SENSORY AND INSTRUMENTAL ANALYSIS OF REDUCED-IN-FAT COOKIES PREPARED WITH A SINGLE HIGH INTENSITY SWEETENER AND HIGH INTENSITY SWEETENER BLENDS

by

ERIN ELIZABETH CARDELLO

Under the direction of Ruthann Swanson

ABSTRACT

Experiment 1: Trained panelists evaluated texture, flavor and aftertastes of 4 treatments of 2 reduced-in-fat cookies (oatmeal or chocolate chip). Sugar (50%) was replaced by acesulfame-K, sucralose, or acesulfame-K/sucralose blend. Physical/physicochemical tests were performed to evaluate texture. Data were analyzed with PROC GLM ($p<0.05$) and PROC MIXED ($p<0.05$). Only one significant flavor effect was found during mastication. All aftertastes were low. Sensory and physical/physicochemical assessment revealed textural differences.

Experiment 2: Using a Consumer Profile Ballot, consumer panelists assessed flavor and texture attributes of 4 treatments of 2 reduced-in-fat cookies (oatmeal or chocolate chip). Sugar (50%) was replaced by acesulfame-K, sucralose, or acesulfame-K/sucralose blend. Consumers' "ideal" cookies were described. Texture was evaluated with physical/physicochemical tests. Data were analyzed with ANOVA and SNK ($p<0.05$). Few significant flavor effects were found, although significant textural differences occurred. Modified cookies did not differ from the control and were acceptable, although less so than the "ideal."

INDEX WORDS: Cookies, Reduced-in-fat, Reduced-in-Sugar, High intensity sweetener(s), Sucralose, Acesulfame-K, Flavor, Texture, Aftertaste(s), Sensory evaluation, Consumer panel, Trained panel, Instrumental Evaluation

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CHAPTER I

INTRODUCTION

The Epidemic of Obesity

According to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK, 2001), 23% of American adults are obese and about 55% of the population is overweight. This epidemic, as it is referred to by The Centers for Disease Control, can lead to severe health problems, such as heart disease, osteoarthritis, hypertension, and diabetes. In fact, diabetes rose an alarming 33% between 1991 and 1998, the majority of the cases being attributed to the increase in obesity (CDC, 2001). On average, the mortality risk for obese individuals is much greater than that for individuals of normal weight, and approximately 300,000 deaths associated with obesity and overweight occur annually. Furthermore, in the year 2000 an estimated $117 billion was spent on direct and indirect costs related to overweight and obesity (USDHHS, 2001). Several factors have contributed to the rise in overweight and obesity, including a decrease in physical activity, the ubiquitous fast food industry, and an increase in the marketing of snack foods (CDC, 1999). An objective of Healthy People 2010 is to assist the adult population in reducing the prevalence of overweight and obesity to less than 15%. Small increases in physical activity combined with small decreases in calories were suggested to help achieve this objective (USDHHS, 2000).

Roles of Fat and Sugar

An increase in the average number of calories consumed over the past 20 years from 1894 to 2002 is a major contributor to overweight and obesity. Calorie increases are attributed to both higher fat and sugar intakes (Tippett and Cleveland, 1999). The 2000 USDA Dietary Guidelines recommend that $<30\%$ of total calories come from fat (USDA, 2000). The percentage of calories coming from fat is 33%, a 7% decrease from 1978 (Tippett and Cleveland, 1999). While the relative percentage of fat in the energy mix has decreased, the increase in actual calories consumed may be a result of increased added fat in the diet. From 1970 to 1996, added fats and oils increased from 49 to 60 grams. In 1995, the average total fat consumed was 101 grams for men and 65 grams for women (USDA, 1998). The Dietary Guidelines recommend approximately 73 grams of *both* added and naturally occurring fat for a 2200 calorie diet (Kantor, 1999). Fat provides 9 kcal per gram as opposed to the 4 kcal per gram obtained from both protein and carbohydrates. Therefore, higher fat levels in the energy nutrient mix leads to an increase in calorie consumption per gram (CCC, 1998). The diet is not complete without fat, however, as it has many important functions. Dietary fat not only allows for the transport of the fat-soluble vitamins A, D, E, and K and provides essential fatty acids, but it also contributes to flavor, texture, and satiety of a food. However, increased risk for such diseases as obesity, coronary heart disease and cancer can occur with excess fat intake (Akoh, 1998; CCC, 1998).

While sugars contribute numerous important functions to foods, such as tenderness, sweetness, and a browned appearance, consuming large amounts may be a threat to good health. Americans consume an average of 64 pounds of caloric sweeteners each year (Sugar Association, 2000). Excess consumption of sugary foods is responsible for dental caries, especially when coupled with poor oral hygiene. Excess sugar consumption will also displace nutrient dense foods in the diet. This leads to an increased caloric intake which could ultimately lead to obesity (Guthrie and Morton, 2000). Insulin resistance, associated with diabetes, may also result from consumption of too many sugars (Brand-Miller and others, 2002). In addition, sugars increase serum triglyceride levels, which may be related to an increased risk for coronary heart disease (Hellerstein, 2002). The Food Guide Pyramid recommends that sugar intake be limited. The new dietary reference intakes (DRI) also recommend that maximum energy from added sugars be limited to 25% or less (FNB and IOM, 2002). In a 2000 kcal diet, approximately 16% of total calories comes from added sugars. While this is still within the DRI guidelines, consumption of added sugars continues to increase (McBride, 2000). Over the last 20 years, a 15% increase in the consumption of cakes, cookies, pies, and pastries, all of which contain high amounts of calories from fat and sugar, have contributed to this increase (Tippett and Cleveland, 1999).

Harvey-Berino (1998) suggests that decreasing total energy intake along with dietary fat is more beneficial than the reduction of dietary fat alone in achieving weight reduction. Fifty-seven obese individuals, all 120-140% of their ideal body weight, were randomly assigned to either a low-calorie diet (997 kcal-1195 kcal) or to a low-fat diet (22-25 g of fat/day) with 20% of total calories from fat. A significantly greater weight loss was seen in those following the low-calorie diet as opposed to the low-fat diet (11.5

kg vs. 5.2 kg). The greater weight loss in these calorically-restricted individuals was attributed to a decrease in the intake of both fat and carbohydrate. A 46% reduction in fat and 40% reduction in carbohydrate resulted from the low-calorie diet. Those in the fat-restricted group had reduced the amount of fat consumed by 92%, but somewhat compensated for this decrease by increasing carbohydrate consumption by 4.8 g each day. Therefore, weight management may be more effective by reducing total calories and focusing on both carbohydrates and fat. However, adherence to a diet low in both carbohydrate and fat may be challenging. While individuals in both groups reported feeling deprived, only those in the calorically-restricted group felt their diet was inconvenient (Harvey-Berino, 1998).

Many Americans have adopted strategies to decrease both their caloric and fat intakes. Peterson and others (1999) evaluated the nutrient and energy intakes of men and women who employed different approaches to help reduce the fat in their diets. They found that by using fat-reduction strategies the men and women were able to lower the amount of both calories and fat they consumed. Examples of fat-reduction strategies included consumption of leaner cuts of meat and replacing 2% milk with skim milk. Those who reduced the fat in their diet had more favorable nutrient profiles than for those who did not employ fat reduction strategies (Peterson and others, 1999). It is apparent from the studies done by Peterson and others (1999) and Harvey-Berino (1998) that acceptable and convenient reduced-in-fat and reduced-in-calorie products may be useful to consumers who are making efforts to improve their health. These products may also help consumers avoid the feeling of deprivation often associated with eating "healthy" foods (ADA, 2002).

Consumer Trends

Cookies are a popular food in the snack food market, with 4.5 billion dollars being spent on cookies in fiscal year 2000 (Sosland, 2000). Chocolate chip cookies remain a favorite, holding 22.6% of the market share in fiscal year 1997. About 5% of the market share was held by oatmeal cookies (Wylie, 1998). Thus, high-calorie, high-fat, and high-sugar foods like cookies are an easily identified target for calorie, fat and/or sugar modification because of their popularity.

Since 1997, the number of new lower fat items introduced has exceeded 3,000 (CCC, 2000). By 1998, reduced-fat foods and beverages were being used by 85% of adults, an increase from the 73% of adults who were consuming reduced-fat items in 1993. Products lower in sugar and lower in calories are also being used more often. In 1998, 144 million American adults bought such items (CCC, 1999).

However, while 61% of consumers continue to buy reduced-calorie, reduced-fat and reduced-sugar items like cookies, cakes and muffins, there has also been a gradual movement toward the purchase of more indulgent products, or ones with some fat and sugar present in order to produce richer flavors and textures (Bloom, 1998; CCC, 1999). Although a significant number of adults consume reduced-fat foods, 88% of these people still want the flavor that fat provides and 86% would choose a food with some fat over one with little fat if it had a better flavor (Sloan, 1995). Consumers have also discovered that foods labeled as fat-free or sugar-free are not always calorie-free. Often products modified in fat and sugar contain about the same amount of calories as the regular product (CCC, 2002a). This may further encourage consumers to purchase products containing higher levels of fat and sugar, and often more acceptable flavors and textures, because the amount of calories consumed will not be drastically increased.

Consumers are also demanding convenience in addition to the more indulgent products (Roberts and Dornblaster, 2002). Harvey-Berino (1998) found that the calorically-restricted group in a weight-loss study thought their diet was "inconvenient." In order to maintain a healthy weight, dietary compliance is critical. However, if an individual feels that a specific diet is an inconvenience, compliance will be an issue. The availability of popular, acceptable items labeled as "light" or "reduced," which are actually lower in calories as well as fat and/or sugar, may help to make compliance with USDA Dietary Guidelines easier (ADA, 1999).

Despite the movement toward more indulgent products, consumers are not giving up on "wellness products," and according to Wylie (1998), "the reduced-fat cookie market is here to stay." Further, the category of cookies with the most growth is one that takes special dietary needs into consideration. For example, in 1998, sales of cookies that were sugar-free rose 15% from the previous year (Wylie, 1998). However, more recent consumer trends suggest the need for products that contain some fat and sugar, and the associated improved flavor, rather than foods devoid of these ingredients (Bloom, 1998).

Obesity and overweight are often associated with diabetes (CDC, 2001), making dietary caloric restriction and carbohydrate monitoring particularly important. In the past, diabetes professionals considered sugar to be a "forbidden food" and advised diabetics to strictly limit simple sugar intake in order to have better control over blood glucose levels (Geil, 1998). However, in 1994 the American Diabetes Association (1994) came out with new recommendations which allowed diabetics to incorporate sucrose into their meal plan. The ADA recommendations were based on several studies, which were reviewed by Franz and others (2002). In these studies, effects of different types and amounts of carbohydrate, such as sugar, fiber and starch, on blood sugar were examined. The total amount of carbohydrate in the diet was more important than the type of carbohydrate, including simple carbohydrates, in controlling blood glucose (Franz and others, 2002). The availability of reduced-in-fat and reduced-in-sugar items is therefore beneficial to the diabetic consumer because it allows favorite foods to fit more easily into their meal plans and may assist in controlling blood sugar and maintaining a healthy lifestyle.

Product Reformulation

While cookies seem to be an obvious product to modify due to their popularity, this baked product typically contains anywhere from 30-75% sugar, 30-60% fat and 7-20% water on a flour-weight-basis (Pyler, 1988). Cookie formulations are typically higher in fat and sugar in relation to water than other baked products. Therefore, it becomes difficult to formulate an acceptable lower calorie cookie by reducing both the fat and sugar. Fat is essential because it not only imparts a desirable flavor, but it also adds volume and structure to the cookie. Use of fat replacers may be able to impart some, but not all, of the functions of fat, including flavor, palatability, appearance, creaminess, texture and lubricity (Akoh, 1998). Similarly, sugar substitutes may be used to successfully replace the sweetness that sugar provides in the product, although the flavor profile may not be easily duplicated and many of the functional properties imparted by sugar are lost. Flavor, air incorporation and bulk are just some of the properties that are minimized when sugar is replaced with sugar substitutes. It is clear that formulating an acceptable cookie by replacing one of these major ingredients, in part or in total, is difficult. Retention of some of the fat and/or sugar in a cookie may help to maintain the functionability of these key ingredients and improve acceptability. Swanson and Munsayac (1999) found that oatmeal and chocolate chip cookies reduced in fat by replacing 50% of the fat with dried plum puree were acceptable when compared to the full-fat control. Perry (2001) found similar results. Acceptable reduced-in-fat and reduced-in-sugar cookies were prepared by replacing half of the fat with dried plum puree and half of the sugar with acesulfame-K (Perry, 2001).

Currently, there is little information about the amount of an alternative sweetener which should be used to replace sugar in baked products like cookies. An ideal sweetener is one that is as sweet or sweeter than sucrose and leaves no unpleasant aftertaste. It is also readily soluble, stable, functional, nontoxic and metabolized normally or excreted from the body unchanged (CCC, 2002a). Different alternative sweeteners vary in their ability to meet these ideal characteristics. Further, the specific product in which an alternative sweetener will be incorporated may dictate the relative importance of its inherent characteristics.

Acesulfame-K (ace-K) is a high-intensity sweetener (HIS) appropriate for use in baked goods due to its stability under baking conditions. It may be impossible, however, to use this sweetener alone because it does not provide the same functional properties as sugar. In addition, ace-K has been reported to possess a sweetness profile very different from sugar, having a quick onset and leaving an unpleasant aftertaste (Peck, 1994). Another HIS, sucralose, is similar to ace-K in that it is also stable with baking. The functional properties of this sweetener are also somewhat different than those imparted by sugar. However, the taste profile of this sweetener has been shown to be somewhat closer to that of sucrose than has been found for ace-K, although it does not match exactly (Chapello, 1998).

One way to overcome the limitations of using just one artificial sweetener in a product is to combine sweeteners. There is limited information about the effects of HIS blends on texture. However, consumer expectations for taste are often better met because the synergistic effects of HIS blends result in a sweetness profile closer to that of sugar (CCC, 2002b). Ultimately, these synergistic flavor effects may overcome the limitations of a single HIS and produce an acceptable product (Verdi and Hood, 1993). However, use of HIS in a reduced-in-fat product may be more complex. The sweetness profile of a food containing HIS is affected by the amount of fat present in the food (Wiet and others,1993). It is evident that the functional properties sugar provides are affected when sugar levels are reduced and replaced with HIS. However, the literature pertaining to the effects of sugar reduction and replacement with HIS in a fat-modified product is limited.

Rationale

Consumers continue to purchase a variety of foods which are low in fat and sugar in an attempt to improve the quality of their diet. Many reduced-in-fat and reduced-in-sugar products, however, are not acceptable to consumers. Therefore, health-conscious individuals may turn to non-modified items that contain more fat and sugar and are associated with a better taste and texture. Further, the currently available modified products often equal or exceed the traditional formulations in calories. Availability of reduced-in-fat and reduced-in-sugar products that are acceptable can better assist consumers in choosing healthier foods and improving their overall health.

Purpose and Hypothesis

The purpose of this experiment was to evaluate reduced-in-fat oatmeal and chocolate chip cookies prepared by replacing half of the sugar with either a single high intensity sweetener or a blend of sweeteners. Acceptability of cookie flavor and texture was evaluated by consumer panelists. In addition, consumers were asked to describe their "ideal" cookie. Trained panelists evaluated texture, flavor, aftertastes and aftersensations for both cookie types to identify potential changes due to formulation modification that may impact acceptability by consumers. It was hypothesized that the flavor profile of the cookie containing sucrose, sucralose and acesulfame-K would be closest to the flavor profile of the full-sugar control cookie due to the synergistic effects of multisweetener blends. It was also expected that consumer panelists would find this cookie to be more acceptable than cookies prepared with a single high intensity sweetener. Textural differences between the full-sugar control cookie and modified cookies were expected due to the reduced level of sugar. However, it was not expected that cookies would be considered unacceptable because of textural differences.

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CHAPTER II

REVIEW OF LITERATURE

The cookie is one of the most popular snack items today. Three-hundred seventy-one new cookie products were introduced in 2001 (Roberts and Dornblaser, 2002). In 1995, 45% of Americans surveyed bought cookies at least once per month (Malovany, 1995). A 1999 survey done by the Calorie Control Council (CCC, 1999) also shows that the number of Americans purchasing reduced-fat and reduced-sugar products, including cookies, is over 50%. However, there is currently a movement away from fat-free and sugar-free baked goods because these items often lack acceptable flavor and texture. The demand for better-tasting items suggests that some fat and sugar should be retained when developing cookies reduced in both fat and sugar. Because cookies contain relatively high amounts of fat and sugar, the texture and flavor of cookies reduced in fat or sugar is expected to be more acceptable than those cookies that are fat or sugar free.

Formulations for cookies are typically high in sugar and fat and low in water. Starch and gluten proteins compete with sugar for the small amount of water in the cookie dough. The sugar and fat, themselves, further inhibit gluten development and starch gelatinization, resulting in a cookie that is tender-crisp (Penfield and Campbell, 1990). A formula with a greater proportion of water typically produces a cookie that is soft and cake-like because of increased starch gelatinization. In general, the water content of reduced-in-fat products is higher than their full-fat counterparts, often because any fat replacers used must be hydrated (Clark, 1994).

The Role of Fat

Fat is an essential component of a product because of the many functional and sensory roles that it plays. Fat provides creaminess, lubricity, and a good appearance to a product (Akoh, 1998; Giese, 1996). Structure and volume are two other critical roles of fat, particularly in baked goods. During the creaming of fat and sugar, leavening gases are evenly distributed and air cells are created. The leavening gases cause the cells to expand during baking, which results in a product with increased volume (Penfield and Campbell, 1990). Because fat is insoluble in water, it is also responsible for tenderizing a product by interfering with gluten development. During mixing, it becomes impossible for gluten to form because fat adsorbs onto the gluten protein surfaces and interferes with hydration and the subsequent development of gluten (Penfield and Campbell, 1990).

Fat is an important contributor to the sensory qualities of a food. Although the fat itself may not have a strong or distinctive flavor, it is able to distribute, release, enhance, and affect the intensity of other ingredients' flavors (Bennett, 1992; Giese, 1996). Flavor sensation is reduced in the absence of fat because fat-soluble flavors are released all at one time (Plug and Haring, 1993). Although fat-soluble volatiles are perceived through the nose or mouth when fat is first consumed, textural qualities and fat-soluble flavors are gradually perceived in the mouth upon chewing and warming of the food (Drewnowski, 1992). Therefore, the flavor profile of a reduced-in-fat product may be altered due to the decreased amount of fat available to contribute to these sensations.

Use of Prune Puree to Replace Fat

The fat in baked goods may be replaced successfully with the use of a fat substitute that is fruit-based. The use of dried plum puree is one such substitute that is known to result in a product that is lower in fat while maintaining sensory characteristics (Perry, 2001; Swanson and Munsayac, 1999). Dried plums typically make up about 45% of the puree. The rest of the ingredients are usually a mixture of water and corn syrup with no additional spices or flavoring. When used in baking, it is recommended that half of the fat in the formula be removed and then replaced by one-half of the volume of fat removed with dried plum puree (CDPB, 1999). Busetti (1995) notes that substituting prune puree for 50-70% of the fat in products is most acceptable. Furthermore, Swanson and Munsayac (1999) found that oatmeal and chocolate chip cookies that were reduced-in-fat by replacing half of the fat with dried plum puree, as recommended, were acceptable when compared to the full-fat cookies. These substitutions resulted in a reduction of calories as well as a reduction in fat (Swanson and Munsayac, 1999).

