar of five color measurements per evaluation were averaged to obtain a single assessment value used for data analysis. Color data included whiteness (L*), redness (a*), and yellowness (b*).

**Descriptive Sensory Analysis**

The chocolate chip cookies were evaluated by an 8-member sensory panel, experienced in using the Spectrum® approach to descriptive sensory analysis. (Meilgaard et al., 1999). Panelists were re-introduced to a previously developed texture and flavor attributes and
definitions (Perry et al., 2003). Attribute applicability was ensured through product evaluations and panel discussions. Panelists reviewed proper evaluation techniques, food references for the 0-15 range of intensities for each texture attribute and a 0 – 15 range of aromatic (flavor) references and basic taste solutions/references at the 0, 5, 10 and 15 intensities. Practice sessions were provided and panel performance was checked using replicated sample testing and data analyses using Senstools v.3.3.2 software (OP&P Product Research BV, Utrecht, The Netherlands). Intensity of 11 flavor attributes/basic tastes and 9 texture attributes was determined for both cookie types. Although the same texture attributes were assessed for both, flavor attributes were specific to cookie type.

All products were evaluated in individual sensory booths under low-pressure sodium vapor lights (CML-18, Trimble House, Norcross, GA). Each treatment was coded with a 3-digit random number and presented to the panelists in random order. Panelists were served a warm-up sample followed by 4 treatment samples in a single session. Treatment samples were presented monadically. After each sample, panelists cleansed their palates with distilled water and their choice(s) from the additional palate cleansers available: unsalted top saltine crackers, carrot sticks, and apple slices. After evaluating each sample, panelists were given a 15-min break to prevent taste fatigue and to prevent carry-over effects caused by sweetness. Data were collected using CompuSense five version 4.8 (Compusense Inc., Ontario, Canada). Intensity of a specific attribute was marked on a 15-point line (0=not perceptible, 15=high intensity) and a cookie profile was established for each formulation.

The panel evaluated the cookies using a randomized complete block design. The design was blocked by cookie type, chocolate chip or oatmeal. Four treatments of each cookie type
were profiled. The descriptive panel was replicated four times for the chocolate chip cookies and three times for the oatmeal cookies.

All data collected from the instrumental and sensory tests were analyzed using SAS version 9.1 for Windows (SAS, Inc., Cary, NC). Equal variance within treatment type for the sensory and instrumental analyses was determined using a PROC MEANS statement. Normality plots were generated using a PROC UNIVARIATE statement; logs were used for data transformation when appropriate. Significant differences (p<0.05) attributable to formulation were identified with a PROC MIXED statement; PDIF was used for LS-means separation. The descriptive sensory data were plotted on a radar graphs which allowed a visual means to examine the variability due to formulation by attribute.

Results and Discussion

Descriptive Sensory Flavor and Texture Profiles

Sensory profiles one day post-bake are found in Figures 4.2 and 4.3 and Appendix A. Each diagram (Figures 4.2 and 4.3) represents LS-mean scores for each treatment plotted on truncated line scales radiating from a center point. Attributes are arranged in the order of their evaluation beginning at the 12 o’clock position.

Cookie Flavor

In general, flavor attributes (Figure 4.2; Appendix A) for both cookie types were in the low to moderate intensity range of the universal scale. There were no significant differences (p>0.05) in flavor attributes due to treatment for either cookie type. Sweetness was the most intense flavor attribute in both cookie types, with intensity in the moderate range of the intensity scale. These results suggest that all of the Splenda® Granular: Isomalt blends successfully mimicked the sweetness intensity imparted by sugar. The lack of a significant difference in
bitterness intensity in the chocolate chip cookies suggests that this sweetener blend overcomes some of flavor defects imparted by the use of other HIS, even when used in combination was a sugar alcohol (Zoulias et al., 2000). Sensory panelists did not identify bitterness as a flavor note present in oatmeal cookies during lexicon development.

**Cookie Texture**

Sensory results for the textural attributes are shown in Figure 4.3. Greater effects of sugar replacement were found in the chocolate chip than in the oatmeal cookies. However, the actual difference in perceived intensity tended to be relatively small despite statistical significance.

Of the ten textural attributes evaluated in the oatmeal cookies (Figure 4.3; Appendix A), only manual hardness differed significantly due to formulation \( p < 0.05 \). In a cookie system, the amount of sugar is a primary determinant of the hardness of the resultant cookie, with higher sugar levels associated with a harder product (Faridi, 1994). In this study, all of the oatmeal cookies prepared with the Splenda® Granular:isomalt blends were softer than were the control cookies when hardness was assessed by breaking the cookies with the hands; the cookies prepared with the alternative sweetener blends did not differ from each other. However, manual hardness for all treatments was within one scalar unit of the control oatmeal cookie, suggesting small changes in intensity despite significance. Further, when hardness was assessed orally, differences were not detected (Figure 4.3). Whether assessed manually or orally, hardness intensity was in the moderately low range \(<5\), indicating that these were relatively soft cookies. During chewing, sensory panelists perceived these cookies as moderately cohesive and moderately low in chewiness with low levels of fracturability. Therefore, the textural
characteristics of the reformulated oatmeal cookies are similar to those of the oatmeal cookies purchased most often (Mintel, 2007).