Reducing the fat in cookies becomes difficult because they are low in moisture. Use of dried plum puree, however, can help to control the moisture and can contribute sweetness and humectancy due to the presence of reducing sugars, fiber, sorbitol and pectin (Littman, 1996; Stockwell, 1995). Dried plum puree contains 15% sorbitol, which functions to sweeten and bind moisture (CDPB, 1999). The pectin also contributes to moisture absorption. Controlling the moisture of the cookies will help to prolong the shelf-life by inhibiting chemical reactions and the growth of microorganisms (Burrington, 1998; Fontana, 2000).

Functions of Sugar

The functional properties that sugar imparts in a baked product are numerous. Physically, sugar is able to crystallize and provide viscosity. Sugar absorbs water at high levels of relative humidity because it is somewhat soluble and hygroscopic. The hydroxyl groups of sugar are responsible for these properties. Sugar may decrease the amount of free water that is present and therefore inhibit microbial growth and chemical reactions (Davis, 1995; Fontana, 2000). Through nonenzymatic browning, sugar is also able to bring about a good flavor and appearance (Penfield and Campbell, 1990), as well as desirable mouthfeel and sweetness. Sugar also provides bulk to a product (Bullock and others, 1992).

Sugar acts as a tenderizing agent during mixing by absorbing water and slowing the development of gluten. When proteins in flour are surrounded by water during mixing, the protein hydrates and with manipulation gluten strands are formed. The gases produced during leavening fill the pockets formed by gluten, allowing the dough to stretch. If too much gluten develops, the dough will be tough and rigid. However, complete development of gluten in cookie dough is prevented because high amounts of sugar compete with the flour proteins for the limited water, resulting in a cookie that is tender rather than one which is tough and rigid (Sugar Association, 2000).

In the creaming stage of cookies, sugar and fat work together to incorporate air into the product (Alexander, 1998). Crystals of sugar become interspersed with fat molecules. Air becomes trapped on the crystals as small air cells. Later these air cells expand when filled with gases produced by leavening agents (Sugar Association, 2000).

Caramelization occurs when sugar is introduced to temperatures higher than its melting point. Any type of sugar, including non-reducing sugars, may participate in this reaction (Penfield and Campbell, 1990). The greater the amount of sugar present in the dough to participate in this non-enzymatic process, the darker brown the surface will become. The browned and slightly crisp surface imparts a good flavor and also helps to retain moisture (Sugar Association, 2000).

Carbonyl-amine, or Maillard, browning differs from caramelization. A reducing sugar, an amine and water are required for this series of reactions. Sucrose does not participate in carbonyl-amine browning because it is not a reducing sugar. However, sucrose quickly breaks down into glucose and fructose. Both of these monosaccharides are reducing sugars which contribute to Maillard browning (Penfield and Campbell, 1990).

In general, use of high intensity sweeteners (HIS) in place of sugar has a great effect on most, if not all, of these properties. Even though HIS impart sweetness to the product, the actual flavor profile may not exactly mimic that of sucrose. Providing the bulk and other functions that sugar brings to a product becomes more complex because smaller quantities of the HIS are used (Alexander, 1998).

Use of Acesulfame-K

Acesulfame-K (ace-K) is a HIS that is a methyl derivative from the oxathiazinone family (Peck, 1994). Ace-K is used in many types of products in the U.S., from a tabletop sweetener to chewing gum to baked goods. While this sweetener is 200 times as sweet as sugar, it is non-caloric, as it passes through the body without being metabolized or stored (IFIC, 1998a). Because of it's stability, ace-K can be used for baking. It is stable below 225°C, thus it does not lose its sweetness at typical baking temperatures. Acesulfame-K also remains stable under the wide range of pH found in baked products such as fruit fillings for pies and cookies, as well as during long storage periods (Peck, 1994).

Acesulfame-K is manufactured by the Stadt Corporation (Brooklyn, NY) under the brand name Sweet One® which is a blend of dextrose and ace-K. According to the manufacturer, this sweetener will not produce an acceptable product when it is used to completely replace sugar in baked goods. By taking out all of the sugar, both volume and moisture would be lost (Sweet One®, 2000). However, the dextrose (glucose) blended with ace-K functions to replace some of the bulk lost when sugar is removed from a product (Lewis, 1989). When used in baked products, the dextrose also contributes to some of the characteristic browning because it is a reducing sugar (Penfield and Campbell, 1990). Consumers are provided with baking recommendations on the packaging.

Use of Sucralose

Splenda®, the brand name for sucralose, is the only high intensity sweetener made from sugar (IFIC, 1998b). Sucralose is made by adding one chlorine atom to the glucose moiety in the 4'-position and two additional chlorine atoms, one at the 1'-position and one at the 6'-position, to the fructose moiety (Hood and Campbell 1990).

Doing so results in a non-caloric white, crystalline solid which is 600 times sweeter than sucrose (IFIC, 1998b). Because of it's stability, sucralose is suitable for use in baked goods. It is also used in other foods, such as salad dressings, puddings and milk products. Sucralose is also stable over long periods of time and under various pH levels (Chapello, 1998; Hood and Campbell, 1990).

Splenda® is manufactured by McNeil Specialty Products Company (New Brunswick, NJ) and is marketed to consumers as a blend of sucralose and maltodextrin. Maltodextrin functions as a texturizer and inhibits sugar crystallization. Most importantly, sucralose is blended with maltodextrin so that some of the bulk lost when sugar is removed from a product may be replaced (IFT, 1999). Sucralose may be used by consumers for baking by following the recommendations on the packaging.

Taste Profiles

Every chemical substance is characterized by its own taste profile, which includes the time of onset, the degree of the sensation at a specific concentration, and the presence or absence of other tastes and feelings, such as "mouthfeel" (Alexander, 1998). Sucrose is characterized by a quick onset of sweetness followed by a cutoff that is distinct. The taste profile of alternative sweeteners should be the same or similar to that of sucrose (Lim and others, 1989; Redlinger and Setser, 1987). The sweetness imparted by sugar is attributed to the hydroxyl (-OH) groups. The chemical structure responsible for the perception of sweetness is a glucophore. This dipolar structure typically contains AH and B groups bound by hydrogen. The proton donor is the AH group, and the B group serves as the proton acceptor. Organic substances tend to have a bitter taste when charges are not equally balanced. In close proximity to the AH and B groups is a gamma group, which tends to be inductive (electron-withdrawing) and hydrophobic. This gamma group may enhance the activity of the AH or B groups. In the case of high intensity sweeteners, a bitter taste may result (Shallenberger, 1998).

The manufacturer of Sweet One® states that ace-K does have a more rapid onset of sweetness than sucrose and there is no lingering aftertaste except when it is used in high concentrations (Hood and Campbell, 1990; Sweet One®, 2000). Research has shown that ace-K has a strong, bitter/metallic aftertaste especially at a sweetness intensity of a 5% sucrose solution (Lim and others, 1989; Wiet and Beyts, 1992). Other ingredients in the formulations may also affect taste profiles of ace-k.

Time intensity for bitterness and sweetness in shortbread cookies prepared using combinations of ace-K, cyclamate, aspartame, and saccharin with and without polydextrose was studied by Lim and others (1989). Polydextrose functioned as the bulking agent. Flavor and texture were evaluated through sensory analysis. The effects on flavor showed that the bitterness scores for cookies containing ace-K were higher than the scores for cookies prepared with sucrose. When polydextrose was present, bitterness increased further for all sweetener combinations. However, cookies prepared with a combination of sweeteners and polydextrose were more similar in texture to cookies made with sucrose than to cookies prepared without sucrose or polydextrose (Lim and others, 1989).

Redlinger and Setser (1987) studied the sweetness profiles of ace-K, saccharin, aspartame, fructose and sucrose in shortbread cookies. Initial, maximum and residual sweetness intensity and nonsweet aftertaste were evaluated by trained panelists. Unbaked cookies containing ace-K were reported to have a high non-sweet aftertaste. Bitter and medicinal notes were also present. Baked cookies containing ace-K were reported to have low sweetness intensities (Redlinger and Setser, 1987).

The information on the taste profile of sucralose conflicts. The manufacturer of Splenda® contends that sucralose "tastes like sugar because it is made from sugar" and that sucralose leaves no unpleasant aftertaste (Splenda®, 1998). However, some studies show that while sucralose may have a taste profile like that of sucrose, an intense sweet aftertaste may result (Hanger and others, 1996). Wiet and Beyts (1992) found the taste profile of sucralose to be very similar to that of sucrose. Sensory characteristics of sucrose, sucralose, aspartame, saccharin and acesulfame-K in an aqueous system were studied. Trained panelists evaluated the taste profiles for each sweetener using category scaling procedures. It was found that sucralose possessed the greatest potency of the sweeteners studied. However, no significant differences were found among sweeteners for sweet aftertaste 20 seconds after swallowing (Wiet and Beyts, 1992). While no differences were found in sweet aftertaste, Wiet and Beyts (1992) caution that the taste profile of any sweetener may differ when used in different foods and beverages.

Hanger and others (1996) evaluated acesulfame-K, aspartame, sucralose, saccharin, and cyclamate both individually and in blends to determine similarity to 4% sucrose solution. Sucralose, either alone or blended with another sweetener, was found to have a higher sweet aftertaste than the majority of the other sweeteners. Results also indicated that a combination of two or more sweeteners had sweetness profiles more similar to sucrose due to a decrease in aftertastes typically associated with use of individual sweeteners.

In order to overcome the potential limitations of using either acesulfame-K or sucralose alone in a product, a combination of the two can be used. In the beverage industry, using combinations of sweeteners helps to improve the flavor profile of a product and use of sweetener blends, particularly aspartame and saccharin, are common (Powers, 1994). Combining sweeteners may create a synergistic effect, improving the taste and stability of the product (Gelardi, 1987). Synergy occurs when the perceived intensity of a mixture of sweeteners is greater than the perceived intensity of each of the sweeteners alone (Hutteau and others, 1998). The synergistic reactions that occur between each of the sweeteners allows lower concentrations to be used (Powers, 1994). In the study previously described by Hanger and others (1996), it was found that the profile of two or more sweeteners blended together was more similar to the profile of sucrose because aftertastes often associated with individual sweeteners were minimized. The high sweet aftertaste imparted by sucralose was minimized by blending sucralose with acesulfame-K. A combination of acesulfame-K and sucralose, in a 1:3 ratio, reduced the sweet aftertaste of sucralose to almost the same level as sucrose. The bitter aftertaste for the acesulfame-K/sucralose blend was also lower than the bitter aftertaste of acesulfame-K when used alone (Hanger and others, 1996).

The flavor profile of a sweetener may be affected by the presence of fat in a product. Wiet and others (1993) looked at the effects of fat on the perceived sweetness of sucrose, aspartame, and sucralose and found that there was a significant reduction in the potency of the sweetener as fat concentration increased. The sweetness intensity of sucralose peaked at 6% fat concentration. Also, as fat increased, the perception of bitterness in sucralose decreased. These effects reflect the complex interaction that occurs between the amount of fat present, the type of sweetener, and the level of sweetness. Therefore, decreased levels of fat in reduced-in-sugar foods could alter the perceived intensity of the sweetener(s) used to replace sugar.

Quality Assessment

Instrumental and physiochemical tests are used to evaluate attributes of foods, such as texture, and to validate information obtained from sensory evaluation, which may employ trained panelists, consumer panelists, or both. Cookie spread, specific gravity, water activity and puncture testing are non-sensory tests often used in the evaluation of cookies.

Sensory Evaluation

Sensory evaluation may be described as measuring, analyzing, and interpreting reactions to characteristics of foods and materials as perceived by the five senses (Penfield and Campbell, 1990). Typically, the ultimate goal in creating a product is its acceptance. Consumer panels provide hedonic responses, the degree to which a product is liked, as well as overall acceptance of a product (Szczesniak, 1986). These responses are based on the panelist's liking of flavor, texture, aroma and appearance of the product (Giese, 1996). Untrained consumer panelists, however, may not be able to detect specific textural or flavor attributes and usually can not uniformly describe what they are sensing. However, Szczesniak and Skinner (1973) found that the qualitative meaning of texture words is understood by consumers in the same way that they are understood by trained panel members. With this information, the Consumer Profile Ballot was validated as a consumer testing technique (Szczesniak, 1975). The ballot consists of a list of descriptive terms, compiled by a trained panel, for specific attributes of the product being tested. A scale of 1 to 6, 1 indicating low and 6 being high, allows consumers to rate intensities for each attribute. Use of this type of scale produces both qualitative and quantitative data. In terms of qualitative data, differences may be attributed to specific characteristics, such as chewiness. Quantitatively, this scale also reveals the extent to which a sample possesses a certain characteristic and how it rates compared to other samples. An advantage of this technique is that only a minimum of 30 panelists is required (Szczesniak, 1975).

Trained panelists identify variations in the intensities of certain parameters of a product, such as the intensity of sweetness or the degree of chewiness. Typically, a trained panel consists of a small group of individuals. Panelists are chosen based on a number of factors, including sensitivity to the properties being studied, descriptive ability and capacity for abstract reasoning. When presented with a stimuli, trained panelists employ rating scales. The intensity of a specific attribute is translated onto the scales with specific values ranging from low to high. A typical scale ranges from one to fifteen (Meilgaard and others, 1999). Fat replacement at different levels in chocolate chip cookies was evaluated by five individuals on a trained panel in an experiment performed by Armbrister and Setser (1994). The panelists described the intensity of surface roughness, residual mouthcoating, and other parameters by determining how intense the attribute was and reporting the intensity on a 15-point scale. References for the parameters were developed prior to testing.

One of the major differences between a trained and consumer sensory panel is that the trained panel does not evaluate acceptability. Although consumer panels are not trained to rate the intensity of a specific parameter, they may be asked to identify specific flavor or textural attributes, such as sweetness or hardness in a cookie. Use of a consumer panel provides information about an identified target population, and whether or not this population finds the flavor or textural attribute of a product to be acceptable. Developers of food products then use this knowledge to help improve an existing product or to create a new product (Meilgaard and others, 1999). Another difference between consumer and trained panels is that trained panel responses may be related to instrumental data. Instrumental data can not be compared to hedonic responses provided by consumers because instruments are not capable of producing the sensory and psychological responses of humans. This makes it more difficult to predict what will be acceptable to the consumer (Szczesniak, 1986).

Reduced-fat chocolate chip cookies made with dried plum puree were evaluated by 93 consumer panelists on a nine-point scale, 1=like extremely and 9=dislike extremely (Charlton and Sawyer-Morse, 1996). The control cookies were rated a 2.11, or “liked very much,” and the cookies prepared with dried plum puree did not differ significantly (3.27) from this control. Consumer panelists were also used to assess reduced-fat chocolate chip and reduced-fat oatmeal cookies made with dried plum puree. Both modified cookie types were found to be acceptable (Swanson and Munsayac, 1999).

With the Consumer Profile Ballot technique consumers describe their "ideal" product before sampling of a product begins using descriptive terms that have been generated by a trained sensory panel for the product (Szczesniak, 1975). Then, the consumer panel profiles the product. Bi-polar descriptive terms, such as soft and hard, serve as an internal check to verify if the panelists understand the meaning of the listed words. Each characteristic is rated on a scale of one to six, ranging from "not at all" to "very much so." Therefore, it would be expected for a cookie that received high scores for softness to also be rated low for hardness (Szczesniak, 1975). The results from the ballot indicate the differences between the consumer's perception of an "ideal" product versus the product being sampled and can assist food developers in increasing the acceptability of the product (Civille, 1978; Penfield and Campbell, 1990). Textural attributes were first used with this technique, but flavor may also be evaluated. Swanson and Penfield (1988) used the Consumer Profile Ballot to assess the flavor and appearance as well as texture of multi-grain bread systems. Perry (2001) also successfully used the ballot to evaluate cookies reduced in fat and reduced in fat and sugar.

Cookie Spread

Cookie spread is determined by taking the ratio of cookie width to cookie thickness (AACC 10-50D, 1995). Cookie spread is related to viscosity. Viscosity controls the spread of the dough and influences when spreading stops and the cookie "sets." As sugar in a product dissolves because of the increase in temperature during baking, viscosity decreases. According to Alexander (1998), the cookie suddenly stops spreading when there is an abrupt increase in viscosity. This sudden change in viscosity is thought to be caused by a glass transition, which causes a continuous matrix to form. In turn, viscosity increases so much that flow is inhibited and spreading, or horizontal expansion, of the cookie stops (Doescher and others, 1987a; Penfield and Campbell, 1990).

Cookie texture is affected by the type and concentration of sugar present. Doescher and others (1987b) examined the effect of different amounts and types of sugars on cookie spread. It was found that glucose and fructose produced smaller spreads than was found for cookies made with sucrose. Also, the final diameter of the cookie increased as the amount of sucrose syrup increased. Water loss measurements were also taken. The hygroscopic nature of sugar allows more water to be "bound." When the amounts of sugar in a product are decreased, there is an increase in the amount of "free" water present (Fontana, 2000). The cookies prepared with 30% or less sucrose lost the least amount of water, suggesting that when sugar concentrations are lower, flour will bind more water and spread of the cookie will not be as great. Because sugar influences the cookie spread, reducing the amount of sugar is expected to cause a decrease in spread and may modify the final texture of the cookie.

Cookie diameter is also affected by the combination of fat and sugar, both of which are typically present in high amounts in cookies. Fat and sugar delay starch gelatinization (Penfield and Campbell, 1990). More specifically, in cookies the presence of sugar raises the temperature of starch gelatinization, and only a small amount of the flour gelatinizes (Kobs, 2001). This tends to produce a cookie that is tender-crisp, as opposed to a cookie with cake-like structure that results from reduced amounts of fat and sugar (Alexander, 1998). The decrease in the amount of fat present to coat the strands of gluten, in addition to a reduction in water-bound sugar molecules, reduces the spread of cookies (Penfield and Campbell, 1990). Similarly, in a solution of flour and water containing high amounts of sugar and shortening, starch molecules with less granular deformation are found when compared to solutions lower in fat and sugar (Hoseney and others, 1977). All of these factors must be considered when reducing the amount of fat and sugar in a cookie.

Specific Gravity

The amount of air incorporated into a product is found by measuring the specific gravity. This test is performed using cookie dough rather then the baked cookie. Specific gravity is found by determining the ratio of a weight of a known substance at a given temperature to the weight of an equal volume of water. Good volume, in batter and dough products, is associated with lower specific gravities and a greater amount of air incorporation (Penfield and Campbell, 1990).

Incorporation of air into a product is influenced by the presence of both sugar and fat (Alexander, 1998). During the creaming stage, sugar crystals become interspersed with fat and air becomes trapped on the sugar crystals (Sugar Association, 2000). As sugar levels in creamed cookie dough increase, the specific gravity increases (Vetter and others, 1984). The specific gravity for cookies prepared with a reduced amount of fat and sugar is therefore expected to be greatly affected due to the lower amount of fat and sugar available to contribute to air incorporation.

Water Activity

Water activity, which may be described as the amount of "free water" available to participate in reactions, differs from the moisture content of a food, or the amount of total water present. Water activity levels for most foods fall in the range of 0.20-1.00. Measuring the amount of "bound" water in a product helps to anticipate potential chemical and biochemical reactions, and microbial growth in a product. Textural properties and stability of a food product may also be influenced by the amount of "bound" water (Fontana, 2000). The majority of microbial activity occurs above 0.90, while molds, mycotoxins and *Staphylococcus aureus* may be active at water activity levels equal to or greater than 0.65. No microbial proliferation occurs below 0.30. Water activity may also alter some chemical and enzymatic reactions, such as nonenzymatic browning, starch gelatinization, starch retrogradation, lipid oxidation and protein denaturation. Water activity levels for traditional low-moisture crisp cookies are typically below 0.30 (Fontana, 2000).

The amount of "free" water in a food is also influenced by the presence of fat and sugar. Both fat and sugar are major ingredients in cookies. Therefore, determining the water activity level in baked products reduced in both fat and sugar becomes particularly important. Humectants, such as sugars and sugar alcohols, bind moisture and therefore reduce the water activity of a food (Burrington, 1998). Sugar forms hydrogen bonds to which water molecules attach, resulting in moisture retention and a lower water activity. A reduction in sugar causes an increase in the amount of "free water" (Burrington, 1998). Furthermore, the reduction in the amount of solute, and therefore osmotic pressure, in the product provides a better environment for microbial growth. Sugar has a high osmotic pressure which leads to an environment unfavorable for growth of microorganisms (Penfield and Campbell, 1990).

The information available about the effect of sugar substitutes on water activity is limited. Peck (1994) reports that acesulfame-K does not affect the moisture balance of a product. Sucralose, because of its chemical makeup and typical levels of use in products, reportedly does not interfere with the amount of “bound” water (Chapello, 1998). However, most of the synthetic HIS are more soluble in water when compared to sucrose which means there is a likely increase in water activity. Therefore, there is an increase in the potential for chemical reactions to take place and for microorganisms to grow (Nelson, 2000).

Partial reduction of fat and substitution with a fat replacer may help to prevent the increase of “free” water associated with total removal of fat and the subsequent increase in the potential for microbial growth and the alteration in chemical reaction rates (Armbrister and Setser; 1994, Fontana, 2000; Roller and Jones, 1996). The use of dried plum puree to replace fat may also increase moisture retention because it contains sorbitol, a sugar alcohol, which increases product humectancy. The water-binding properties of sorbitol may decrease the water activity of the system resulting in shelf-life extension and a decreased potential for microbial growth (Burrington, 1998; CDPB, 1999; Fontana, 2000).

Water activity also has an affect on the texture of a food (Fontana, 2000). Foods with lower water activities may be described as hard, dry, or tough. Moist, tender, or chewy foods usually have a higher water activity. The texture of foods which typically have a low water activity may also be described as crunchy and crisp, but increased water activity levels could result in a soggy texture (Fontana, 2000). Crispness, for example, may be lost in a product when moisture is adsorbed. The mechanical strength of the product is altered because water softens the starch/protein matrix. Macromolecules in the matrix begin to move and slip past one another as water increases above a specific level, causing the product to lose crispness (Katz and Labuza, 1981). Thus, reaching a certain water content, or certain water activity, may compromise the acceptability of the product due to changes in texture.

Crispness of four different dry snack foods was evaluated by an untrained panel in a study by Katz and Labuza (1981). In each of the products, as water activity increased, crispness decreased. Panelists began rating the snack foods as unacceptable when the water activity was in a range of 0.35-0.50. It is within this range when mobilization of food constituents begins (Katz and Labuza, 1981).

Perry and others (2003) employed a trained panel to evaluate hardness of reduced-in-fat and reduced-in-fat-and-sugar cookies. Hardness tended to decrease and water activity increased when both fat and sugar were reduced.

Puncture Testing

The amount of information available that pertains to instrumental testing of reduced-in-fat and reduced-in-sugar cookies is limited. Traditionally, the Bailey Shortometer has been used in assessing the texture of crisp products like cookies and crackers. This three-point break technique is used to determine the force needed to break the sample as well the time to achieve maximum force (Johnson, 1992). In performing this method, the product sits on two beams a known distance apart. The distance is determined based on the size of the product. Another beam above the product is lowered so that it touches the center of the product. This beam then continues to move down until the product becomes deformed and finally breaks or snaps (Gaines, 1994). The beam that is lowered into the product has a surface which is rounded so that crushing and cutting of the food is minimized (Bruns and Bourne, 1975). While crisp cookies are evaluated successfully with this method because they tend to break rather than bend, this technique may be inappropriate for softer, chewier cookies which are more bendable. Johnson (1992) indicated that textural properties of chewy products, such as bagels and fig bars, may be measured more accurately with puncture testing rather than the three-point break technique.

Puncture testing, also known as probing, is a textural analysis technique defined as the force required to push a probe through a food product (Gaines and others, 1992). By probing a product, characteristics from the outside surface of the product into or through the product may be measured. Specific characteristics include hardness of the crust and softness of the interior (Johnson, 1992). To perform a puncture test, the sample sits on a plate with a hole that will accept the probe. The probe lowers into the sample and measures the force needed to puncture the product. A curve is produced which represents the point at which the sample matrix changes in resistance to the probe. Firmness, hardness and toughness of a food may be determined by puncture testing (Bourne, 1965; Gaines, 1994; Perry and others, 2003; Sanchez and others, 1995). **Figure**

2.1 shows a curve produced by the Texture Analyzer for a full-fat, full-sugar cookie. The letter A represents the maximum force in kilograms to penetrate the cookie, which is suggested as a measure of hardness (Gaines and others, 1992). Letter B is the area under the curve which takes into account both maximum force to penetrate and the force measured over distance or time. Perry and others (2003) found that this portion of the curve, rather than the maximum force, was a better measure of cookie hardness. Sanchez and others (1995) studied fat replacement in shortbread cookies. Area under the curve was suggested to indicate cookie toughness, which had a tendency to increase with fat replacement. The time to achieve maximum force, or the slope of the curve, is represented by the letter C. This may be an indicator of brittleness (Gaines, 1994).

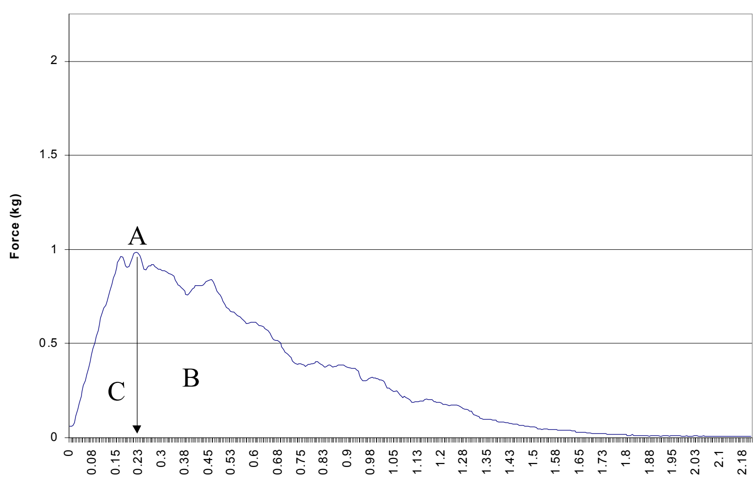

Figure 2.1. Representative probing curve of a single, full-fat, full-sugar cookie. Graph reflects downward stroke only. (A) = maximum force to penetrate the cookie (kg). (B) = area under the curve. (C) = time to achieve maximum force (sec).

When choosing the size of the probe, it is suggested that the largest probe that will not break the product be used (Gaines and others, 1992). In order to maintain the semi-infinite geometry, the product diameter should be about at least 3 times as large as the diameter of the probe (Bourne, 1999). Semi-infinite geometry indicates that the sample being tested is large enough so that no effects from the sides, bottom or edges of the sample are reflected in the probing pattern. The bottom or the edge of the product may fracture or split if the probe and the sample have similar diameters. In addition, the hole made in the product by the probe should be clean and apparent (Bourne, 1999).

The base plate should be chosen carefully as well. In order to avoid compression of the product against the plate, a plate with a hole in the center of the punch is suggested. Bourne (1999) recommends that the hole in the base plate be 1.5 to 3.0 times the diameter of the punch. Gaines and others (1992) used a base plate with a hole of 0.6 cm in diameter, with probe sizes of 4.5 mm, 3.5 mm or 2.0 mm depending on the method used to make the cookies. Perry and others (2003) employed a base plate with a hole of 0.6 cm in diameter, with a probe size of 0.3 cm, to successfully probe reduced-in-fat and reduced-in-fat-and-sugar cookies.

Gaines and others (1992) employed both probing and the three-point break technique in evaluating three cookie formulations which differed in their ratios of sugar, shortening, and water. All of the cookies were successfully evaluated using both of the techniques, but probing was considered to be more practical than the three-point break technique. Probing requires less product because multiple measurements can be taken on each cookie, in contrast to the single measurement that the Bailey Shortometer allows.

Due to the increased number of measurements per cookie, within-cookie variation can be reduced which can increase reliability. Better estimates can also be made for between-cookie variation because of the decrease in the amount of product used (Gaines and others, 1992).

Probing has been shown to provide more accurate data when used with reduced-in-fat-and-sugar cookies. According to Jowitt (1974), sensory hardness, or firmness, is high resistance to deformation by an applied force. He also defines chewiness as the persistent resistence to deformation (Jowitt, 1974). While these definitions relate to sensory evaluation, they may be extrapolated to instrumental evaluation. Perry and others (2003) probed full-sugar cookies, as well as cookies reduced-in-fat and reduced-in-fat-and-sugar. Reduced-in-fat-and-sugar cookies were considered chewier than the other cookies types. These cookies exhibited persistent resistance to penetration, which increased the time to penetration. Armbrister and Setser (1994) employed the probing technique on different formulations of chocolate chip cookies. Vegetable shortening was used in one of the formulations, and fat replacers were used to replace both 50% and 75% of the fat in the formula. Control cookies were considered to be the hardest cookies, as they required more force to penetrate than the reduced-fat formulations. Their assumptions were similar to those of Gaines and others (1992) in that the maximum peak was indicative of cookie hardness.

Perry and others (2003) suggest that other parts of the curve generated by the probe, in addition to or instead of the maximum peak, may be better indicators of cookie texture. Full-fat control, reduced-in-fat, and reduced-in-fat-and-sugar versions of oatmeal and chocolate chip cookies were probed. The area under the curve, rather than the maximum peak, was considered the best indicator of cookie hardness. The area is determined by both the force necessary for the probe to penetrate the cookie and the extent to which the cookie bends and deforms before it is penetrated. Eighty-one to eighty-five percent of the variation in sensory hardness was explained by the area under the curve for chocolate chip cookies. Sixty to seventy-seven percent of the variation was explained for oatmeal cookies (Perry and others, 2003).

Objectives

The primary objective of this research was to investigate the effects of sugar reduction and replacement with one or more high intensity sweeteners on the flavor and texture of reduced-in-fat oatmeal and chocolate chip cookies. Consumer panelists were employed to rate the acceptability of flavor and texture for both cookie types as well as to describe their "ideal" cookie and provide information for continuing product development. Trained panelists evaluated texture, flavor, and aftertastes/feels for both cookie types. It was expected that the flavor profile of the cookie containing sucrose, sucralose and acesulfame-K would be closest to the flavor profile of the full-sugar control cookie due to the synergistic effects of multisweetener blends. It was also expected that this cookie would be more acceptable to consumers than cookies made with a single high intensity sweetener. The full-sugar control cookie and all modified cookies were expected to differ in texture. These differences, however, were not expected to make the cookies unacceptable.

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CHAPTER III

METHODS

Experimental Design

Trained Sensory Panel and Instrumental Evaluation

A randomized, balanced, incomplete block design was used for sensory evaluation by the trained panel. Cookie type was blocked over the complete design. Trained sensory panelists (n=8) evaluated four treatments: full-sugar control, ace-K, sucralose, and ace-K/sucralose blend during a single session. All four treatments were reduced-in-fat. The descriptive panel study was replicated three times. Instrumental evaluation occurred on the same days as the trained sensory panel. Factorial designs for sensory and instrumental tests are shown in **Table 3.1**. Cookies were randomly assigned for trained sensory panel and instrumental evaluation.

Consumer Sensory Panel and Instrumental Evaluation

A randomized block design was used for the Consumer Sensory Study. In two separate sensory sessions, consumers were recruited to evaluate either oatmeal (n=30 panelists) or chocolate chip cookies (n=31 panelists). Each panelist evaluated 4 samples (full-sugar control, ace-K, sucralose, and ace-K/sucralose blend) from one cookie type. Presentation order was randomized and cookies were randomly assigned for sensory and instrumental evaluation. Factorial designs for each test are shown in **Table 3.1**.

Sample Preparation

Four different cookie samples were prepared: full-sugar control, and three types of reduced-sugar cookies according to the formulas in **Tables 3.2 and 3.3**. The full sugar and ace-K formulations were developed by Swanson and Munsayac (1999) and Perry (2001). All cookies were reduced-in-fat, containing dried plum puree (CDPB, 1999) to partially replace fat. The reduced-fat, full-sugar control contained no high intensity sweeteners (HIS).

Table 3.1. Factorial design of sensory and instrumental tests

Sensory Tests	
Trained panel	2x4x3x8[1]
Consumer panel	2x4x30[2]
	2x4x31[2]
Physical/Physiochemical/Instrumental Tests[3]	
Specific Gravity	2x4x3x2[4]
Cookie Spread	2x4x3x2[5]
Water Activity	2x4x3x3[6]
Probing	2x4x3x4x9[7]

[1]cookie type x treatment x replications x panelists; Spectrum Method™ was used as descriptive analysis technique (Meilgaard and others, 1999).
[2]cookie type x treatment x replications x panelists; 30 panelists were recruited to evaluate oatmeal cookies; 31 panelists were recruited to evaluate chocolate chip cookies; Consumer Profile Ballot technique used for evaluation (Szczezniak, 1975).
[3]Physical/physicochemical/instrumental tests were performed on samples assigned randomly each day sensory evaluation was conducted; 3 replications per sensory test (trained or consumer) were conducted.
[4]cookie type x treatment x replications x samples; measured using the method described by Penfield and Campbell (1990).
[5]cookie type x treatment x replications x samples; AACC method 52-10 (1995).
[6]cookie type x treatment x replications x samples; measured using Aqua Lab (Decagon Devices, Pulman, WA). Aliquots were taken from composite samples prepared from cookies as described by Curley and Hoseney (1984).
[7]cookie type x treatment x replications x samples x assessments; measured using a 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert, version 1.20, Stable Micro Systems, Haselmere, Surrey, England, with a 0.3 cm probe at a crossarm speed of 5 mm/sec as described by Bourne (1965, 1982) and Gaines and others (1992).

Sugar was reduced by 50% in all other cookie treatments. Half of the sugar was replaced by either acesulfame-K/dextrose blend (Sweet One®, Stadt Corporation, Brooklyn, NY), sucralose/maltodextrin blend (Splenda®, McNeil Specialty Foods, New Brunswick, NJ), or a combination of the ace-K/dextrose and sucralose/maltodextrin blends. Ratios of ace-K/dextrose and sucralose/maltodextrin combinations differed between the two cookie types (**Tables 3.2 and 3.3)**. Ratios were based on preliminary work and a review of studies employing blends of acesulfame-K and sucralose (Hanger and others, 1996; Hutteau and others, 1998; Perry, 2001). Sugar was substituted in cookies prepared with acesulfame-K/dextrose blend based on the suggestions of the manufacturer and previous findings (Sweet One®, 2000; Perry, 2001). For best results, the manufacturer states that Sweet One® should not be used to completely replace any type of sugar in baked goods (Sweet One®, 2000). Every 16.6 grams of the granulated sugar was substituted with 1 gram of Sweet One® (Sweet One®, 2000; Perry, 2001). The manufacturer of Splenda® also suggests substituting their product for granulated sugar only (Splenda®, 1998). Sucralose substitutions were made based on the following equivalency: 8.3 grams of the granulated sugar was substituted with 1 gram of Splenda® (Splenda®, 1998).

Ingredient sources are found in **Tables 3.2 and 3.3.** All dry ingredients were weighed one day before baking. On the day of baking, the eggs, butter and vanilla were measured. For the oatmeal cookies, eggs and butter were allowed to sit at room temperature for 15 minutes prior to mixing. Eggs and butter for chocolate chip formulations sat at room temperature for 45 minutes prior to mixing. When there were multiple lots of one ingredient, lots were combined and aliquots were taken.

Table 3.2. Oatmeal cookies: formula and procedure[a]

Ingredient	Control (g)	Ace-K [b] (g)	Sucralose[c] (g)	Blend [d] (g)	Product Information
All-purpose flour	222.6	222.6	222.6	222.6	ConAgra, Inc, Omaha, NE
Baking Soda	3.0	3.0	3.0	3.0	Kroger Co., Cincinnati, OH
Salt	2.8	2.8	2.8	2.8	Kroger Co., Cincinnati, OH
Oats	160.0	160.0	160.0	160.0	Quaker Oats Co., Chicago, IL
Cinnamon	1.1	1.1	1.1	1.1	Kroger Co., Cincinnati, OH
Cloves	0.3	0.3	0.3	0.3	Kroger Co., Cincinnati, OH
Nutmeg	0.6	0.6	0.6	0.6	Kroger Co., Cincinnati, OH
Sugar	**100.0**	**50.0**	**50.0**	**50.0**	**Monarch Regency, Greenville, SC**
SweetOne®	**-------**	**3.0**	**-------**	**1.3**	**Stadt Corporation Brooklyn, NY**
Splenda®	**-------**	**-------**	**6.0**	**3.0**	**McNeil Specialty Foods New Brunswick, NJ**
Brown sugar	165.0	165.0	165.0	165.0	Colonial, Savannah, GA
Vanilla	2.0	2.0	2.0	2.0	Greinoman's Unified Industry Cumming, GA
Butter	26.0	26.0	26.0	26.0	Kroger Co., Cincinnati, OH
Egg	85.0	85.0	85.0	85.0	Kroger Co., Cincinnati, OH
Shortening	62.5	62.5	62.5	62.5	Proctor and Gamble Cincinnati, OH
Dried plum puree	61.0	61.0	61.0	61.0	Sunsweet Growers, Inc. Yuba City, CA

[a]Procedure: A Kitchen-Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater, mixed the cookie dough. Cookies were baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Flour, soda, salt, oatmeal, sugar, ace-K and/or sucralose, brown sugar, cinnamon, cloves, and nutmeg was blended for 2 min. at speed 1. Dried plum puree, butter, shortening, eggs and vanilla were added and mixed for 1.5 min. at speed 1. 18 cookies (6 down, 3 across) were portioned out on a 41.91-cm X 30.48 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10). Cookie were baked for 9 min. at 176EC (350EF). Cookies containing sucralose were baked for 8 min. at 176EC (350EF).

[b]Acesulfame-K substitutions: 3.0 grams Sweet One® (ace-K/dextrose blend) for 50 grams of sugar (3.0 grams for 50% of the sugar in the control)

[c]Sucralose substitutions: 6.0 grams Splenda® (sucralose/maltodextrin blend) for 50 grams of sugar (6.0 grams for 50% of the sugar in the control)

[d]Ace-K/sucralose substitutions: 1.3 grams of Sweet One® (ace-K/dextrose blend) for 25.0 grams of sugar; 3.0 grams of Splenda® (sucralose/maltodextrin blend) for 25.0 grams of sugar (1.3 for 25% of the sugar in the control, 3.0 grams for 25% of the sugar in the control).