In the chocolate chip cookies, sugar replacement with the sweetener blends altered perceived fracturability whether assessed manually or orally; incorporation of the sweetener blends tended to increase fracturability (Figure 4.2 and Appendix A), although all of these cookies exhibited moderately low fracturability (<5). Unlike the oatmeal cookies, no effects of sugar replacement with any of the Splenda® Granular: Isomalt blends on perceived hardness was found. Further, all of the chocolate chip cookies were moderately low in hardness (Figure 4.2 and Appendix B), whether this attribute was assessed manually or orally.

In general, replacement of sugar with the alternative sweetener blends in the chocolate chip cookies decreased the perceived intensity of both cohesiveness and chewiness (Figure 4.2). There was not, however, a linear trend between sweetener blend ratios and the decrease in these attributes. All chocolate chip cookies exhibited moderately low cohesiveness and chewiness (<5). Both of these parameters are related to ease with which the cookie samples can be broken apart; cohesiveness was assessed after one bite with the molars, whereas chewiness was assessed during chewdown (Appendix A). These substitution effects on these textural attributes contradict the expected effect of sugar replacement with alternative sweeteners. Recrystallization of sucrose in cookies post-bake is associated with increased rather than decreased fracturability (Curley and Hoseney, 1984); increased chewiness rather than its decrease has been previously associated with sugar reduction (Alexander, 1998). Unlike these chocolate chip cookies, the same effects were not observed in the oatmeal cookies evaluated in this study. However, differences in cohesiveness and chewiness detected by the sensory panel in the chocolate chip cookies were within one scalar unit. All of these formulations produced chocolate chip cookies that are
relatively soft, and slightly chewy. These are the characteristics of the chocolate chip cookies that dominate sales (Mintel, 2007).

Fig. 4.2: LS-Mean scores of flavor attributes for chocolate chip (top) and oatmeal (bottom) cookies. Attributes are arranged in the order of evaluation beginning at 12 o’clock. Attributes followed by * indicates a significant differences (p<0.05) among treatments. The LS-Means are across 7-8 panelists and 3-4 replications. Attribute designated by acronyms are: BSUGAR
(brown sugar), CCHIP (chocolate chip), BSODA (baking soda), CINN (cinnamon), and ASTRING (astringent).

Fig. 4.3 : LS-Mean scores of sensory texture attributes for chocolate chip (top) and oatmeal (bottom) cookies. Attributes are arranged in the order of evaluation beginning at 12 o’clock. Attributes followed by * indicates a significant differences (p<0.05) among treatments. The LS-Means are across 7-8 panelists and 3-4 replications. Attribute designated by acronyms are: MHARD (manual hardness), MFRACT (manual fracturability), ROUGH (roughness), OFRACT
(oral fracturability), COHESIVE (cohesiveness), OHARD (oral hardness), CHEWI (chewiness), RESPART (residual particles), and OMOUTH (oily mouthfeel)

Physical and Physicochemical Analysis

Physicochemical and physical measurements are reported by cookie type in Tables 4.2 and 4.3. In general, both cookie types showed similar effects of modification.

Water activity

Water activity is defined as “a measure of the energy status of the water in a system and its availability to act as a solvent and participate in chemical and biochemical reactions and growth of microorganisms.” (Fontana, 2000) Within cookie type, water activity did not differ with cookie formulation. The aW (Table 4.2) for the chocolate chip cookies ranged from 0.31 to 0.36, whereas, oatmeal cookies ranged from 0.51 to 0.54. The cookies were out of the danger zone for microbial growth, suggesting that alternative handling information is unnecessary for consumers who choose the modified cookies. In addition, modification does not appear to affect chemical or biochemical reaction rates that affect shelflife of the products (Fontana, 2000).

Concern about the effects of sugar alternatives rather than sugar incorporation on water activity (Nelson, 2000) do not appear to be an issue with the use of this alternative sweetener system in either cookie. Control of water activity is one of the functional roles that polyols can play in reformulated food systems (Deis, 2000).