Table 3.3. Chocolate chip cookies: formula and procedure[a]

Ingredient	Control (g)	Ace-K [b] (g)	Sucralose[c] (g)	Blend (g)	Product Information
All-purpose flour	308.3	308.3	308.3	308.3	ConAgra, Inc, Omaha, NE
Baking Soda	3.0	3.0	3.0	3.0	Kroger Co., Cincinnati, OH
Salt	5.5	5.5	5.5	5.5	Kroger Co., Cincinnati, OH
Sugar	**150.0**	**75.0**	**75.0**	**75.0**	**Monarch Regency Greeneville, SC**
SweetOne®	**-------**	**4.5**	**-------**	**1.3**	**Stadt Corporation Brooklyn, NY**
Splenda®	**-------**	**-------**	**7.5**	**6.0**	**McNeil Specialty Foods New Brunswick, NJ**
Brown sugar	109.0	109.0	109.0	109.0	Colonial, Savannah, GA
Vanilla	4.0	4.0	4.0	4.0	Greinoman's United Industry, Cumming, GA
Butter	113.0	113.0	113.0	113.0	Kroger Co., Cincinnati, OH
Egg	114.0	114.0	114.0	114.0	Kroger Co., Cincinnati, OH
Dried plum puree	61.0	61.0	61.0	61.0	Sunsweet Growers, Inc. Yuba City, CA
Chocolate chips	200.0	200.0	200.0	200.0	Nestle USA, Solon, OH

[a]Procedure: A Kitchen-Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater, mixed the cookie dough. Cookies were baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Flour, soda, and salt were combined in a separate bowl. Butter, dried plum puree, sugar, ace-K, and/or sucralose, brown sugar, and vanilla were blended for 1 min. at speed 1. Beaten egg was added and incorporated for 1 min. at speed 1. Flour mixture was gradually added over a 2 minute period while continuing to mix at speed 2. Chocolate chips were added and mixed at speed 1 for 1 min. 18 cookies (6 down, 3 across) were portioned out on a 41.91-cm X 30.48 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10). Cookie were baked for 10 min. at 190EC (375EF). Cookies containing sucralose were baked for 9 min. at 190EC (375EF).
[b]Acesulfame-K substitutions: 4.0 grams Sweet One® (ace-K/dextrose blend) for 75 grams of sugar (4.0 grams for 50% of the sugar in the control).
[c]Sucralose substitutions: 7.5 grams Splenda® (sucralose/maltodextrin blend) for 75 grams of sugar (7.5 grams for 50% of the sugar in the control).
[d]Ace-K/sucralose substitutions: 1.3 grams of Sweet One® (ace-K/dextrose blend) for 25.0 grams of sugar; 6.0 grams of Splenda® (sucralose/maltodextrin blend) for 50.0 grams of sugar (1.3 for 25% of the sugar in the control, 6.0 grams for 25% of the sugar in the control).

Nutrient values for the cookies are presented in **Table 3.4**. The reduced-in-sugar oatmeal cookies had 7% less calories and 40% less sugars than the full-sugar control. Chocolate chip cookies reduced in sugar had 6% fewer calories and 13% less sugars compared to the full-sugar control. The percentage of sugar reduction exceeded that of calorie reduction in both oatmeal and chocolate chip cookies.

Table 3.4. Nutrient analysis of reduced-in fat oatmeal and chocolate chip cookies[1]

	Oatmeal		Chocolate Chip	
Nutrients per serving (15 g)	Full-sugar control	Reduced-in-sugar[2]	Full-sugar control	Reduced-in-sugar[3]
Calories (kcal)	56.3	52.4	59.5	55.9
Fat (g)	2.1	2.1	2.3	2.3
Sugars (g)	2.5	1.5	5.6	4.9

[1]Nutrient analysis conducted using Food Processor, version 7.21, ESHA Research, Salem, OR, copyright 1998.
[2]50% of the sugar was replaced by Sweet One® (ace-K/dextrose blend), Splenda® (sucralose/maltodextrin blend), or a 1:3 ratio of Sweet One® and Splenda®; Sweet One® and Splenda® do not provide any calories, fat or sugars.
[3]50% of the sugar was replaced by Sweet One® (ace-K/dextrose blend), Splenda® (sucralose/maltodextrin blend), or a 1:6 ratio of Sweet One® and Splenda®; Sweet One® and Splenda® do not provide any calories, fat, or sugars.

A Kitchen Aid Mixer (model K5SS, St. Joseph, MI) was used to mix the ingredients for both cookies. The mixer was plugged in to a timer (GraLab, U.S.A., Model 171) during mixing. All dry ingredients, including any HIS, for the oatmeal cookies were mixed at speed one for two minutes. Dried plum puree, eggs, shortening, butter and vanilla were added all at once and mixed for one and a half minutes at speed one. The chocolate chip cookies were prepared by mixing together the flour, salt, and baking soda. The eggs were lightly beaten. Dried plum puree, butter, sugar, brown sugar, any HIS and vanilla were mixed for two minutes at speed two. The flour mixture was added gradually over two minutes while blending at speed two. Mini chocolate chips were added last and mixed for one minute at speed one.

Once mixing was completed, a #70 scoop was used to divide the cookie dough. Each scoop was weighed and then deposited onto a half-sheet pan (41.91 cm X 30.48 cm) lined with parchment paper lightly sprayed with Pam® non-stick cooking spray (International Home Foods, Inc., Parsippany, NJ). The weight of each scoop was 15±1 grams. Cookies were flattened and then rolled to 1.3-cm thickness using wooden dough guides (AACC 52-10, 1995). To ensure heat was distributed evenly, the cookies were baked in a rotary oven (National Manufacturing Co., Lincoln, Neb.). The manufacturer of Splenda® (1998) suggests that cookies made with their product will cook one to two minutes faster than the baking time for cookies with a full-sucrose formula. Therefore, cooking time was adjusted accordingly. The full sugar control and ace-K oatmeal control were baked at 176EC (350EF) for 9 minutes. All oatmeal cookies containing sucralose were baked for 8 minutes. Chocolate chip full sugar control and ace-K cookies were baked for 10 minutes at 190EC (375EF). All chocolate chip cookies containing sucralose were baked for 9 minutes. Baking order of treatments was randomized within each cookie type.

After baking, cookies were cooled at room temperature for about one hour on wire racks. Once completely cooled, cookie spread was evaluated. All cookies were placed individually in a sandwich-sized plastic bag (6.5 X 3.25 in., 1.15 mm thickness, Kroger Co, Cincinnati, OH) and then placed into a gallon sized plastic bag (10.6 X 11 in., 1.75 mm thickness, Kroger Co., Cincinnati, OH) and stored flat. For each day of data collection, all four treatments within each cookie type were prepared. Barometric pressure was recorded.

One day after baking, consumer panelists evaluated the flavor and texture of the cookies, as well as their preference for the cookies. Trained panelists evaluated flavor and textural attributes, as well as any aftertastes/feels one day after baking. The remaining cookies were used for puncture testing and water activity, both of which were performed on the day of sensory evaluation.

Physicochemical and Instrumental Techniques

Specific gravity was performed on the unbaked cookie dough using the method described by Penfield and Campbell (1990) on the day of mixing. For each treatment within cookie type and formulation, this comparison was made in duplicate.

Cookie spread was performed following the AACC method 52-10 (1995). Six cookies from each formulation were used to calculate height, width, and height:width ratio. This was done twice, using the same six cookies each time. Cookies used in this nondestructive test were subsequently subjected to puncture testing and measurement of water activity.

Water activity of the cookies was determined by using the Aqua Lab device (Decagon Devices, Pulman, WA). Immediately following probing, a Cuisinart DLC1 Mini-Prep Processor (East Windsor, NJ) was used to grind the four probed cookies from each treatment so that particle size was uniform. For each treatment, the measurements were taken on three aliquots of the composite samples as described by Curley and Hoseney (1984).

The day after baking, puncture testing was performed. The cookies were probed according to the method described by Bourne (1965, 1999) and Perry (2001). Four cookies from each treatment were punctured 9 times in an offset bull's-eye pattern (**Figure 3.1**), each with a 0.3-cm probe at a crossarm speed of 5mm/second and trigger force of 10 grams (Bourne, 1965; Gaines and others, 1992; Perry, 2001). Because edge effects may have an effect on hardness, the outer 15% of the cookie was avoided (Gaines and others, 1992). A baseplate with a hole 0.6-cm in diameter was used to accept the probe as it passed through the sample. A 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert Software, version 1.20 (Stable Micro Systems, Haselmere,

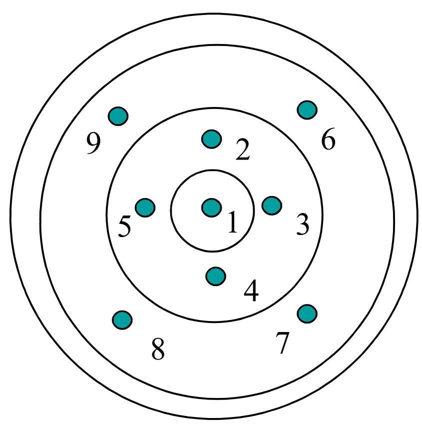

Figure 3.1. Representative probing pattern for reduced-in-fat oatmeal and chocolate chip cookies using a 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert, Version 1.20 (Stable Micro Systems, Haselmere, Surrey, England) and a 0.3 cm probe at a crossarm speed of 5 mm/s.

Surrey, England) was used. Parameters of the force/time curve that were analyzed included maximum force to achieve penetration, slope and area under the curve.

Sensory Testing

Trained Sensory Panel

Panelists went through a training period of about 50 hours. Texture and flavor attributes, along with aftertastes/feels to be assessed were reviewed. A lexicon of terms describing cookies was developed and specific attributes to be evaluated were identified. The terms and definitions used to evaluate specific attributes was clarified during the training period. References were also established to use as anchor points on the linescales used during product evaluation (Meilgaard and others, 1999). Attributes, terms and references are listed in detail in **Table 3.5**. Data were analyzed during the training period to determine the performance of the panelists, the appropriateness of terminology being used to judge product differences, redundancy of terms and actual product differences (Powers, 1984). The panel discussed appropriate terms and their redundancy. Means and standard deviations were used to evaluate the ability of panelists to discriminate.

One day after baking, sensory evaluation of cookies was performed in individual booths under low pressure, sodium vapor light (CML-18, Trimble House, Norcross, GA). Each station was equipped with computers and networked for test presentation, data entry, and retrieval using Compusense®*fiv*e (CSA*five*, release 4.0, Compusense, Inc., Guleph, Ontario, Canada). Three-digit random numbers were used to code each sample, and a balanced order of presentation was used. A reduced-fat cookie prepared with margarine instead of butter was presented to panelists as a warm-up sample to allow self-calibration. Four test cookie samples (full-sugar control, ace-K, sucralose, ace-K/sucralose) from one cookie type (oatmeal or chocolate chip) were then presented monadically. Each panelist received two cookies from each treatment, one used for texture evaluation, one for evaluating flavor and the aftertastes perceived post-swallow. During evaluation, jars of aromatic reference samples were available for use. These samples assist in standardizing panelist responses (Meilgaard and others, 1999).

Each texture and flavor attribute and aftertaste/feel was presented as a 15-point linescale on the monitor screen (**Appendix A**). Panelists used a mouse to move the cursor to a point along the line that corresponded to the perceived intensity of the specific attribute in the sample. In phase one, textural attributes were evaluated; phase two involved the descriptive analysis of flavor. The third phase of evaluation occurred post-swallow. Panelists were prompted every 30 seconds for 120 seconds to check a box to indicate the presence of a any aftertastes/feels, such as slick, sweet, or astringent. Panelists also rated the intensity of any perceived aftertastes on the 15-point scale at each time interval.

Upon completion of each test, a 7.5% sucrose solution, carrots, unsalted crackers and carbon-filtered water were available for palate cleansing. Crackers and water are traditionally used to cleanse the palate. The carbohydrates or natural sugars in carrots help to displace any possible aftertastes, such as astringency or lingering sweetness, from

Table 3.5. Sensory profile attributes, definitions and references used by trained sensory panel to evaluate oatmeal and chocolate chip cookies[a]

OATMEAL	CHOCOLATE CHIP		
Texture attributes		***Definitions:***	***Reference products***[b]
Manual Hardness	Manual Hardness	Manual force required to break or separate the sample into pieces	Pringle (4) Ginger snap (10)
Roughness	Roughness	Amount of particles in the surface as detected by the lips.	Gelatin (0) Pringle (8) Rye wafer (15)
Cohesiveness	Cohesiveness	Degree to which the sample deforms rather than crumbles, cracks or breaks at first chew with molar teeth	Corn bread (1) Raisin (10 Chewing gum (15)
Oral Hardness	Oral Hardness	Force required to bite through sample at first chew with molar teeth	American cheese (4) Peanuts (9.5) Lifesavers (14.5)
Chewiness	Chewiness	Amount of work to chew sample to point of swallow	Rye bread (1.5) Gum drop (5.8) Tootsie roll (13)
---	Oily Mouthcoat	Amount of oily coating in the mouth during mastication	Keebler Chips Deluxe Soft and Chewy (~5)
Flavor attributes/Basic tastes[c]		***Definitions***:	***Reference samples***[d] ***or solutions***[b]
Cinnamon/woody	---	Aromatic/taste sensations associated with cinnamon and non-specific spices	0.3 g cinnamon/clove/nutmeg mixture
Brown sugar (molasses)	---	Aromatic/taste sensations associated with brown sugar/molasses	4.5 g light brown sugar
Dried plum puree	Dried plum puree	Aromatic/taste sensations associated with dried plum puree	6.0 g dried plum puree
Grainy/oatmeal	Grainy/oatmeal	Aromatic/taste sensations associated with non-specific grain/oatmeal	6.5 g old-fashioned oats
---	Brown sugar (caramelized)	Aromatic/taste sensations associated with brown sugar/caramelization	4.5 g light brown sugar

---	Chocolate	Aromatic/taste sensations associated with chocolate	18.0 g semi-sweet chocolate chips
Sweet	Sweet	Basic taste on the tongue stimulated by sugars and high potency sweeteners	Sucrose, solution in water 2% (2)---5%(5)---10%(10)---15%(15)
Salty	Salty	Basic taste on the tongue stimulated by solutions of caffeine, quinine and certain other alkaloids	Caffeine, solution in water 0.05%(2)-0.35%(5)-0.50%(8.5)-0.7%(15)
Astringency	---	Feeling of drying of the linings of the mouth	Tea bags/1 h soak (6.5)
Aftertastes[c]		*Definitions:*	*Reference solutions*[b]
Sweet	Sweet	See above	See above
Bitter	---	See above	See above

[a]All flavor definitions were determined by the trained panel. Basic taste definitions were obtained from Civille and Lyon (1996) and basic taste references were obtained from Meilgaard and others (1999). All texture definitions and references were obtained from Meilgaard and others (1999), except the references for manual hardness and chewiness which were determined by the trained panel.

[b]References products and solutions followed by a number in parentheses indicates intensity of that product or solution on a 15-point scale, with 0=low and 15=high.

[c]The universal flavor scale was applied to all flavor attributes and aftertastes/feels (Meilgaard and others, 1999).

[d]Reference samples were held in screw top 3.5-oz. jars. Panelists opened and immediately closed the jars after sniffing as needed during product evaluation.

the high intensity sweeteners (Booth, 2001). A 10-minute wait between samples was imposed to eliminate the effects of taste fatigue and lingering aftertastes.

Consumer Sensory Panel

A total of 61 consumer sensory panelists provided biographical information and information about product usage and evaluated cookies on two different days. Only one cookie type was evaluated each day. Thirty panelists evaluated the oatmeal cookies, and thirty-one different panelists evaluated chocolate chip cookies with a Consumer Profile Ballot (**Appendices B and C**). Prior to evaluation of cookie samples, consumers completed a ballot in order to provide information about their "ideal" cookie. Information about the "ideal" cookie provides some direction for future product reformulation (Szczezsniak, 1975). Three-digit random numbers were used to code each of the 4 samples evaluated within cookie type. The order of serving was balanced within cookie type and across the panel to avoid potential psychological errors. Panelists evaluated cookie samples in individual booths under white light. The panelists were instructed to cleanse their palate with unsalted crackers and distilled water between samples.

Statistical Analysis

All results from the sensory and instrumental tests were analyzed using SAS software (SAS for Windows, version 8.2, SAS, Inc., Cary, NC). Equal variances within each treatment were verified (PROC MEANS). Normality plots were produced by PROC UNIVARIATE in order to verify that the data were normally distributed. When data lacked either equal variance or normality, transformations were done in order to meet the assumptions necessary for valid analysis. The data from the trained sensory panel and associated physical/physicochemical tests for the main effects and their interactions were analyzed for variance ($p<0.05$) using PROC MIXED. Least-square means and standard errors (LS means±SE) were generated. When appropriate, the PDIFF option was used for means separation. ANOVA (PROC GLM) was used to analyze results from the consumer sensory panel and associated physical/physicochemical tests ($p<0.05$). Means separation was performed using Student-Newman-Kuels (S-N-K).

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CHAPTER IV

CONSUMER ACCEPTABILITY OF REDUCED-IN-FAT COOKIES PREPARED WITH HIGH INTENSITY SWEETENERS (HIS) AND HIS BLENDS[1]

[1]Cardello EE and Swanson RB. To be submitted to *J Fam Con Sci*.

Abstract

Increased availability of acceptable reduced-in-fat and sugar foods may reduce excess fat and simple carbohydrate consumption associated with chronic diseases. Cookies are a popular, high-fat, high-sugar food. Sucralose and acesulfame-K (ace-K), high intensity sweeteners (HIS), are suitable for use in baked products. Both provide sweetness, although taste profiles do not mimic that of sucrose. Synergistic effects between sweeteners may overcome reported limitations. Effects on texture are unknown.

The purpose of this study was to evaluate consumer acceptability of 50% sugar reduction and replacement in reduced-in-fat oatmeal and chocolate chip cookies. Using a Consumer Profile Ballot, 61 consumer panelists evaluated sensory attributes of 4 formulations of 2 cookie types. "Ideal" cookies were also described on this 6-point scale. Physical tests were performed. Data were analyzed with ANOVA and SNK ($p<0.05$).

Overall, use of HIS had a greater affect on texture than flavor. Both cookie types were considered less acceptable in flavor and texture than the "ideal" cookie. Physical tests supported sensory results. Although the "ideal" may not be easily formulated, the profile identifies specific product attributes for improvement.

Introduction

The number of "healthy" foods available to assist consumers in improving their eating habits is abundant. Over 60% of consumers buy "healthier" foods, such as reduced-calorie, reduced-fat or reduced-sugar items. When modifying products for health benefits, sensory attributes must be considered (Setser and Racette, 1992). Foods that are considered "healthy" are often associated with undesirable flavors and textures and an overall unpleasant eating experience (Messenger, 1992). Recently, there has been a gradual movement toward the purchase of more indulgent products, both full fat and sugar, and ones with at least some fat and sugar present in order to produce richer flavors and textures (Bloom, 1998; CCC, 1999). In fact, 88% of adults who consume reduced-in-fat foods still want the flavor that fat provides and 86% would choose a food with some fat over one with little fat if it had a better flavor (Sloan, 1995). Thus, taste continues to override health concerns in the selection among available food products (FMI, 2000). Studies have shown that acceptable reduced-in-fat and reduced-in-calorie products may be useful to consumers who are making efforts to improve their health (Harvey-Berino, 1998; Peterson and others, 1999). These acceptable products may also help consumers avoid the feeling of deprivation often associated with eating "healthy" foods (ADA, 2002).

Cookies are a favorite high-fat and high-sugar food. Sales of full-fat and sugar cookies have increased with the movement towards the purchase of products with a better taste (Bloom, 1998; Wylie, 1998). However, while high-fat and sugar products remain popular, the market for healthier versions of indulgent favorites remains strong (Sosland, 1998). Sales of sugar-free cookies, for example, increased by 15% in 1997 (Wylie, 1998). In cookies, fat and sugar contribute largely to flavor and texture. Partial, rather than total, replacement of both of these major ingredients may help to reduce calories while maintaining sensory attributes preferred by consumers (Sloan, 1995).

Two sugar substitutes, Sweet One®, marketed as an acesulfame-K/dextrose blend, and Splenda®, sold as a sucralose/maltodextrin blend, are available for consumer use. Both high intensity sweeteners (HIS) are heat stable, and therefore useful for baking. These HIS do provide sweetness, but their flavor profile does not mimic that of sucrose (Lim and others, 1989). Time of onset, degree of the sensation at a specific concentration, and the presence or absence of other tastes and feelings, such as "mouthfeel," are included in a taste profile (Alexander, 1998). Sucrose, for example, is characterized by a quick onset of sweetness followed by a cutoff that is distinct (Lim and others, 1989). Acesulfame-K (ace-K), however, is reported to have a sweetness onset more rapid than that of sucrose (Peck, 1994), and it may also leave a bitter/metallic aftertaste (Lim and others, 1989). In addition, sucralose has been described as the most potent sweetener when compared with other HIS (Wiet and Beyts, 1992) and has been found to leave an intense sweet aftertaste (Hanger and others, 1996). One approach that may be used to overcome the limitations of using just one of these sweeteners in a product is to combine sweeteners. Use of HIS blends often better meet consumer expectations for taste because synergistic effects of the two HIS result in a sweetness profile closer to that of sugar (CCC, 2002). However, many functions of sugar, such as providing bulk or incorporating air into a product, are minimized with sugar reduction (Hood and Campbell, 1990; IFIC, 1998a, 1998b; Peck, 1994). In addition, use of HIS in a fat-modified product may have different effects than in a full-fat product. Wiet and others (1993) found that the sweetness profile of a food containing HIS is affected by the amount of fat present in the food. Further, there is limited information on the effects of sugar replacement with HIS blends on texture of cookies.

The degree to which a product is liked, as well as overall acceptance, may be tested by consumer panelists (Szczesniak, 1986). These responses are based on the panelist's liking of flavor, texture, aroma, and appearance of the product (Giese, 1996). The Consumer Profile Ballot is a useful consumer testing technique that can provide additional information about the consumer's perception of the product (Szczesniak, 1975). This sensory technique has been validated as a consumer testing technique for describing product characteristics and has been used to assess the flavor and appearance as well as texture of multi-grain bread systems and doughnuts (Brochetti and others, 1991; Swanson and Penfield, 1988; Szczesniak, 1975). Perry (2001) also successfully used the ballot to evaluate cookies reduced in fat and reduced in fat and sugar. Although large variation in scores among untrained consumer panelists is common, consumers are still providing information about product characteristics (Penfield and Campbell, 1990).

The Consumer Profile Ballot consists of a list of descriptive terms, complied by a trained sensory panel, for specific attributes of the product being tested. Szczesniak and Skinner (1973) verified that consumers understand the qualitative meaning of texture words in the same way that the words are understood by trained panelists. Subsequently, the technique has been successfully applied to appearance and flavor attributes (Brochetti and others, 1991; Swanson and Penfield, 1988). In addition, bi-polar descriptive terms, such as soft and hard, serve as an internal check to verify that panelists understand the meaning of the listed words. Consumer panelists rate each characteristic on a 6-point scale, where 1=not at all and 6=very much so. Use of this type of scale produces both qualitative and quantitative data. In terms of qualitative data, differences may be attributed to specific characteristics, such as chewiness or hardness. Quantitatively, this scale also reveals the extent to which a sample possesses a certain characteristic and how it compares to other samples. A minimum of 30 panelists is required (Szczesniak, 1975).

When using the Consumer Profile Ballot, consumers are also able to describe their imaginary "ideal" product prior to evaluating a product sample using the same descriptive terms used for evaluating the actual product samples (Szczesniak, 1975). The results indicate the differences between the consumer's perception of an "ideal" product versus the product being sampled and can assist food developers in increasing the acceptability of the product (Civille, 1978; Penfield and Campbell, 1990). Instrumental methods are often helpful in explaining consumer sensory responses. These instrumental methods, which are often used to measure changes in texture, are also useful in quality control (Meilgaard and others, 1999).

The objectives of this study were (1) to examine the flavor and textural attributes and (2) to assess consumer acceptability of reduced-in-fat oatmeal and chocolate chip cookies prepared with one or more HIS.

Methods

Sample Preparation

Four reduced-in-fat cookie formulas for each of two cookie types (oatmeal and chocolate chip) were prepared. These reduced-in-fat, full-sugar control cookies were found to be acceptable by consumer panelists in a previous study; these cookies contained no HIS (Perry, 2001). The full-sugar control and three reduced-sugar cookies were prepared according to the formulas and procedures in **Tables 4.1 and 4.2**. All cookies were reduced-in-fat, containing dried plum puree to partially replace fat (CDPB, 1999). The reduced-fat, full-sugar control contained no HIS. Sugar was reduced by 50% in the three reduced-sugar cookie treatments. Half of the sugar was replaced by either acesulfame-K/dextrose blend (Sweet One®, Stadt Corporation, Brooklyn, NY), sucralose/maltodextrin blend (Splenda®, McNeil Specialty Foods, New Brunswick, NJ), or a combination of the ace-K/dextrose and sucralose/maltodextrin blends. Ratios of ace-K/dextrose and sucralose/maltodextrin blends differed between the two cookie types (**Tables 4.1 and 4.2**) and were based on preliminary work and a review of studies employing blends of acesulfame-K and sucralose (Hanger and others, 1996; Hutteau and others, 1998).

Physicochemical and Instrumental Techniques

Specific gravity was performed on the unbaked cookie dough using the method described by Penfield and Campbell (1990) on the day of mixing. For each treatment within cookie type and formulation, this comparison was made in duplicate.

Cookie spread (height, width, and height:width ratio) was performed following the AACC method 52-10 (1995). Two measurements per replication were obtained.

Water activity of the cookies was determined by using the Aqua Lab device (Decagon Devices, Pulman, WA). A Cuisinart DLC1 Mini-Prep Processor (East Windsor, NJ) was used to grind four cookies from each treatment to a uniform particle

Table 4.1. Oatmeal cookies: formula and procedure[a]

Ingredient	Control (g)	Ace-K [b] (g)	Sucralose[c] (g)	Blend [d] (g)	Product Information
All-purpose flour	222.6	222.6	222.6	222.6	ConAgra, Inc, Omaha, NE
Baking Soda	3.0	3.0	3.0	3.0	Kroger Co., Cincinnati, OH
Salt	2.8	2.8	2.8	2.8	Kroger Co., Cincinnati, OH
Oats	160.0	160.0	160.0	160.0	Quaker Oats Co., Chicago, IL
Cinnamon	1.1	1.1	1.1	1.1	Kroger Co., Cincinnati, OH
Cloves	0.3	0.3	0.3	0.3	Kroger Co., Cincinnati, OH
Nutmeg	0.6	0.6	0.6	0.6	Kroger Co., Cincinnati, OH
Sugar	**100.0**	**50.0**	**50.0**	**50.0**	**Monarch Regency, Greenville, SC**
SweetOne®	**-------**	**3.0**	**-------**	**1.3**	**Stadt Corporation Brooklyn, NY**
Splenda®	**-------**	**-------**	**6.0**	**3.0**	**McNeil Specialty Foods New Brunswick, NJ**
Brown sugar	165.0	165.0	165.0	165.0	Colonial, Savannah, GA
Vanilla	2.0	2.0	2.0	2.0	Greinoman's Unified Industry Cumming, GA
Butter	26.0	26.0	26.0	26.0	Kroger Co., Cincinnati, OH
Egg	85.0	85.0	85.0	85.0	Kroger Co., Cincinnati, OH
Shortening	62.5	62.5	62.5	62.5	Proctor and Gamble Cincinnati, OH
Dried plum puree	61.0	61.0	61.0	61.0	Sunsweet Growers, Inc. Yuba City, CA

[a]Procedure: A Kitchen-Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater, mixed the cookie dough. Cookies were baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Flour, soda, salt, oatmeal, sugar, ace-K and/or sucralose, brown sugar, cinnamon, cloves, and nutmeg was blended for 2 min. at speed 1. Dried plum puree, butter, shortening, eggs and vanilla were added and mixed for 1.5 min. at speed 1. 18 cookies (6 down, 3 across) were portioned out on a 41.91-cm X 30.48 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10). Cookie were baked for 9 min. at 176EC (350EF). Cookies containing sucralose were baked for 8 min. at 176EC (350EF).

[b]Acesulfame-K substitutions: 3.0 grams Sweet One® (ace-K/dextrose blend) for 50 grams of sugar (3.0 grams for 50% of the sugar in the control)

[c]Sucralose substitutions: 6.0 grams Splenda® (sucralose/maltodextrin blend) for 50 grams of sugar (6.0 grams for 50% of the sugar in the control)

[d]Ace-K/sucralose substitutions: 1.3 grams of Sweet One® (ace-K/dextrose blend) for 25.0 grams of sugar; 3.0 grams of Splenda® (sucralose/maltodextrin blend) for 25.0 grams of sugar (1.3 for 25% of the sugar in the control, 3.0 grams for 25% of the sugar in the control).

Table 4.2. Chocolate chip cookies: formula and procedure[a]

Ingredient	Control (g)	Ace-K [b] (g)	Sucralose[c] (g)	Blend (g)	Product Information
All-purpose flour	308.3	308.3	308.3	308.3	ConAgra, Inc, Omaha, NE
Baking Soda	3.0	3.0	3.0	3.0	Kroger Co., Cincinnati, OH
Salt	5.5	5.5	5.5	5.5	Kroger Co., Cincinnati, OH
Sugar	**150.0**	**75.0**	**75.0**	**75.0**	**Monarch Regency Greeneville, SC**
SweetOne®	**-------**	**4.5**	**-------**	**1.3**	**Stadt Corporation Brooklyn, NY**
Splenda®	**-------**	**-------**	**7.5**	**6.0**	**McNeil Specialty Foods New Brunswick, NJ**
Brown sugar	109.0	109.0	109.0	109.0	Colonial, Savannah, GA
Vanilla	4.0	4.0	4.0	4.0	Greinoman's United Industry, Cumming, GA
Butter	113.0	113.0	113.0	113.0	Kroger Co., Cincinnati, OH
Egg	114.0	114.0	114.0	114.0	Kroger Co., Cincinnati, OH
Dried plum puree	61.0	61.0	61.0	61.0	Sunsweet Growers, Inc. Yuba City, CA
Chocolate chips	200.0	200.0	200.0	200.0	Nestle USA, Solon, OH

[a]Procedure: A Kitchen-Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater, mixed the cookie dough. Cookies were baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Flour, soda, and salt were combined in a separate bowl. Butter, dried plum puree, sugar, ace-K, and/or sucralose, brown sugar, and vanilla were blended for 1 min. at speed 1. Beaten egg was added and incorporated for 1 min. at speed 1. Flour mixture was gradually added over a 2 minute period while continuing to mix at speed 2. Chocolate chips were added and mixed at speed 1 for 1 min. 18 cookies (6 down, 3 across) were portioned out on a 41.91-cm X 30.48 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10). Cookie were baked for 10 min. at 190EC (375EF). Cookies containing sucralose were baked for 9 min. at 190EC (375EF).

[b]Acesulfame-K substitutions: 4.0 grams Sweet One® (ace-K/dextrose blend) for 75 grams of sugar (4.0 grams for 50% of the sugar in the control).

[c]Sucralose substitutions: 7.5 grams Splenda® (sucralose/maltodextrin blend) for 75 grams of sugar (7.5 grams for 50% of the sugar in the control).

[d]Ace-K/sucralose substitutions: 1.3 grams of Sweet One® (ace-K/dextrose blend) for 25.0 grams of sugar; 6.0 grams of Splenda® (sucralose/maltodextrin blend) for 50.0 grams of sugar (1.3 for 25% of the sugar in the control, 6.0 grams for 25% of the sugar in the control).

size. For each treatment, measurements were taken on three aliquots of the composite samples as described by Curley and Hoesney (1984).

The day after baking, puncture testing was performed. The cookies were probed according to the method described by Bourne (1965, 1999) and Perry and others (2003). Four cookies from each treatment were punctured 9 times in an offset bull's-eye pattern (**Figure 4.1**), each with a 0.3-cm probe at a crossarm speed of 5 mm/second and trigger force of 10 grams (Bourne, 1965; Gaines and others, 1992; Perry and others, 2003). Because edge effects may have an effect on hardness, the outer 15% of the cookie was avoided (Gaines and others, 1992). A baseplate with a hole 0.6-cm in diameter was used to accept the probe as it passed through the sample. A 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert Software, version 1.20 (Stable Micro Systems, Haselmere, Surrey, New England) was used.

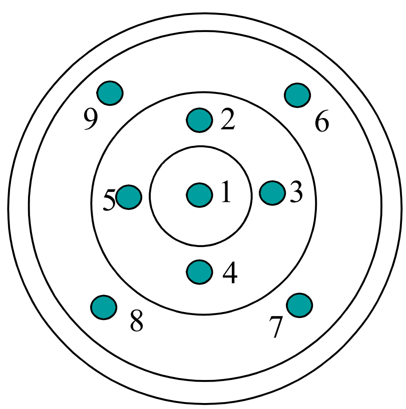

Figure 4.1. Representative probing pattern for oatmeal and chocolate chip cookies using a 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert, version 1.20 (Stable Micro Systems, Haselmere, Surrey, England) and a 0.3 cm probe at a crossarm speed of 5 mm/s.

A force-time curve was produced from each probe. Parameters of the curve that were analyzed included maximum force to achieve penetration, slope and area under the curve. For statistical analysis, the center probe (probe 1), the average inner concentric circle value (probes 2, 3, 4, and 5) and the average outer concentric circle values (probes 6, 7, 8, and 9) were used.

Consumer Sensory Panel

A total of 61 consumer panelists evaluated cookies the day after baking. Thirty panelists evaluated the four oatmeal cookie treatments and thirty-one panelists evaluated the four chocolate chip cookie treatments. Each panelist evaluated only one cookie type. The order or serving was balanced within cookie type and across the panel to avoid potential psychological errors. Three-digit random numbers were also used to code each sample to avoid bias.

Panelists evaluated samples in individual booths under white light. The panelists were instructed to cleanse their palate with unsalted crackers and distilled water between samples. Each panelist used a Consumer Profile Ballot to rate the intensity of each flavor and texture attribute on a 6-point scale. Flavor attributes evaluated included sweet, salty, bland, good, off-flavors, buttery, strong, bitter, and brown sugar for oatmeal and chocolate chip cookies. Molasses flavor for oatmeal cookies and chocolate flavor for chocolate chip cookies were also evaluated. Texture attributes evaluated included crisp, greasy, chewy, hard, bad, crumbly, good, rough, and soft for both cookie types. Prior to sampling the cookies, consumers also completed a ballot in order to describe their "ideal" cookie. Desired intensity of each attribute in this imaginary cookie was identified. Each participant also provided biographical information as well as information about product use.

Statistical Analysis

All results from the sensory and instrumental tests were analyzed using SAS software (SAS for Windows, version 8.2, SAS, Inc., Cary, NC). Equal variances within each treatment were verified (PROC MEANS). Normality plots were produced by PROC UNIVARIATE in order to verify that the data were normally distributed. The data from the main effects and their interactions were analyzed for variance ($p<0.05$) using PROC GLM. Means separation was performed using Student-Newman-Kuels (S-N-K).

Results and Discussion

Physicochemical and Instrumental Tests

Results from all physicochemical and instrumental tests are found in **Table 4.3**. Specific gravity of cookie doughs either remained the same or decreased with sugar reduction. Previously, Perry and others (2003) reported that reduced-in-fat and reduced-in-fat and sugar cookie dough had a greater specific gravity than the full-sugar control, indicating increased dough aeration (Alexander, 1998; Kamel, 1994). Specific gravity also increased in chocolate chip cookies reduced-in-fat by 50% and 75% when compared

Table 4.3. Means and standard deviations of physicochemical/instrumental tests for oatmeal (OAT) and chocolate chip (CC) cookies[a]

		Cookie Treatment[b]			
Cookie type	Test	Full-sugar control	Acesulfame-K[c]	Sucralose[d]	Blend[e]
OAT	Specific gravity[f]	1.04±0.01a	1.04±0.03a	1.03±0.02a	1.02±0.01a
	Cookie spread[g]	7.66±0.40a	6.98±0.10b	7.53±0.50c	7.59±0.15a
	Water activity[h]	0.52±0.04a	0.51±0.01b	0.57±0.39c	0.57±0.01d
	Probe--				
	Height (mm)[i]	8.92±0.65a	9.42±0.59b	8.42±0.54c	8.70±0.57a
	Force (g)[i]	540.74±155.57a	541.66±12.31a	406.62±78.10b	382.69±100.26b
	Time (s)[i]	0.61±0.15a	0.70±0.31a	0.72±0.29a	0.76±0.35a
	Slope (g/s)[i]	752.79±533.85a	674.05±440.56	454.47±223.50b	430.84±293.58c
	Area[i]	1560.0±1048.14a	1833.07±1550.05a	1458.76±1522.72b	1246.73±1032.09b
CC	Specific gravity[f]	1.10±0.08a	1.06±0.09b	1.06±0.08b	1.06±0.10b
	Cookie spread[g]	7.38±0.52a	6.36±0.29b	6.15±0.24c	6.23±0.17d
	Water activity[h]	0.40±0.03a	0.49±0.05b	0.54±0.04c	0.52±0.03d
	Probe--				
	Height (mm)[i]	9.87±0.83a	9.85±0.83a	10.32±0.87a	10.04±0.86a
	Force (g)[i]	835.66±617.49a	897.04±554.81ab	662.28±204.80c	739.38±556.80ab
	Time (s)[i]	0.63±0.23a	0.57±0.21a	0.71±0.24a	0.61±0.24a
	Slope (g/s)[i]	1852.76±383.16a	2107.76±301.12a	1073.37±799.25b	1533.09±1428.63a
	Area[i]	838.91±495.07a	850.52±459.58a	717.93±445.06a	838.91±661.4a

[a]Means within cookie type and parameter followed by different letters were significantly different according to ANOVA and SNK ($p<0.05$).
[b]All treatments were reduced-in-fat formulations prepared with dried plum puree (Sunsweet Growers, Inc., Yuba City, CA).
[c]3.0 g ace-K/dextrose blend (Sweet One®, Stadt Corp, Brooklyn, NY) was used to replace 50 g (50%) of granulated sugar in oatmeal cookies; 4.5 g Sweet One® replaced 7.5 g (50%) of granulated sugar in chocolate chip cookies.
[d]6.0 g sucralose/maltodextrin blend (Splenda®, McNeil Specialty Products, New Brunswick, NJ) was used to replace 50 g (50%) granulated sugar in oatmeal cookies; 7.5 g Splenda® replaced 75 g (50%) granulated sugar in chocolate chip cookies.
[e]A 1:3 Sweet One®:Splenda® blend (oatmeal cookies) and 1:6 Sweet One®:Splenda® blend (chocolate chip cookies) replaced 50% of granulated sugar.
[f]Means are across 3 replications on 2 samples per replication.
[g]Means are across 2 determinations and 3 replications (AACC method 52-10, 1995).
[h]Means are across 3 replications with 4 analyses per replication; measured using Aqua Lab (Decagon Devices, Pullman, WA).
[i]Means based on 3 values per cookie per 3 replications; determined with a 50-kg capacity TA.XT2 Texture Analyzer (Stable Micro Systems, Haselmere, Surrey, England), and a 3.0-cm probe at a crossarm speed of 5 mm/s (Bourne, 1999; Gaines and others, 1992).

with the full-fat control (Armbrister and Setser, 1994). The decreased specific gravity for modified cookies in this study suggests that dough aeration decreased and effects on texture of the baked cookies may occur.

Cookie spread, and overall indicator of cookie quality, decreased in both cookie types when sugar was reduced. This is similar to findings previously reported for reduced-in-fat and sugar cookies (Perry and others, 2003). In reduced-sugar products, dough fluidity decreases because there is less sugar present to melt and contribute to spread during baking. Reduction of sugar also allows flour to bind more water (Doescher and others, 1987), leading to increased starch gelatinization and a reduced spread (Spies and Hoseney, 1982). Therefore, these modified cookies tend to be thicker with a smaller diameter than is found for the control.