Color

Color is evaluated instrumentally to help assess product quality, ingredient effect on color, storage, processing, and consistency of the product (Good, 2002). Instrumental color assessment (Table 4.2) revealed there were no significant differences in color measurements $L^*$,
a*, and b* for oatmeal cookies due to formulation. For chocolate chip cookies (Table 4.2), only lightness (L*) differed significantly. The control cookies were significantly lighter than were the modified ones.

**Cookie Spread**

Cookie spread is a measure of the ratio of cookie diameter to cookie thickness. Effects of modification on cookie spread differed with cookie type (Table 4.2). The modified oatmeal cookies spread significantly less than the control, although the cookie prepared with the 30% Splenda® Granular : 70% Isomalt did not differ from the control oatmeal cookie. Sugar replacement in oatmeal cookies resulted in a thicker cookie with a reduced diameter. Dough fluidity associated with the melting of sugar during baking is reduced in the absence of sugar. The delay in gelatinization (Spies and Hoseney, 1982) and the increase in gluten glass transition temperatures typically associated with sugar (Doescher et al, 1987a) was also absent in these cookies, thereby decreasing spread. Further, sugar replacement likely resulted in less spread because more water was bound by the flour, facilitating increased gluten formation (Doescher et al 1987b). Similar results have been previously reported in oatmeal cookies in which both fat and sugar were reduced (Perry et al., 2003).

Conversely, in the chocolate chip cookies (Table 4.2), the greatest spread was exhibited by those cookies with the highest levels of Isomalt in the sweetener system blends, although all modified chocolate chip cookies exhibited significantly greater spread than did the control. These modified cookies were thin with a wide diameter. These results, which are consistent with differences in texture perceived by the trained sensory panel (Figure 4.3), suggest a product specific response to sugar replacement.

**Probing**
Texture was assessed instrumentally (Table 4.3) with the probing technique. For the oatmeal cookies, significant differences were found for time and distance the probe traveled prior to breaking the surface of the cookie. An increase in both of these parameters suggests that the cookies exhibited resistance to penetration, even though the force required to penetrate the surface did not differ. These instrumental results coupled with the descriptive sensory results (Figure 4.2) suggest that the resistance to penetration is associated with deformation prior to rupture of the oatmeal cookie surface.

Probing revealed no significant differences in the chocolate chip textural parameters (Table 4.3) due to treatment, despite exhibiting increased spread ratios (Table 4.2) and differences in fractuability, cohesiveness and chewiness when assessed with descriptive sensory techniques (Figure 4.3). This apparent contradiction may be due to the heterogeneous nature of chocolate chip cookies which have inclusions (the chocolate chips) in a matrix (the cookie base). Both cookie spread and descriptive sensory assessments reflect the total cookie. Conversely, the probing technique allows for “spot” assessment in 5 areas on each cookie surface. Each puncture of the cookie was 3mm in diameter.

**Nutrient Analysis**

Modification resulted in reformulated cookies that were lower in calories, carbohydrates and sugar (Table 4.4). The effect on total calories was small even though sugar constitutes a relatively large percentage of the formula weight. The potential reduction in calories contributed by sugar was replaced in part with the inclusion of Isomalt in the sugar alternative blend. Isomalt contributed two calories per gram.

The most impact was seen on sugar levels. The modified cookies were 30% lower in sugar. Under current Federal Food Labeling Guidelines, these cookies could be classified as
containing “less, fewer, or reduced” grams of sugar. To meet this qualification, the products must contain 25% less of a nutrient or calories than a reference food or the original product. (CFR, 2008).

**Conclusions**

The multiple ingredient approach was successful in this study, suggesting these alternative sweetener blends have potential in cookie as well as cake products. Quality assessment suggests these modified cookies have flavor and texture characteristics that are very similar to the full sugar product, justifying future consumer evaluation of their acceptability. The trained sensory descriptive panelists found no significant differences in not only sweetness but the other flavor attributes as well. Although several textural attributes did differ significantly when assessed using both descriptive sensory and non-sensory techniques, the variation found was limited. The specific ratio of the sugar alternatives utilized had little effect on the characteristics of the modified product as perceived by sensory panelists. Therefore, effects on spread and color, as well as, cost, ease of handling and nutrition effects can serve as the basis of selecting the ratio within the range studied for further evaluation. Differences in spread may have implications for packaging or display for sale. Color differences may impact consumer selection.