Water activity increased in modified oatmeal and chocolate chip cookies, although water activity levels remained below 0.60. Susceptibility to microbial growth occurs when water activity rises above 0.60. Increased water activity for reduced-in-fat (Swanson and Munsayac, 1999) and reduced-in-fat-and-sugar cookies has been reported (Perry and others, 2003). Sugar functions to bind water and therefore lower the water activity of the food (Alexander, 1998).

Instrumentally, a chewy product is associated with an increased time to reach maximum force and a decreased slope during probing. Reduced-in-fat-and-sugar cookies tend to be chewier because of the reduced amount of fat and sugar and associated increase in moisture content and gluten development (Perry and others, 2003). Similar results have been found in reduced-in-fat cookies (Armbrister and Setser, 1994). In this study, there were no significant differences in time to penetration with modification for either cookie type. Slope, however, decreased significantly when either sucralose or an ace-K/sucralose blend was used in oatmeal cookies and in chocolate chip cookies prepared with sucralose. The lack of change in time to penetration coupled with a decreased slope in cookies containing sucralose suggests that this HIS, when used to partially replace sugar, produces a cookie that may be described as being tender, rather than chewy.

Sucralose and ace-K/sucralose blend cookies were less hard than other cookies. Gaines and others (1992) reported that hardness was indicated by the force measured as the probe penetrated through a cookie. For both cookie types, modification with sucralose and ace-K/sucralose blend decreased maximum penetration force, while use of ace-K alone increased force. Ace-K cookies, however, did not differ from the full-sugar control. When fat and sugar are reduced in cookies, the texture becomes softer and cake-like due to increased starch gelatinization (Penfield and Campbell, 1990). In addition, dried plum puree, which contains hygroscopic compounds, was used as the fat replacer in these cookies. Therefore, gluten development associated with a decrease in fat and an increase in flour hydration may have been minimized, resulting in a softer cookie.

Maximum force to penetrate and slope are integrated when measuring area under the curve. Toughness of reduced-in-fat cookies has been interpreted by analyzing area under the curve (Sanchez and others, 1995). Perry and others (2003), however, suggested that area under the curve was a good predictor of oral hardness, chewiness, and cohesivenss. For oatmeal cookies, area under the curve for control and ace-K cookies was significantly larger than the area of cookies prepared with sucralose or ace-K/sucralose blend. Area under the curve did not differ for chocolate chip cookies.

Sensory Flavor Attributes

In **Figures 4.2 and 4.3**, sensory attribute means for each cookie sample are plotted as deviations from the “ideal” product which was also described using the Consumer Profile Ballot. This information can be used to determine how closely the “ideal” matches the samples evaluated, including the control. This facilitates the process of product modification by providing a target for modification (Szczesniak, 1975). “Ideal” oatmeal and chocolate chip cookies had moderately high sweetness, brown sugar and butter flavors. Levels of bitterness, blandness and off-flavors were low. “Ideal” oatmeal cookies had moderately intense molasses flavor. Chocolate chip “ideal” cookies were high in chocolate flavor and low in saltiness.

Few significant flavor differences were found among full-sugar control and modified cookies. Full-sugar oatmeal cookies and those prepared with ace-K did not differ from each other but were significantly different in salty and buttery flavors from sucralose and ace-K/sucralose blend oatmeal cookies. Off-flavors were significantly greater in sucralose and ace-K/sucralose blend chocolate chip cookies than in full-sugar and ace-K cookies. For oatmeal cookies, differences also existed between the modified cookies, which did not differ from each other, and the control for brown sugar flavor.

Combining ace-K and sucralose has been found to minimize undesirable effects of each of these sweeteners (Hanger and others, 1996; Lim and others, 1989), such as an increased sweetness onset or “potent” sweetness (Hood and Campbell, 1990; Wiet and Beyts, 1992). No significant differences, however, were found in

Figure 4.2a Oatmeal Cookie Flavor Attributes

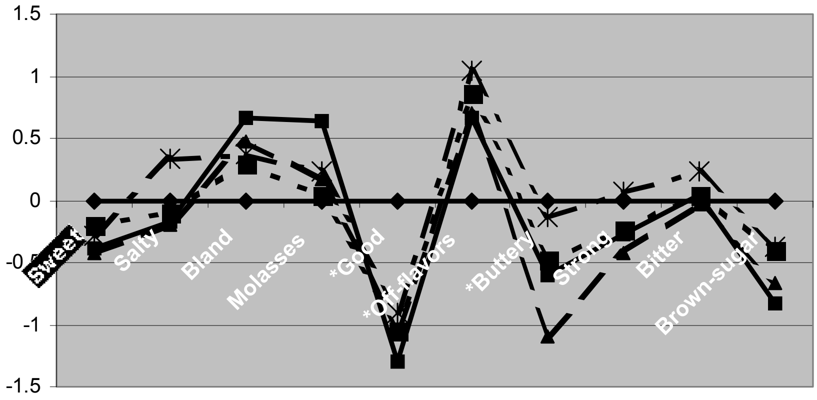

Figure 4.2b. Chocolate Chip Cookie Flavor Attributes

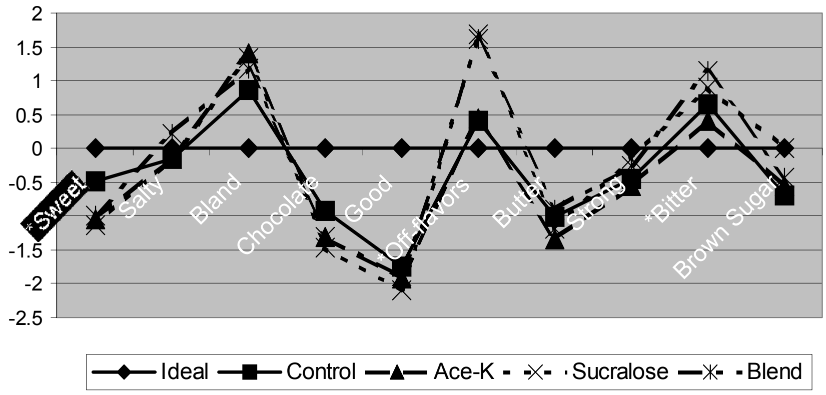

Figure 4.2. Flavor attributes: descriptive profiles of oatmeal (4.2a) and chocolate chip(4.2b) cookies prepared in four formulations: full-sugar control, acesulfame-K (ace-K), sucralose, and ace-K/sucralose blend (blend). Means of each attribute are plotted as deviations from the “ideal” cookie. *Indicates a significant difference among treatments.

Figure 4.3a. Oatmeal Cookie Texture Attributes

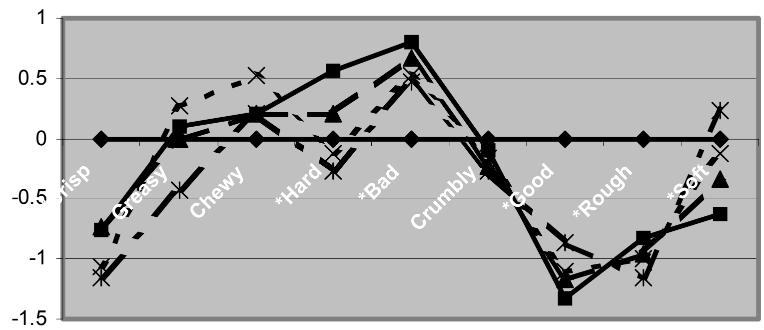

Figure 4.3b. Chocolate Chip Cookie Texture Attributes

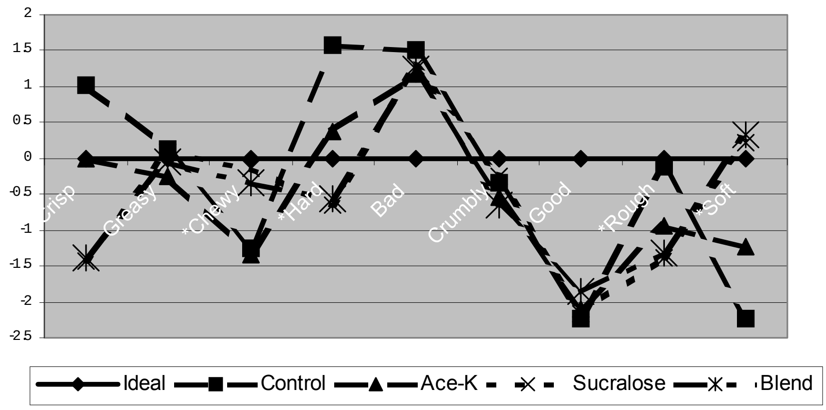

Figure 4.3. Texture attributes: descriptive profiles of oatmeal (4.3a) and chocolate chip(4.3b) cookies prepared in four formulations: full-sugar control, acesulfame-K (ace-K), sucralose, and ace-K/sucralose blend (blend). Means of each attribute are plotted as deviations from the "ideal" cookie. *Indicates a significant difference among treatments.

sweetness among reduced-in-fat and reduced-in-fat-and-sugar oatmeal cookies. Although the modified chocolate chip cookies did not differ from one another in sweetness, differences from the control were found. Only the chocolate chip cookies prepared with ace-K were as sweet as the control; the successful use of both of these HIS may be attributed to the partial retention of sugar and fat in these cookies. In addition, when ace-K is combined with sorbitol, the initial sweetness of ace-K is improved and becomes more balanced (Bullock and others, 1992). Dried plum puree, which contains sorbitol, was used as the fat replacer. Malic acid in the dried plum puree may have also minimized the intense sweetness often associated with sucralose. Malic acid functions to enhance other flavors in the system. During mastication malic acid is slowly released and has a greater carry-through which may have contributed to the decreased perception of sweetness (CDPB, 1999).

Overall oatmeal cookie flavor acceptability (4.60±1.25), indicated by the attribute “good,” did not differ, although samples were less acceptable than the “ideal” (5.67±0.84). Overall, flavor acceptability of chocolate chip cookies did not differ (3.93±1.20), although samples were less acceptable than the “ideal” (5.84±0.45). While the “ideal” provides a target for modification, reformulation to achieve the “ideal” flavor may not be technically possible (Szczesniak, 1975).

Sensory Texture Attributes

“Ideal” oatmeal cookie texture exhibited moderately high softness and chewiness with low levels of greasiness/oiliness and crumbliness. “Ideal” texture of chocolate chip cookies exhibited moderately high softness and chewiness with low levels of hardness, crispness, roughness, crumbliness, and greasiness/oiliness.

Full-sugar oatmeal cookies did not differ from the "ideal" with the exception of crispness, hardness, and roughness. Full-sugar and all modified cookies were significantly less crisp then the "ideal." The modified oatmeal cookies did not differ from the "ideal" in hardness, but the full-sugar control was significantly harder than the "ideal" and the modified cookies. Instrumental data also indicate that the full-sugar control cookies were harder than all modified cookies, except for those prepared with ace-K alone. All cookies were also more rough than the "ideal." Overall texture acceptability of all oatmeal cookie samples, as indicated by the attribute "good," did not differ and was lower (4.85±1.23) than the "ideal" (5.79±0.79).

Consumers found full-sugar chocolate chip cookies to be significantly crisper and harder than the "ideal." Modified cookies were less crisp and less hard than the control. Instrumental data also show that sucralose and ace-K/sucralose cookies were softer than the full-sugar control. Thus, the modified cookies matched the "ideal" better than the control. Full-sugar control cookies were significantly less chewy than the "ideal." Overall texture acceptability of all chocolate chip cookie samples did not differ, as indicated by the attribute "good," but was lower (3.86±1.15) than the "ideal" (5.94±0.25) chocolate chip cookies.

Conclusions

Consumers are able to describe their "ideal" product using the Consumer Profile Ballot. Product reformulation may be based on the "ideal," although modification may not actually be possible (Szczesniak, 1975). In general, modified oatmeal cookies were more similar to each other and to the "ideal" than to the full-sugar control in both flavor and texture. All chocolate chip cookies were similar to one another, with ace-K cookies most closely matching the "ideal." Instrumental tests supported the perception of consumer panelists. In terms of overall acceptability, modified cookies in this experiment did not differ from the control, and all cookies, both oatmeal and chocolate chip, were less acceptable than the "ideal."

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CHAPTER V

DESCRIPTIVE ANALYSIS OF REDUCED-IN-FAT COOKIES PREPARED WITH HIGH INTENSITY SWEETENERS (HIS) OR A BLEND OF HIS[1]

[1]Cardello EE, Swanson RB, Lyon BG and Savage EM. To be submitted to *J Am Diet Assoc*.

Abstract

Objectives To evaluate the flavor and texture effects of reducing and replacing 50% of the sucrose in reduced-in-fat oatmeal and chocolate chip cookies with acesulfame-K (ace-K), sucralose, or a blend of ace-K/sucralose.

Design/Subjects Eight trained, descriptive sensory panelists employed the Spectrum Method™ to evaluate 3 replications of 4 cookies (full-sugar control, ace-K, sucralose, ace-K/sucralose blend) of each cookie type (oatmeal and chocolate chip). Overall, 16 different flavor and texture attributes and 2 aftertastes specific to each cookie type were evaluated on a 15-point intensity scale using Compusense®*five* software. Specific gravity, cookie spread, water activity and puncture testing were performed.

Analysis Data were analyzed using SAS software, version 8.2, to determine differences in texture and flavor during mastication and existence of aftertastes.

Results Although no significant flavor effects were found during mastication of either cookie type, textural differences and aftertastes did exist for both cookie types. Specific gravity was significantly affected by sugar reduction. Cookie spread decreased and water activity increased with modification. Results of the texture probe test revealed that control cookies were the hardest, and that cookies prepared with ace-K alone were most similar to full-sugar cookies.

Applications/Conclusions Availability of reduced-in-fat and sugar foods may reduce excess fat and simple carbohydrate consumption associated with chronic diseases, while allowing retention of some favorite foods in the diet. Sensory attributes must be considered when products are modified for health benefits. Use of high intensity

sweeteners to partially replace sugar in foods can help to decrease calories while maintaining flavor, although textural changes may occur. Trained panelists assist in the development of reduced-in-fat and sugar foods through descriptive analysis; specific product attributes are evaluated and sensory texture and flavor profiles of the products are produced.

Introduction

Obesity and chronic diseases associated with excess body weight have increased dramatically in the United States over the past 20 years (CDC, 1999). Calorie consumption among Americans has also risen, with increased fat and sugar consumption being major contributors to this increase (Tippett and Cleveland, 1999). The percentage of calories in the energy mix coming from total fat is 33%, a 7% decrease from 1978. However, the actual number of calories consumed has increased by 6% during this time period, resulting in an increase in the grams of actual fat consumed (Tippett and Cleveland, 1999). Consumption of added fat, or fats incorporated into processed products or during food preparation, increased by 11 grams between 1970 and 1996 (Kantor, 1999).

The higher fat levels in the energy nutrient mix leads to an increase in calorie consumption per gram (CCC, 1998). However, the diet is not complete without fat. Nutritionally, fat helps to transport fat-soluble vitamins and provide essential fatty acids. From a gustatory perspective, it contributes to flavor, texture, and satiety of a food. However, increased risk for diseases such as obesity, coronary heart disease and cancer can occur with excess fat intake (Akoh, 1998; CCC, 1998). The 2000 USDA Dietary Guidelines recommend that <30% of total calories come from fat (USDA, 2000).

While sugars contribute numerous important functions in foods, such as tenderness, sweetness, and a browned appearance (Sugar Association, 2000a), consuming large amounts may be a threat to good health. On average, Americans consume 64 pounds of caloric sweeteners each year (Sugar Association, 2000b). Excess consumption of sugary foods has long been associated with dental caries. The displacement of nutrient dense foods by those high in sugar may lead to an increased caloric intake and, ultimately, obesity (Guthrie and Morton, 2000). Resistance to insulin, associated with diabetes, may also result from consumption of too many sugars (Brand-Miller, Holt, Pawlak, and McMillan, 2002). Further, sugars increase serum triglyceride levels, which may be related to an increased risk for coronary heart disease (Hellerstein, 2002). The Food Guide Pyramid recommends that sugar intake be limited. The new dietary reference intakes (DRI) also recommend that maximum energy from added sugars be limited to 25% or less (FNB and IOM, 2002). In a typical 2000 kcal American diet, approximately 16% of total calories comes from added sugars. While this is still within the DRI guidelines, consumption of added sugars continues to increase (McBride, 2000). Over the last 20 years, a 15% increase in the consumption of cakes, cookies, pies, and pastries, all of which contain high amounts of calories from fat and sugar, have contributed to this trend (Tippett and Cleveland, 1999).

While consumers continue to eat high-fat and high-sugar foods, there has also been an increase in the availability of foods that have been reduced in fat and/or sugar.

CCC (1999) reported that 85% of adults purchase reduced-fat foods and 144 million Americans use sugar-free products. Ironically, the increased consumption of foods modified in fat and sugar seems to parallel the increase in obesity. Many products modified in fat and sugar contain calories that equal the traditional product (CCC, 2002). Further, consumers have indicated they would choose a food with some fat over one with no fat if it had a better flavor (Sloan, 1995). The desire for improved flavor has led to the recent gradual increase in consumption of more indulgent foods, or foods with some fat and sugar present in order to produce a more acceptable product (Bloom, 1998; CCC, 1999).

When modifying products for health benefits, sensory attributes must be considered (Setser and Racette, 1992). In weight reduction, decreasing both calories and fat is more beneficial than decreasing fat alone (Harvey-Berino, 1998). Therefore, modifying popular high-fat, high-sugar foods, like cookies, to ultimately produce a product that is lower in calories while maintaining sensory characteristics may facilitate maintenance of a healthy weight and the retention of preferred foods in the diet (Bloom, 1998).

Cookies are a popular baked snack food, but are higher in fat and sugar compared to other baked products. Formulations are 30-75% sugar, 30-60% fat and 7-20% water on a flour-weight-basis (Pyler, 1988). Therefore, it is difficult to maintain the sensory characteristics of a cookie when fat and sugar are reduced. Fat not only imparts a desirable flavor, but it also adds volume and structure to the cookie. Use of fat replacers may be able to impart some, but not all, of the functions of fat, including flavor, palatability, appearance, creaminess, texture and lubricity (Akoh, 1998). Similarly, sugar substitutes may be used to replace the sweetness that sugar provides in the product, although the flavor profile of sucrose may not be easily duplicated and many of the functional properties are lost. Flavor, air incorporation, and bulk are among the properties that are minimized when sugar is replaced with substitutes (Alexander, 1998; Penfield and Campbell, 1990).

Dried plum puree, a fruit-based fat substitute, has been used successfully to replace fat in cookies. The fiber, pectin, sorbitol, and reducing sugars in the puree contribute sweetness and humectancy, which facilitates the formulation of reduced-in-fat baked products (Stockwell, 1995). Swanson and Munsayac (1999) found that both oatmeal and chocolate chip cookies reduced in fat by replacing 50% of the fat with dried plum puree were acceptable when compared to the full-fat control. However, chocolate chip cookies in which 70% of fat was replaced with dried plum puree were considered less acceptable than the full-fat cookie (Charlton and Sawyer-Morse, 1996).

Partial reduction of sugar in addition to fat reduction may facilitate desired calorie, fat and sugar reduction while maintaining sensory characteristics. Two sugar substitutes, acesulfame-K (ace-K), available as an ace-K/dextrose blend, and sucralose, marketed as a sucralose/maltodextrin blend, are heat stable and suitable for use in baked products. Although sweet, their flavor profiles do not mimic that of sucrose. Undesirable aftertastes have also been associated with these two high intensity sweeteners (HIS). In addition, functional properties of sugar are minimized when ace-K or sucralose is used as a sugar substitute (Chapello, 1998; Peck, 1994). However, partial, not total, replacement of sugar with HIS may help maintain desirable sensory characteristics. Potential synergistic effects between two HIS or a combination of sucrose and HIS may overcome the limitations of using one sweetener (Hanger, Lotz and Lepeniotis, 1996; Hutteau, Mathlouthi, Portmann, and Kilcast, 1998; Verdi and Hood, 1993).