Although caloric content of the modified cookies was reduced by only 6.1 to 8.8%, the reduction in sugar ranged from 34.1% to 38.0%. Therefore the reformulated products meet the criteria for a “reduced-in-sugar” health claim (CFR, 2008). For consumers who wish to reduce their intake of sugar, these modified cookies provide an additional option. Availability of these products may allow indulgent foods that are favorites to be retained in an overall “healthier diet” potentially increasing dietary compliance.
Table 4.2: Chocolate Chip\textsuperscript{a} and Oatmeal Cookies\textsuperscript{b}: LS Means and standard error for cookie spread\textsuperscript{c}, cookie color\textsuperscript{d}, and water activity (aw)\textsuperscript{e}

<table>
<thead>
<tr>
<th></th>
<th>Chocolate Chip</th>
<th></th>
<th></th>
<th>Oatmeal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LS Means</td>
<td>Std Error</td>
<td>LS Means</td>
<td>Std Error</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control 100% Sucrose</td>
<td></td>
<td>Control 100% Sucrose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cookie Spread</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30%S: 70%I\textsuperscript{f}</td>
<td>40%S: 60%I\textsuperscript{g}</td>
<td>50%S: 50%I\textsuperscript{h}</td>
<td>50%S: 50%I\textsuperscript{h}</td>
<td></td>
</tr>
<tr>
<td>Color L</td>
<td>52.53a</td>
<td>69.34c</td>
<td>66.92c</td>
<td>60.97b</td>
<td>0.377</td>
</tr>
<tr>
<td></td>
<td>61.04a</td>
<td>56.35b</td>
<td>57.24b</td>
<td>57.51b</td>
<td>0.567</td>
</tr>
<tr>
<td>Color a</td>
<td>4.65</td>
<td>4.16</td>
<td>4.14</td>
<td>3.97</td>
<td>0.197</td>
</tr>
<tr>
<td>a\textsubscript{w}</td>
<td>0.31</td>
<td>0.32</td>
<td>0.34</td>
<td>0.36</td>
<td>0.014</td>
</tr>
</tbody>
</table>

\textsuperscript{a} LS – Means indicate 4 replications across 4 formulations per cookie type; LS-Means within cookie type and parameter followed by a different letter are significantly different (p<0.05) according to mixed ANOVA and LS-Means separation with PDIF\textsuperscript{F}

\textsuperscript{b} LS – Means indicate 3 replications across 4 formulations per cookie type; LS-Means within cookie type and parameter followed by a different letter are significantly different (p<0.05) according to mixed ANOVA and LS-Means separation with PDIF\textsuperscript{F}

\textsuperscript{c} Cookie spread determined according to AACC 10-50D, 2000.

\textsuperscript{d} Values measured using Minolta Color Spectrophotometer (Model CM-508d, Minolta Co. Ltd., Ramsey, NJ)

\textsuperscript{e} Measured with Aqua Lab (Model CX-2, Decagon Devices, Pulman, WA)

\textsuperscript{f} 30%S: 70%I = a blend of 30% Splenda® Granular to 70% Isomalt was replaced for 100% of the granulated sugar

\textsuperscript{g} 40%S: 60%I = a blend of 40% Splenda® Granular to 60% Isomalt was replaced for 100% of the granulated sugar

\textsuperscript{h} 50%S: 50%I = a blend of 50% Splenda® Granular to 50% Isomalt was replaced for 100% of the granulated sugar
**Table 4.3: Chocolate Chip\(^a\) and Oatmeal Cookies\(^b\): LS Means and standard error of probing parameters for treatment effects**

<table>
<thead>
<tr>
<th>Probe Parameter</th>
<th>Control 100% Sucrose</th>
<th>30%S: 70%I(^c)</th>
<th>40%S: 60%I(^d)</th>
<th>50%S: 50%I(^e)</th>
<th>Control 100% Sucrose</th>
<th>30%S: 70%I(^c)</th>
<th>40%S: 60%I(^d)</th>
<th>50%S: 50%I(^e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force(^f)</td>
<td>1.80</td>
<td>1.97</td>
<td>1.61</td>
<td>1.54</td>
<td>0.82</td>
<td>0.67</td>
<td>0.69</td>
<td>0.69</td>
</tr>
<tr>
<td>Time(^f)</td>
<td>0.65</td>
<td>0.50</td>
<td>0.43</td>
<td>0.36</td>
<td>0.020</td>
<td>0.48a</td>
<td>0.72b</td>
<td>0.68b</td>
</tr>
<tr>
<td>Distance(^f)</td>
<td>3.18</td>
<td>2.47</td>
<td>2.11</td>
<td>1.76</td>
<td>0.099</td>
<td>2.35a</td>
<td>3.54b</td>
<td>3.34b</td>
</tr>
<tr>
<td>Slope(^g)</td>
<td>0.73</td>
<td>0.63</td>
<td>0.44</td>
<td>0.34</td>
<td>0.027</td>
<td>0.27</td>
<td>0.31</td>
<td>0.33</td>
</tr>
<tr>
<td>Area(^h)</td>
<td>1.62</td>
<td>1.62</td>
<td>1.36</td>
<td>1.74</td>
<td>0.031</td>
<td>1.15</td>
<td>1.02</td>
<td>1.07</td>
</tr>
</tbody>
</table>