Use of HIS blends often better meet consumer expectations for taste. Synergistic effects of the two HIS result in a sweetness profile closer to that of sugar (CCC, 2002). There is limited information, however, about the effects of HIS blends or HIS-sucrose blends on texture. Furthermore, incorporation of HIS in reduced-in-fat products may also be more complex as the sweetness profile is affected by the amount of fat present in the food (Wiet, Ketelsen, Davis and Beyts, 1993).

A trained sensory panel, typically comprised of 8-10 individuals, is a useful tool in the product modification process because different product formulations can be compared quantitatively, allowing those products most like the standard product to be further refined (Knehr, 2002). Unlike consumer panels, trained panelists are not used to determine acceptability of a product (Meilgaard, Civille, and Carr, 1999). Rather, product sensory characteristics are identified, and in some cases quantified, in order to facilitate discussion about the product. Sensory profiles of a product are generated by rating intensities of each perceived characteristic on rating scales (Knehr, 2002; Meilgaard, Civille, and Carr, 1999). Perry, Swanson, Lyon and Savage (2003) employed a trained panel to provide sensory texture and flavor profiles of reduced-in-fat and reduced-in-fat-and-sugar cookies. Instrumental methods, typically used in quality control, may also be used to assess texture. Instrumental assessment is helpful, only when validated with a sensory panel (Meilgaard, Civlle, and Carr, 1999)

The primary purpose of this study was to evaluate reduced-in-fat oatmeal and chocolate chip cookies prepared by replacing half of the sugar with either a single HIS or with a blend of sweeteners. Texture, flavor and aftertastes for both cookie types were assessed by trained sensory panelists. Physicochemical and instrumental tests were also used to assess effects of the modifications on cookie texture.

Methods

Sample preparation

Four different cookie formulations of each cookie type (oatmeal or chocolate chip) were prepared: full-sugar control and three types of reduced-sugar cookies (ace-K, sucralose, and ace-K/sucralose blend) according to the formulas and procedures in **Tables 5.1 and 5.2**. All cookie formulations were reduced-in-fat, containing dried plum puree to replace half of the added fat (CDPB, 1999). The reduced-fat, full-sugar control contained no high intensity sweetener (HIS) and had previously been found to be acceptable by consumer sensory panelists (Perry, 2001). Sugar was reduced by 50% in all other cookie formulations by replacing half of the sugar with either ace-K/dextrose blend (SweetOne®, Stadt Corporation, Brooklyn, NY), sucralose/maltodextrin blend (Splenda®, McNeil Specialty Foods, New Brunswick, NJ), or a combination of the ace-K/dextrose and sucralose/maltodextrin blends. Ratios of ace-K/dextrose and

Table 5.1. Oatmeal cookies: formula and procedure[a]

Ingredient	Control (g)	Ace-K [b] (g)	Sucralose[c] (g)	Blend[d] (g)	Product Information
All-purpose flour	222.6	222.6	222.6	222.6	ConAgra, Inc,Omaha, NE
Baking Soda	3.0	3.0	3.0	3.0	Kroger Co,Cincinnati, OH
Salt	2.8	2.8	2.8	2.8	Kroger Co, Cincinnati,OH
Oats	160.0	160.0	160.0	160.0	Quaker Oats Co., Chicago, IL
Cinnamon	1.1	1.1	1.1	1.1	Kroger Co, Cincinnati,OH
Cloves	0.3	0.3	0.3	0.3	Kroger Co, Cincinnati,OH
Nutmeg	0.6	0.6	0.6	0.6	Kroger Co, Cincinnati,OH
Sugar	**100.0**	**50.0**	**50.0**	**50.0**	**Monarch Regency Greenville, SC**
SweetOne®	**-------**	**3.0**	**-------**	**1.3**	**Stadt Corporation Brooklyn, NY**
Splenda®	**-------**	**-------**	**6.0**	**3.0**	**McNeil Specialty Foods New Brunswick, NJ**
Brown sugar	165.0	165.0	165.0	165.0	Colonial, Savannah, GA
Vanilla	2.0	2.0	2.0	2.0	Greinoman's Unified Industry, Cumming, GA
Butter	26.0	26.0	26.0	26.0	Kroger Co, Cincinnati,OH
Egg	85.0	85.0	85.0	85.0	Kroger Co, Cincinnati,OH
Shortening	62.5	62.5	62.5	62.5	Proctor and Gamble Cincinnati, OH
Dried plum puree	61.0	61.0	61.0	61.0	Sunsweet Growers, Inc. Yuba City, CA

[a]Procedure: Ingredients were mixed with a Kitchen-Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater and baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Flour, soda, salt, oatmeal, sugar, ace-K and/or sucralose, brown sugar, cinnamon, cloves, and nutmeg were blended for 2 min. at speed 1. Dried plum puree, butter, shortening, eggs and vanilla were added and mixed for 1.5 min. at speed 1. Eighteen cookies (6 down, 3 across) were portioned out on a 41.91-cm X 30.48 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10). Cookie were baked for 9 min. at 176EC (350EF). Cookies containing sucralose were baked for 8 min. at 176EC (350EF).

[b]Acesulfame-K substitutions: 3.0 grams Sweet One® (acesulfame-K/dextrose blend) for 50 grams of sugar (3.0 grams for 50% of the sugar in the control)

[c]Sucralose substitutions: 6.0 grams Splenda® (sucralose/maltodextrin blend) for 50 grams of sugar (6.0 grams for 50% of the sugar in the control)

[d]Ace-K/sucralose substitutions: 1.3 grams of Sweet One® (acesulfame-K/dextrose blend) for 25.0 grams of sugar; 3.0 grams of Splenda® (sucralose/maltodextrin blend) for 25.0 grams of sugar (1.3 for 25% of the sugar in the control, 3.0 grams for 25% of the sugar in the control).

Table 5.2. Chocolate chip cookies: formula and procedure[a]

Ingredient	Control (g)	Ace-K [b] (g)	Sucralose[c] (g)	Blend[d] (g)	Product Information
All purpose flour	308.3	308.3	308.3	308.3	ConAgra, Inc, Omaha, NE
Baking Soda	3.0	3.0	3.0	3.0	Kroger Co, Cincinnati,OH
Salt	5.5	5.5	5.5	5.5	Kroger Co, Cincinnati,OH
Sugar	**150.0**	**75.0**	**75.0**	**75.0**	**Monarch Regency Greeneville, SC**
SweetOne®	**-------**	**4.5**	**-------**	**1.3**	**Stadt Corporation Brooklyn, NY**
Splenda®	**-------**	**-------**	**7.5**	**6.0**	**McNeil Specialty Foods New Brunswick, NJ**
Brown sugar	109.0	109.0	109.0	109.0	Colonial, Savannah, GA
Vanilla	4.0	4.0	4.0	4.0	Greinoman's United Industry, Cumming, GA
Butter	113.0	113.0	113.0	113.0	Kroger Co, Cincinnati,OH
Egg	114.0	114.0	114.0	114.0	Kroger Co, Cincinnati,OH
Dried plum puree	61.0	61.0	61.0	61.0	Sunsweet Growers, Inc. Yuba City, CA
Chocolate chips	200.0	200.0	200.0	200.0	Nestle USA, Solon, OH

[a]Procedure: Ingredients were mixed with a Kitchen Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater and baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Flour, soda, and salt were combined in a separate bowl. Butter, dried plum puree, sugar, ace-K, and/or sucralose, brown sugar, and vanilla were blended for 1 min. at speed 1. Beaten egg was added and incorporated for 1 min. at speed 1. Flour mixture was gradually added over a 2 minute period while continuing to mix at speed 2. Chocolate chips were added and mixed at speed 1 for 1 min. Eighteen cookies (6 down, 3 across) were portioned out on a 41.91-cm X 30.48 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10). Cookies were baked for 10 min. at 190EC (375EF). Cookies containing sucralose were baked for 9 min. at 190EC (375EF).

[b]Acesulfame-K substitutions: 4.0 grams Sweet One® (acesulfame-K/dextrose blend) for 75 grams of sugar (4.0 grams for 50% of the sugar in the control).

[c]Sucralose substitutions: 7.5 grams Splenda® (sucralose/maltodextrin blend) for 75 grams of sugar (7.5 grams for 50% of the sugar in the control).

[d]Ace-K/sucralose substitutions: 1.3 grams Sweet One® (acesulfame-K/dextrose blend) for 25.0 grams of sugar; 6.0 grams Splenda® (sucralose/maltodextrin blend) for 50.0 grams of sugar (1.3 for 25% of the sugar in the control, 6.0 grams for 25% of the sugar in the control).

sucralose/maltodextrin blends differed between the two cookie types (**Tables 5.1 and 5.2**) and were selected based on preliminary work and a review of studies employing blends of ace-K and sucralose (Hanger, Lotz and Lepeniotis, 1996; Hutteau, Mathlouthi, Portmann, and Kilcast, 1998). Three replications of each formulation were produced for evaluation with sensory, physicochemical and physical techniques.

Selection and training of sensory panel members

Eight sensory panelists were chosen based on their ability to detect and describe various product characteristics and their intensities using verbal and scaling techniques. Panelists could also successfully identify basic tastes and discriminate among similar products. An interest in participation, general good health, and availability were also considered (Meilgaard, Civille and Carr, 1999). All panelists had previous experience evaluating sensory properties of cookies and were familiar with the test conditions, test procedures, and the computerized scoring system (Compusense®*five*, release 4.0, Compusense, Inc., Guelph, Ontario, Canada).

The total training period lasted approximately 50 hours. The basic tastes and their intensities were reviewed by sampling solutions that differed in concentration for each of the basic tastes (sweet, sour, salty, bitter). A lexicon of terms describing cookies was also reviewed and specific texture and flavor attributes to be evaluated were identified by assessing a variety of products. The list of possible terms was condensed and products which represented the terms were identified as references (**Table 5.3**).

Table 3.5. Sensory profile attributes, definitions and references used by trained sensory panel to evaluate oatmeal and chocolate chip cookies[a]

OATMEAL	**CHOCOLATE CHIP**		
Texture attributes		***Definitions:***	***Reference products[b]***
Manual Hardness	Manual Hardness	Manual force required to break or separate the sample into pieces	Pringle (4) Ginger snap (10)
Roughness	Roughness	Amount of particles in the surface as detected by the lips.	Gelatin (0) Pringle (8) Rye wafer (15)
Cohesiveness	Cohesiveness	Degree to which the sample deforms rather than crumbles, cracks or breaks at first chew with molar teeth	Corn bread (1) Raisin (10 Chewing gum (15)
Oral Hardness	Oral Hardness	Force required to bite through sample at first chew with molar teeth	American cheese (4) Peanuts (9.5) Lifesavers (14.5)
Chewiness	Chewiness	Amount of work to chew sample to point of swallow	Rye bread (1.5) Gum drop (5.8) Tootsie roll (13)
---	Oily Mouthcoat	Amount of oily coating in the mouth during mastication	Keebler Chips Deluxe Soft and Chewy (~5)
Flavor attributes/Basic tastes[c]		***Definitions*:**	***Reference samples[d] or solutions[b]***
Cinnamon/ woody	---	Aromatic/taste sensations associated with cinnamon and non-specific spices	0.3 g cinnamon/clove/nutmeg mixture
Brown sugar (molasses)	---	Aromatic/taste sensations associated with brown sugar/molasses	4.5 g light brown sugar
Dried plum puree	Dried plum puree	Aromatic/taste sensations associated with dried plum puree	6.0 g dried plum puree
Grainy/oatmeal	Grainy/oatmeal	Aromatic/taste sensations associated with non-specific grain/oatmeal	6.5 g old-fashioned oats

---	Brown sugar (caramelized)	Aromatic/taste sensations associated with brown sugar/caramelization	4.5 g light brown sugar
---	Chocolate	Aromatic/taste sensations associated with chocolate	18.0 g semi-sweet chocolate chips
Sweet	Sweet	Basic taste on the tongue stimulated by sugars and high potency sweeteners	Sucrose, solution in water 2% (2)---5%(5)---10%(10)---15%(15)
Salty	Salty	Basic taste on the tongue stimulated by sodium salt, especially sodium chloride	NaCL, solution in water 0.2%(2)—0.35%(5)—0.5%(10)—0.7%(15)
Sour	Sour	Basic taste on the tongue stimulated by acids	Citric acid, solution in water 0.05%(2)—0.08%(5)—0.15%(10)—0.2%(15)
---	Bitter	Basic taste on the tongue stimulated by solutions of caffeine, quinine and certain other alkaloids	Caffeine, solution in water 0.05%(2)—0.35%(5)—0.50%(8.5)—0.7%(15)
Astringency	---	Feeling of drying of the linings of the mouth	Tea bag/1 hr soak
Aftertastes[c]		*Definitions:*	*Reference solutions*[b]
Sweet	Sweet	See above	See above
Bitter	---	See above	See above

[a]All flavor definitions were determined by the trained panel. Basic taste definitions were obtained from Civille and Lyon (1996) and basic taste references were obtained from Meilgaard, Civille, and Carr (1999). All texture definitions were obtained from Meilgaard, Civille, and Carr (1999), except the references for manual hardness and chewiness which were determined by the trained panel.
[b]Reference products and solutions followed by a number in parentheses indicates intensity of that product or solution on a 15-point scale, with 0=low and 15=high.
[c]The universal flavor scale was applied to all flavor attributes and aftertastes (Meilgaard, Civille, and Carr, 1999).
[d]Reference samples were held in closed screw top 3.5-oz jars. Panelists opened and immediately closed the jars after sniffing as needed during product evaluation.

For textural attributes, panelists defined the attribute intensity of reference products on a 15-point scale. These texture reference intensities were used as anchor points on the linescales during subsequent product evaluation (Meilgaard, Civille and Carr, 1999). For example, all panelists agreed that the manual force required to break ginger snap cookies rated 10 on the 15-point scale. The universal flavor scale was applied to all flavor attributes except sweetness and bitterness. When using universal scaling, flavor intensities that panelists have previously experienced in specific products are used as a reference point for the products being evaluated (Meilgaard, Civille and Carr, 1999). For example, all panelists agreed that the intensity of cinnamon flavor in Big Red chewing gum was 12 on the 15-point scale. Therefore, during evaluation, panelists could compare the intensity of texture and flavor reference products to the intensity of the actual product attributes. When using the universal scale, the actual flavors present in the reference is unimportant, only its relative intensity is considered. Solutions with increasing concentrations of sucrose and caffeine were used to define reference intensities for sweetness and bitterness, respectively (**Table 5.3**).

Data were analyzed during the training period to determine the appropriateness of terminology being used to judge product differences, redundancy of terms and actual product differences (Powers, 1984). Through discussion, panelists identified appropriate terms and eliminated redundant ones. Means and standard deviations were used to evaluate the ability of panelists to discriminate among practice samples.

Sensory descriptive analysis

One day after baking, sensory evaluation of cookies was performed by eight trained sensory descriptive panelists. Evaluations were performed in individual booths under low pressure, sodium vapor light (CML-18, Trimble House, Norcross, GA). Each station was equipped with computers and networked for test presentation, data entry, and retrieval using Compusense®*fiv*e (CSA*five*, release 4.0, Compusense, Inc., Guleph, Ontario, Canada).

Three-digit random numbers were used to code each sample, and a balanced order of presentation was used. Four samples, either chocolate chip or oatmeal, were evaluated per session. A reduced-fat cookie prepared with margarine instead of butter was used as a warm-up sample to allow panelists to self-calibrate. During evaluation, jars of aromatic reference samples were available for use. These samples assist in standardizing panelist responses (Meilgaard, Civille, and Carr, 1999). Four test cookie samples (full-sugar control, ace-K, sucralose, ace-K/sucralose) from one cookie type (oatmeal or chocolate chip) were then presented monadically. Each panelist received two cookies from each treatment, one used for texture evaluation, one for evaluating flavor and the aftertastes perceived post-swallow (**Table 5.3**). In phase one, textural attributes were evaluated; phase two involved the descriptive analysis of flavor. The attributes and 15-point linescales were presented on the monitor screen. Panelists used a mouse to move the cursor to a point along the line that corresponded to the perceived intensity of the specific attribute in the sample. The third phase of evaluation occurred post-swallow. Panelists were prompted at 60 seconds post-swallow to check a box to indicate the presence of a sweet aftertaste in oatmeal cookies, or sweet and bitter aftertastes in chocolate chip cookies. Panelists also rated the intensity of any perceived aftertastes on the 15-point scale.

Upon completion of each test, a 7.5% sucrose solution, carrots, unsalted crackers and carbon-filtered water were available for palate cleansing. Crackers and water are traditionally used to cleanse the palate. The carbohydrates or natural sugars in carrots help to displace any possible aftertastes, such as astringency or lingering sweetness, from the high intensity sweeteners. A 10-minute wait between samples was imposed to eliminate the effects of taste fatigue and lingering aftertastes.

Physicochemical and instrumental evaluation

Specific gravity was performed on the unbaked cookie dough using the method described by Penfield and Campbell (1990) on the day of baking. For each formulation within cookie type, this comparison was made in duplicate.

Cookie spread (height, width, and height:width ratio) was performed following AACC method 52-10 (1995). Two measurements per replication were obtained.

Water activity of the cookies was determined by using the Aqua Lab device (Decagon Devices, Pulman, WA). A Cuisinart DLC1 Mini-Prep Processor (East Windsor, NJ) was used to grind four cookies from each treatment to a uniform particle size. For each treatment, measurements were taken on three aliquots of the composite samples as described by Curley and Hoseney (1984).

A 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert Software, version 1.20 (Stable Micro Systems, Haselmere, Surrey, England) was used to perform puncture testing (probing) on the cookies the day after baking (Bourne,1965, 1999; Perry, Swanson, Lyon, and Savage, 2003). Four cookies from each treatment were punctured 9 times in an offset bull's-eye pattern **(Figure 5.1)**, with a 0.3-cm probe at a crossarm speed of 5mm/second and trigger force of 10 grams. Because edge effects may have an effect on hardness, the outer 15% of the cookie was avoided (Gaines, Kassuba, and Finney, 1992). A baseplate with a hole 0.6-cm in diameter was used to accept the probe as it passed through the sample.

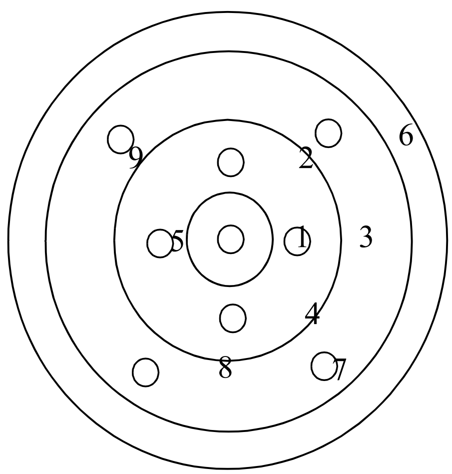

Figure 5.1. Representative probing pattern for oatmeal and chocolate chip cookies using a 50-kg capacity TA.XT2 Texture Analyzer equipped with Texture Expert, Version 1.20 (Stable Micro Systems, Haselmere, Surrey, England) and a 0.3 cm probe at a crossarm speed of 5 mm/s.