\(^a\) LS-Means are across 4 replications with 5 probes per cookie and 6 cookies per replication; measured using a 50-kg capacity TA.XT2 Texture Analyzer (equipped with Texture Expert Exceed, Version 2.61, Stable Micro Systems, Haselmere, Surrey, England) and 0.3-cm probe at a crossarm speed of 5mm/sec, (Bourne, 1965, Gaines et al, 1992, Perry et al., 2003, Cardello 2003); LS-Means within cookie type and parameter followed by a different letter are significantly different (p<0.05) according to mixed ANOVA and LS-Means separation with PDIFF.

\(^b\) LS-Means are across 3 replications with 5 probes per cookie and 6 cookies per replication; measured using a 50-kg capacity TA.XT2 Texture Analyzer (equipped with Texture Expert Exceed, Version 2.61, Stable Micro Systems, Haselmere, Surrey, England) and 0.3-cm probe at a crossarm speed of 5mm/sec, (Bourne, 1965, Gaines et al, 1992, Perry et al., 2003, Cardello 2003); LS-Means within cookie type and parameter followed by a different letter are significantly different (p<0.05) according to mixed ANOVA and LS-Means separation with PDIFF.

\(^c\) 30%S:70%I = a blend of 30% Splenda® Granular to 70% Isomalt was replaced for 100% of the granulated sugar

\(^d\) 40%S:60%I = a blend of 40% Splenda® Granular to 60% Isomalt was replaced for 100% of the granulated sugar

\(^e\) 50%S:50%I = a blend of 50% Splenda® Granular to 50% Isomalt was replaced for 100% of the granulated sugar

\(^f\) Force, Time, Distance – force, time, and distance traveled required to penetrate the surface of the cookie

\(^g\) Slope – to maximum force

\(^h\) Area – area under the curve to the end of the downward stroke
Table 4.4: Nutrient Analysis\textsuperscript{a} of Chocolate Chip and Oatmeal Cookies

<table>
<thead>
<tr>
<th></th>
<th>Chocolate Chip</th>
<th>Oatmeal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control 100% Sucrose</td>
<td>Control 100% Sucrose</td>
</tr>
<tr>
<td>Total Calories</td>
<td>69.36</td>
<td>86.29</td>
</tr>
<tr>
<td>(kcals)</td>
<td>66.38</td>
<td>81.10</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>9.04</td>
<td>7.99</td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>5.61</td>
<td>3.60</td>
</tr>
<tr>
<td>% Change in Sugar</td>
<td>36.41</td>
<td>38.01</td>
</tr>
<tr>
<td>% Change in Calories</td>
<td>8.75</td>
<td>6.01</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Nutrient Analysis determined with ESHA Food Processor SQL (Salem, Oregon); 1 gram Isomalt = 2 kcals
\textsuperscript{b} 30%S:70%I = a blend of 30\% Splenda\textsuperscript{®} Granular to 70\% Isomalt was replaced for 100\% of the granulated sugar
\textsuperscript{c} 40%S:60%I = a blend of 40\% Splenda\textsuperscript{®} Granular to 60\% Isomalt was replaced for 100\% of the granulated sugar
\textsuperscript{d} 50%S:50%I = a blend of 50\% Splenda\textsuperscript{®} Granular to 50\% Isomalt was replaced for 100\% of the granulated sugar
REFERENCES


Chapter V

CONCLUSIONS

Obesity is an epidemic in the United States that is affecting adults and children across all ethnic and gender groups. Current data indicates that nearly 1/3 of Americans reported being overweight or obese (Ogden et al, 2006). As the rates of overweight and obesity rise, so do associated health problems, such as diabetes, hypertension, hyperlipidemia, and heart disease. These health problems at one time were thought to only affect adults; they are now being seen in children and adolescents (Dietz, 1998).

The incidence of overweight and obesity can be largely attributed to the American diet, which is high in calories, fat, and sugar, and low in fruits, vegetables and dairy (Mokdad et al, 2001). Specific dietary factors that have influenced the obesity trend include increased portion size and caloric intake (Hedley et al, 2004). The average American consumes 138.9 lbs. of sugar annually (USDA – ERS, 2008). Trends suggest that consumption of foods high in sugars contribute to excess caloric intake and therefore, increased obesity and associated health risks (Henkle, 1999; Vermunt et al., 2003). Moreover, dietary incorporation of modified products is associated with improved nutrient profiles (Sigman – Grant and Hsieh, 2005).

Cookies, which tend to be high-calorie, high-fat, and high-sugar, are an easy target for modification due to their popularity across all age groups. The most acceptable reformulated products have sensory attributes that closely match their traditional counterparts (CCC, 2007). In this study, chocolate chip and oatmeal cookies were reformulated with various ratios of a
Splenda® Granular and Isomalt blend. The HIS/polyols blend replaced 100% of the granulated sugar. The full sugar cookie formulation served as the control for both cookie types.

Splenda® Granular is a sucralose/maltodextrin blend readily available to consumers. Isomalt is a sugar alcohol or polyol available to consumers via the internet sources. Use of blends of alternative sweeteners have been more successful in replacing sugar in food products than have individual HIS or sugar replacers such as polyols (Cardello, 2003, Johnson et al, 2006). Previously, cupcakes reformulated with a 30% Splenda® Granular to 70% Isomalt blend were found to have flavor and texture profiles most similar to the full sugar control cupcake when assessed by trained descriptive sensory panel. Consumer sensory panels found the 30% Splenda® Granular to 70% Isomalt sugar alternative blend produced an acceptable product. However, trends suggested that higher Splenda® Granular to Isomalt ratio may produce a product which better matched the full sugar control. (Johnson et al., 2006). Some HIS/sugar alcohol blends had been unsuccessful as a sugar alternative in cookies, although others appear to have promise (Zoulias et al, 2000). Suitability of Splenda® Granular and Isomalt has not been investigated. The replacement of granulated sugar with this alternative sweetener blend in the chocolate chip and oatmeal cookies was expected to impact both the flavor and texture of the cookies, due to the many functional roles that sugar plays in the product. The following ratios on a volumetric basis were investigated: 30% Splenda® Granular to 70% Isomalt, 40% Splenda® Granular to 60% Isomalt, and 50% Splenda® Granular to 50% Isomalt.

The descriptive sensory flavor results revealed no significant differences in either cookie type regardless of formulation when compared to its respective control. These findings are consistent with a previous study (Cardello, 2003) which utilized Splenda® Granular and Acesulfame potassium (Ace-K) to replace 50% of the granulated sugar in chocolate chip and
oatmeal cookies. However, the blend of these two sugar alternatives, sucralose/maltodextrin and Isomalt, appears to allow greater replacement of sugar with less detrimental effects on flavor. These results indicate that all of the Splenda® Granular: Isomalt blends successfully mimicked the sweetness of granulated sugar. Further, these results do not indicate a significant difference in bitterness as found by Zoulias and others (2000) when an Ace-K/mannitol blend was investigated as a sugar replacer in cookies.

Textural attributes were found to differ significantly with reformulation, according to the descriptive sensory analysis results. However, the actual difference in perceived intensity tended to be relatively small (ranging from 3.45 to 5.02, on a 15-point line scale) despite statistical significance.

Ten textual attributes were evaluated for each cookie type. Only one sensory attribute was significantly different for the oatmeal cookies, manual hardness. The control cookies were perceived as being harder than the modified cookies. This might be expected in a cookie system because increased amounts of sugar in the formulation is associated with increased hardness in the baked cookie (Faridi, 1994). It should be noted that no differences were detected in hardness when assessed orally. Whether assessed manually or orally, hardness intensity was in the moderately low range (<5), indicating these were soft cookies. The sensory panelists found the modified cookies to moderately cohesive and chewy, while having low levels of fracturability. Instrumentally, few textural differences were found. Thus, the modified oatmeal cookies are similar to those oatmeal cookies purchased most often (Mintel, 2007).

Significant differences in four textural sensory attributes were detected in the modified chocolate chip cookies (p<0.05). These significant results in cookie chip cookies contradict the expected effect of sugar replacement with alternative sweeteners. Both manual and oral
fracturability differed significantly, with the sweetener blend incorporation increasing perceived fracturability, although hardness did not differ. The closely related sensory attributes cohesiveness and chewiness also differed significantly from the control with sugar replacement. However, the differences detected by the sensory panel were within one scalar unit, and were not supported by instrumental probing data. All formulations produced a soft, slightly chewy chocolate chip cookie, characteristic of those that Americans purchase at the grocery store (Mintel, 2007).

Of the other physical/physicochemical tests performed, significant differences were noted in cookie spread, and color $L^*$, although the effects were not consistent across both cookie types. Whereas modified chocolate chip cookies exhibited increased spread with replacement, the modified oatmeal cookies exhibited decreased spread. Water activity did not differ for either cookie type with reformulation, suggesting few if any effects on shelflife or safety and further suggesting that the sugar replacer blend utilized, like sugar, adequately controlled water activity.

Overall, the effects of reformulation on quality characteristics were limited. Few and inconsistent effects of the ratios of Splenda® Granular to Isomalt within the range studied were found, suggesting that factors other than functional effects on flavor and texture could serve as the decision point for blend ratio selection. Effects on spread and color as well as cost, ease of handling and nutrition impacts could serve as the basis for selecting the “ideal” ratio within the range studied. Differences in spread may have implications for packaging and/or display for sale. Color differences may impact consumer selection. These potential limitations should be further investigated.

From a nutritional standpoint, caloric content of the modified cookies was reduced by only 6.1 to 8.8%, however, the reduction in sugar ranged from 36.4% to 38.0%. Therefore the
reformulated products meet the criteria for a “reduced-in-sugar” health claim (CFR, 2008). The multiple ingredient approach was successful in this study, suggesting these alternative sweetener blends have potential in cookie as well as cake products. Consumer acceptability was not assessed as a part of this study, but these descriptive sensory and instrumental assessments suggests the modified cookies have flavor and textural characteristics similar to the full sugar control meeting consumers “wants” for products reformulated to improve their nutrient profile.

For consumers who wish to reduce their intake of sugar, these modified cookies may provide an additional option. Availability of these products may allow indulgent foods that are favorites to be retained in an overall “healthier diet” potentially increasing dietary compliance. Consumer acceptability of the reformulated cookies should be determined.
REFERENCES


REFERENCES


APPENDIX A

DESCRIPTIVE SENSORY PANEL RESULTS OF FLAVOR AND TEXTURE

ATTRIBUTES OF CHOCOLATE CHIP AND OATMEAL COOKIES
Table A–1: Chocolate Chip\textsuperscript{a} and Oatmeal Cookies\textsuperscript{b} LS Means and Standard Error of Sensory Flavor Attributes\textsuperscript{c}

<table>
<thead>
<tr>
<th></th>
<th>Chocolate Chip</th>
<th></th>
<th>Oatmeal</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LS Means</td>
<td>Std Error</td>
<td>LS Means</td>
<td>Std Error</td>
<td>LS Means</td>
<td>Std Error</td>
</tr>
<tr>
<td></td>
<td>Control 100%</td>
<td>30%S: 70%\textsuperscript{f}</td>
<td>40%S: 60%\textsuperscript{f}</td>
<td>50%S: 50%\textsuperscript{f}</td>
<td>30%S: 70%\textsuperscript{f}</td>
<td>40%S: 60%\textsuperscript{f}</td>
</tr>
<tr>
<td>Attribute\textsuperscript{d}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinnamon/ woody spice</td>
<td>4.17</td>
<td>3.94</td>
<td>3.91</td>
<td>3.77</td>
<td>2.46</td>
<td>2.43</td>
</tr>
<tr>
<td>Grainy/ Oatmeal</td>
<td>3.84</td>
<td>3.97</td>
<td>3.92</td>
<td>3.94</td>
<td>3.76</td>
<td>3.68</td>
</tr>
<tr>
<td>Chocolate Chip</td>
<td>2.90</td>
<td>2.97</td>
<td>2.92</td>
<td>2.97</td>
<td>2.46</td>
<td>2.43</td>
</tr>
<tr>
<td>White Wheat Flour</td>
<td>2.63</td>
<td>2.68</td>
<td>2.74</td>
<td>2.70</td>
<td>2.76</td>
<td>2.43</td>
</tr>
<tr>
<td>Brown Sugar</td>
<td>1.86</td>
<td>1.99</td>
<td>1.96</td>
<td>1.93</td>
<td>2.25</td>
<td>2.38</td>
</tr>
<tr>
<td>Butter</td>
<td>5.80</td>
<td>5.79</td>
<td>5.86</td>
<td>5.85</td>
<td>5.36</td>
<td>5.20</td>
</tr>
<tr>
<td>Vanilla</td>
<td>2.86</td>
<td>2.83</td>
<td>2.92</td>
<td>2.88</td>
<td>3.14</td>
<td>3.04</td>
</tr>
<tr>
<td>Baking Soda</td>
<td>2.83</td>
<td>2.66</td>
<td>2.69</td>
<td>2.56</td>
<td>2.45</td>
<td>2.43</td>
</tr>
<tr>
<td>Sweet</td>
<td>1.83</td>
<td>1.70</td>
<td>1.79</td>
<td>1.63</td>
<td>2.62</td>
<td>2.59</td>
</tr>
<tr>
<td>Astringent</td>
<td>4.17</td>
<td>3.94</td>
<td>3.91</td>
<td>3.77</td>
<td>2.46</td>
<td>2.43</td>
</tr>
</tbody>
</table>

\textsuperscript{a} LS Means are across 8 panelists and 4 replications  
\textsuperscript{b} LS Means are across 8 panelists and 3 replications  
\textsuperscript{c} Sensory scale ranged from 0 (not perceptible) to 15 (high intensity)  
\textsuperscript{d} LS mean within cookie type and attribute followed by a different letter were significantly different (p<0.05) according to mixed ANOVA and LS-Means separation with PDIFF  
\textsuperscript{e} 30%S:70%I = a blend of 30% Splenda Granular to 70% Isomalt was replaced for 100% of the granulated sugar  
\textsuperscript{f} 40%S:60%I = a blend of 40% Splenda Granular to 60% Isomalt was replaced for 100% of the granulated sugar  
\textsuperscript{g} 50%S:50%I = a blend of 50% Splenda Granular to 50% Isomalt was replaced for 100% of the granulated sugar
Table A–2: Chocolate Chip\textsuperscript{a} and Oatmeal Cookies\textsuperscript{b} LS Means and Standard Error of Sensory Texture Attributes\textsuperscript{c}

<table>
<thead>
<tr>
<th>Attribute\textsuperscript{d}</th>
<th>Chocolate Chip</th>
<th>Oatmeal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LS Means</td>
<td>Std Error</td>
</tr>
<tr>
<td></td>
<td>Control 100% Sucrose</td>
<td>30%S: 70%I\textsuperscript{e}</td>
</tr>
<tr>
<td>Manual Hardness*</td>
<td>4.59</td>
<td>5.02</td>
</tr>
<tr>
<td>Manual Fracturability</td>
<td>3.72a</td>
<td>4.57b</td>
</tr>
<tr>
<td>Roughness</td>
<td>4.69</td>
<td>4.93</td>
</tr>
<tr>
<td>Fracturability</td>
<td>3.67a</td>
<td>4.73c</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>4.39a</td>
<td>3.66b</td>
</tr>
<tr>
<td>Hardness</td>
<td>4.87</td>
<td>4.60</td>
</tr>
<tr>
<td>Oiliness</td>
<td>3.15</td>
<td>3.13</td>
</tr>
<tr>
<td>Chewiness</td>
<td>4.08a</td>
<td>3.81b</td>
</tr>
<tr>
<td>Residual Particles</td>
<td>3.47</td>
<td>3.52</td>
</tr>
<tr>
<td>Oily Mouthcoat</td>
<td>3.08</td>
<td>3.10</td>
</tr>
</tbody>
</table>

\textsuperscript{a} LS Means are across 8 panelists and 4 replications
\textsuperscript{b} LS Means are across 8 panelists and 3 replications
\textsuperscript{c} Sensory scale ranged from 0 (not perceptible) to 15 (high intensity)
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APPENDIX B

MACRO PROGRAM FOR TEXTURE ANALYZER
Clear Graph Results
Redraw
Search Forwards
Go to Min. Time
Drop Anchor
Go to Peak +ve Value
Mark Value Force
Mark Value Time
Mark Value Distance
Drop Anchor
Go to Abs. +ve Value
Mark Value Force
Mark Value Time
Mark Value Distance
Drop Anchor
Go to ..Time
Mark Value Distance
Drop Anchor
Select Anchor
Select Anchor
Area
Gradient
Select Anchor
Select Anchor
Area
Gradient
Select Anchor
Select Anchor
Average Gradient
Area

Force
peak1
time1
disfrac
Force
peakmax
time to max
dismax
5sec
distance
1
2
Active vs Active
Active vs Active
1
3
Active vs Active
Active vs Active
1
4
Active vs Active
Active vs Active
APPENDIX C

BUILD-A-COOKIE FORMULATIONS
Ratio amounts calculated on a volumetric basis, assuming:

1 cup granulated sugar = 200g

1 cup Splenda® Granulated = 27.4g

1 cup Isomalt = 198g

Ratios evaluated:

30% Splenda® Granular to 70% Isomalt

40% Splenda® Granular to 60% Isomalt

50% Splenda® Granular to 50% Isomalt

Table C–1: Splenda® Granular : Isomalt Substitutions

<table>
<thead>
<tr>
<th></th>
<th>Chocolate Chip</th>
<th>Oatmeal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Splenda® Granular(g)</td>
<td>Isomalt(g)</td>
</tr>
<tr>
<td>30% Splenda® Granular</td>
<td>5.56</td>
<td>103.95</td>
</tr>
<tr>
<td>to 70% Isomalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40% Splenda® Granular</td>
<td>7.41</td>
<td>74.25</td>
</tr>
<tr>
<td>to 60% Isomalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% Splenda® Granular</td>
<td>9.27</td>
<td>89.10</td>
</tr>
<tr>
<td>to 50% Isomalt</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aThe Splenda® Granular to Isomalt ratios replaced only the white granulated sugar for both cookie types.