A force-time curve was produced from each probe. Parameters of the graph analyzed included maximum force to achieve penetration, slope to maximum peak, time to maximum peak and area under the curve. Product height was also determined. For statistical analysis, the center point (probe 1), the average inner concentric circle value (probes 2, 3, 4, and 5), and the average outer concentric circle value (probes 6, 7, 8, and 9) were used **(Figure 5.1).**

Cookie nutrient content

Calorie and sugar content of the cookies were determined using Food Processor, version 7.21, ESHA Research, Salem, OR, 1998. Reduced-in-sugar oatmeal cookies had 7% less calories and 40% less sugars than the full-sugar control. Chocolate chip cookies reduced in sugar had 6% fewer calories and 13% less sugars compared to the full-sugar control. The percentage of sugar reduction exceeded that of calorie reduction in both oatmeal and chocolate chip cookies. All cookies were reduced-in-fat.

Statistical analysis

All results from the sensory and instrumental tests were analyzed using SAS for Windows (version 8.2, SAS, Inc., Cary, NC). Equal variances within each treatment were verified (PROC MEANS). Normality plots, produced by PROC UNIVARIATE, verified normal data distribution. The data from the main effects and their interactions were analyzed for variance ($p<0.05$) using PROC GLM. Student-Newman-Kuels (SNK) test was used for means separation.

Results

Manufacturers recommendations were followed when incorporating HIS into the reduced-in-fat cookie system (Splenda®, 1998; Sweet One®, 2000). Replacement of 50% of the granulated sugar in the full-sugar control with one or more HIS affected sensory attributes. In **Figures 5.2 and 5.3**, sensory attribute mean scores for each treatment are plotted on truncated line scales radiating from the center of each profile.

Sensory texture attributes

Sensory texture profiles for each cookie type and treatment are found in **Figures 5.2a and 5.2b**. Oatmeal full-sugar control cookies were significantly harder (5.0±1.2) and more cohesive (6.7±1.1) than cookies prepared with sucralose or a blend of ace-K/sucralose. Ace-K oatmeal formulations did not differ significantly from any other treatment, including the control. Modified chocolate chip cookies did not differ from one another but were significantly less hard, cohesive, rough, and chewy than the control (4.3±1.3 to 6.7±1.6).

Sensory flavor attributes and aftertastes

Sensory flavor profiles for each cookie type and treatment are found in **Figures 5.3a and 5.3b**. No significant flavor differences due to sugar modification in either oatmeal or chocolate chip cookies were found during mastication. All oatmeal cookies were moderately low in brown sugar, dried plum, and astringent flavors (<3.4). Cinnamon, grainy and sweetness levels were moderately low to moderate (4.2±0.6 to 5.9±0.6). All chocolate chip cookies were low in salty, bitter and sour

Figure 5.2a. Oatmeal Cookies

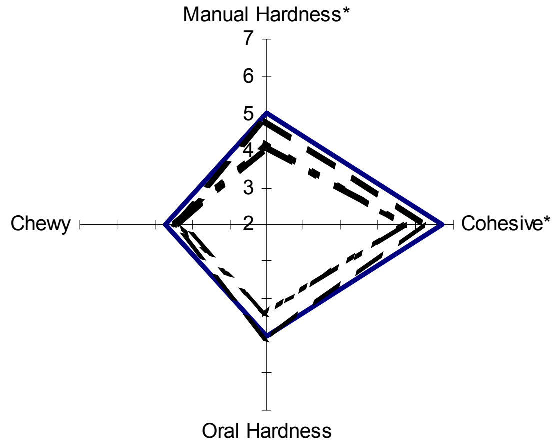

Figure 5.2b. Chocolate Chip Cookies

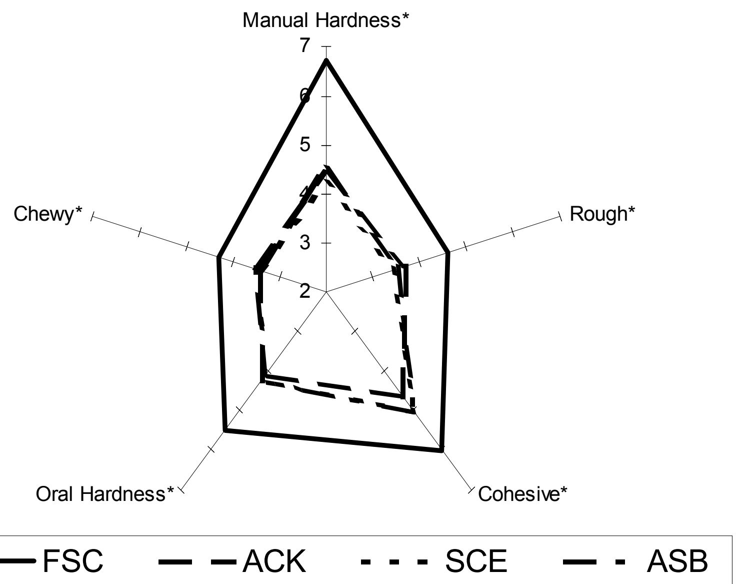

Figure 5.2. Texture attributes: descriptive profiles of oatmeal (5.2a) and chocolate chip (5.2b) cookies prepared in four formulations: full-sugar control (FSC), ace-K (ACK), sucralose (SCE), and ace-K/sucralose blend (ASB). Means of each attribute for each formulation are plotted on truncated line scales radiating from the center. Significant differences among formulations are denoted by a *.

Figure 5.3a. Oatmeal Cookies

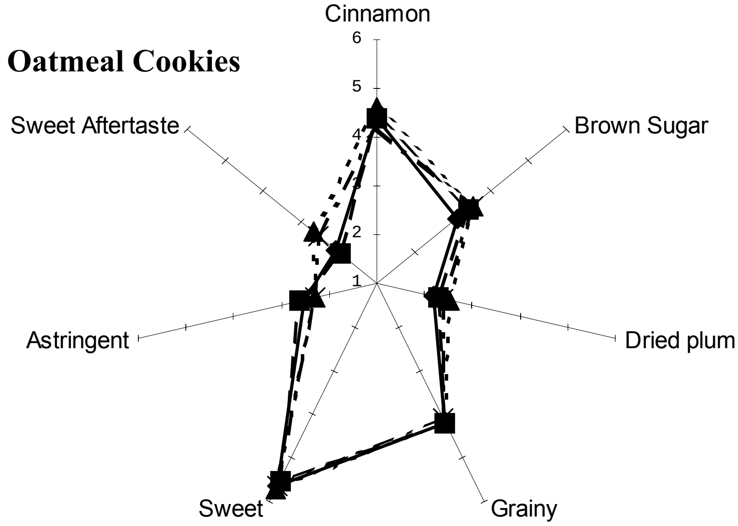

Figure 5.3b. Chocolate Chip Cookies

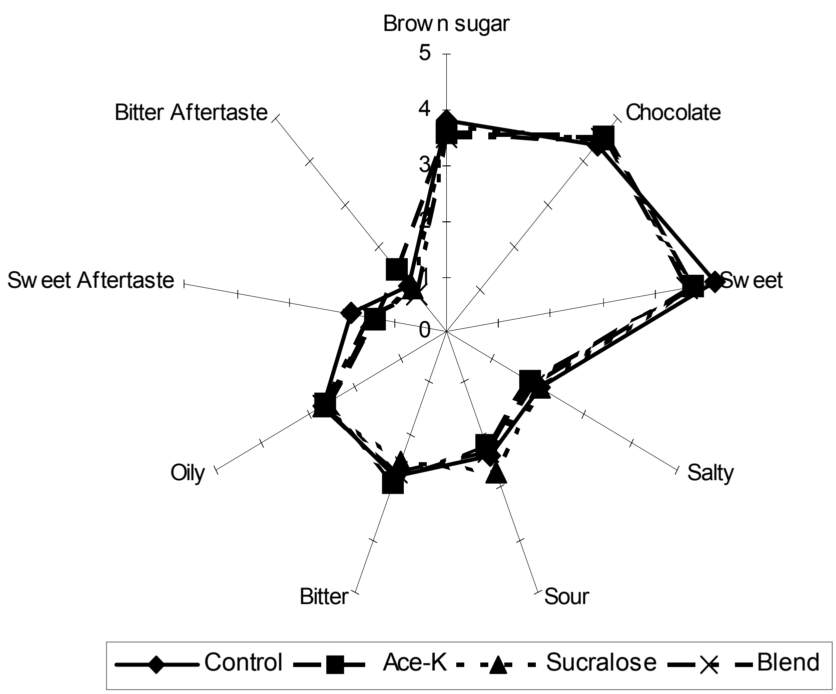

Figure 5.3. Flavor attributes: descriptive profiles of oatmeal (5.3a) and chocolate chip (5.3b) cookies prepared in four formulations: full-sugar control (FSC), ace-K (ACK), sucralose (SCE), and ace-K/sucralose blend (ASB). Means of each attribute for each formulation are plotted on truncated line scales radiating from the center. Significant differences among formulations are denoted by a *.

flavors (<2.7), and moderately low (3.6±0.8 to 4.8±0.8) in brown sugar, chocolate and sweet intensities.

Aftertastes existed in all treatments of both oatmeal and chocolate chip cookies at 60 seconds post-swallow. Although oatmeal cookies exhibited a sweet aftertaste, levels were low with no significant differences among treatments. Chocolate chip cookies exhibited very low levels of sweet and bitter aftertastes with no significant differences among treatments.

Physicochemical and instrumental tests

Physicochemical and instrumental measurements are reported by cookie type and treatment in **Table 5.4**. Specific gravity did not differ among oatmeal cookie doughs, whereas specific gravity of modified chocolate chip cookie doughs was significantly lower than that of the control. Cookie spread of modified cookies decreased with modification, with the exception of the ace-K/sucralose blend oatmeal cookies which increased in spread. Water activity for modified cookies significantly increased although levels remained below 0.6. Probing revealed no effect of modification on time to reach penetration of the cookies, whereas, force, slope and area decreased with incorporation of ace-K, sucralose and ace-K/sucralose blend in chocolate chip cookies. In oatmeal cookies, decreases were found only when sucralose or the HIS blend were used.

Table 5.4. Means and standard deviations of physicochemical and instrumental tests for oatmeal (OAT) and chocolate chip (CC) cookies[a]

		Cookie treatment[b]			
Cookie Type	Test	Full-sugar control	Ace-K[c]	Sucralose[d]	Blend[e]
OAT	Specific gravity[f]	1.09±0.09a	1.09±0.10a	1.10±0.10a	1.09±0.10a
	Cookie spread[g]	7.63±0.49a	7.34±0.45b	7.25±0.38b	7.83±0.36b
	Water activity[h]	0.51±0.01a	0.52±0.03b	0.59±0.01c	0.57±0.01d
	Probe - height (mm)[i]	8.36±0.68ac	9.22±0.65b	8.42±0.47a	8.66±0.57c
	Probe - Force (g)[i]	576.96±128.15a	527.04±123.06a	352.62±72.106b	383.98±99.71b
	Probe - Time (s)[i]	0.65±0.24a	0.77±0.38a	0.72±0.29a	0.77±0.34a
	Probe - Slope (g/s)[i]	202.66±69.17a	176.58±71.33a	110.71±33.94b	118.82±43.16b
	Probe - Area[i]	3875.00±740.34a	3763.18±875.6a	3655.55±789.55b	2852.75±963.25b
CC	Specific gravity[f]	1.05±0.02a	1.02±0.28b	1.01±0.02b	1.02±0.03b
	Cookie spread[g]	7.36±0.49a	6.41±0.28b	6.35±0.28b	6.36±0.20b
	Water activity[h]	0.37±0.01a	0.48±0.06b	0.50±0.02c	0.49±0.03d
	Probe - height (mm)[i]	8.94±0.66a	9.97±0.83b	9.90±0.77b	9.94±0.94b
	Probe - Force (g)[i]	1681.90±369.2a	782.25±444.87b	499.78±204.80c	555.61±133.51d
	Probe - Time (s)[i]	0.53±0.20a	0.55±0.26a	0.64±0.22a	0.61±0.21a
	Probe - Slope (g/s)[i]	783.14±383.16a	403.90±301.12b	196.37±121.95c	220.97±103.07c
	Probe - Area[i]	7633.80±1520.43a	3601.81±1599.03b	2655.61±698.71c	2977.82±661.4d

[a]Means within cookie type and parameter followed by different letters were significantly different according to ANOVA and SNK ($p<0.05$).
[b]All treatments were reduced-in-fat formulations prepared with dried plum puree (Sunsweet Growers, Inc., Yuba City, CA).
[c]3.0 g ace-K/dextrose blend (Sweet One®, Stadt Corp., Brooklyn, NY) was used to replace 50 g (50%) of granulated sugar in oatmeal cookies; 4.5 g Sweet One® replaced 75 g (50%) of granulated sugar in chocolate chip cookies.
[d]6.0 g sucralose/maltodextrin blend (Splenda®, McNeil Specialty Products, New Brunswick, NJ) was used to replace 50 g (50%) granulated sugar in oatmeal cookies; 7.5 g Splenda® replaced 75 g (50%) granulated sugar in chocolate chip cookies.
[e]A 1:3 Sweet One®:Splenda® blend (oatmeal cookies) and 1:6 SweetOne®:Splenda® blend (chocolate chip cookies) were used to replace 50% of granulated sugar.
[f]LS-means are across 3 replications on 2 samples per replication.
[g]LS-means are across 2 determinations and 3 replications (AACC method 52-10, 1995).
[h]LS-means are across 3 replications with 4 analyses per replication; measured using Aqua Lab (Decagon Devices, Pulman, WA) and sampling method described by Curley and Hoseney (1984).
[i]LS-means based on 3 values per cookie per 3 replications; determined with a 50-kg capacity TA.XT2 Texture Analyzer (Stable Micro Systems, Haselmere, Surrey, England), and a 3.0-cm probe at a crossarm speed of 5 mm/s (Bourne, 1999, Gaines, Kassuba, and Finney, 1992).

Discussion

Generally, modified cookies were more similar to each other than to the full-sugar control. Sugar substitution had a greater effect on texture than on flavor. The manufacturer of Sweet One® claims that the sweetness provided by ace-K is similar to that provided by sugar, although sweetness onset is more rapid (Hood and Campbell, 1990). Only partial replacement of sugar with ace-K is recommended, in order to maintain volume and texture contributed by sugar (Sweet One®, 2000). In this study, the successful use of ace-K in cookies to provide sweetness is attributed to partial retention of the sugar and the use of dried plum puree, which contains sorbitol, as the fat replacer (CDPB, 1999). Initial sweetness of ace-K is rounded out and improved, rather than having an intense sweetness onset, when combined with sorbitol (Bullock, Handel, Segall, and Wasserman, 1992).

Ace-K has been reported to elicit a strong, bitter/metallic aftertaste especially at a sweetness intensity of a 5% sucrose solution (Ott, Edwards, and Palmer, 1991). The bitterness associated with use of ace-K was minimized by combining it with another HIS (Lim, Setser, and Kim, 1989; Wiet and Beyts, 1992). A low bitter aftertaste was found in chocolate chip cookies in this study, although no significant difference existed among all treatments. This suggests that the bitterness was attributable to other ingredients present. Chocolate liquor, an ingredient in chocolate, has been previously described as having a bitter flavor note (Stauffer, 1996).

Similar mastication and aftertaste flavor results were found when sucralose rather than ace-K was used in both cookie types. According to the manufacturer, Splenda® leaves no unpleasant aftertaste and it "tastes like sugar because it is made from sugar" (Splenda®, 1998). However, an intense sweet aftertaste has been associated with this sweetener, which is minimized when it is used in blends with one or more additional sweeteners (Hanger, Lotz and Lepeniotis, 1996). Components of the dried plum puree, specifically malic acid, may also moderate the intense sweetness previously found with sucralose incorporation. Malic acid enhances other flavors in the system and has a greater carry-through during mastication because of its slow release (CDPB, 1999).

Combining two or more HIS has been shown to minimize negative effects of using a single HIS (Hanger, Lotz and Lepeniotis, 1996; Lim, Setser, and Kim, 1989). However, flavor during mastication and aftertaste of cookies prepared with an ace-K/sucralose blend did not differ significantly from other formulations. This suggests that use of HIS blends in a reduced-in-fat cookie system is not as advantageous as combining HIS for use in other food systems.

Textural changes resulting from a decrease in bulk and an increase in moisture availability were expected when HIS were used to replace sucrose (Bullock, Handel, Segall, and Wasserman, 1995; Sweet One®, 2000). However, modification had little effect on dough specific gravity (**Table 5.4**), suggesting there would be few textural effects due to altered dough aeration (Alexander, 1998; Vetter, Bright, Utt, and McMaster, 1984). Perry, Swanson, Lyon, and Savage (2003) reported specific gravity increased in reduced-in-fat-and-sugar cookies.

Water activity increased in all cookies reduced in sugar, as previously reported (Perry, Swanson, Lyon, and Savage, 2003). Sugars typically bind water which lowers the water activity (Burrington, 1998). Therefore, reducing the amount of sugar in a product is expected to cause an increase in water activity.

Generally, cookie spread, an overall indicator of cookie quality, decreased when the cookies were reduced in sugar (**Table 5.4**). Oatmeal ace-K/sucralose blend cookies, were the exception. Height data produced from probing reflects cookie spread. Because sugars increase gluten glass transition temperatures, a reduction in sugar typically lowers the gluten glass transition temperature and decreases cookie spread (Doescher, Hoseney, and Milliken, 1987a). A reduced level of sugar in cookie doughs may also allow more water to be bound by the flour, which increases gluten development, and thus limits cookie spread (Doescher, Hoesney, Milliken, and Rubenthaler, 1987b).

Both full-sugar oatmeal and chocolate chip cookies were significantly more cohesive than modified cookies. Cohesiveness relates to the inner structure of the product and the manner in which the structure resists deformation. Reduced-fat cookies have previously been described as cohesive, mainly attributable to reduced levels of fat and an increase in moisture content and gluten development (Armbrister and Setser, 1994; Perry, Swanson, Lyon, and Savage, 2003). Perry, Swanson, Lyon, and Savage (2003) also reported that cookies reduced in both fat and sugar by 50% were less cohesive then those reduced in fat alone.

Surface roughness of full-sugar chocolate chip cookies was significantly greater than that of cookies reduced in fat and sugar. Decreases in surface roughness of reduced-in-fat cookies may be caused by a decrease in shortening and subsequent increase in water content (Armbrister and Setser, 1994). Use of HIS to replace 50% of sugar in cookies in this experiment may have moderated the surface roughness due to decreasing moisture content associated with sugar reduction.

Instrumentally, hardness has been reported as the force measured by the probe as it pushes the sample (Gaines, Kassuba, and Finney, 1992). Full-sugar oatmeal cookies in this study were harder than all modified oatmeal cookies, except the ace-K oatmeal cookies which equaled the control in hardness. In chocolate chip cookies, ace-K resulted in a cookie that was most like the control in hardness. Trained panelists reported similar results for both manual and oral hardness for most cookie formulations. Full-sugar oatmeal cookies required more force to break apart than modified cookies containing sucralose alone or in a blend. Ace-K oatmeal cookies did not differ from the control in manual hardness. Panelists found all oatmeal cookies to be similar to one another in oral hardness, or the force necessary to bite through the sample. Full-sugar chocolate chip cookies were harder than all modified cookies whether assessed manually or orally.

In terms of sensory evaluation, a chewy product exhibits resistance to continued or persistent penetration by the teeth (Jowitt, 1975). Instrumentally, increased chewiness would be associated with increased time to maximum force and slope during probing. Increased chewiness was not observed in this study when HIS were used. In oatmeal cookies, these instrumental results were supported by sensory assessment. However, full-sugar chocolate chip cookies did exhibit increased chewiness when assessed by sensory panelists.

Both the time to maximum force and maximum force required for penetration determine the area under the curve. Perry, Swanson, Lyon, and Savage (2003) reported that area under the curve best reflected oral hardness in reduced-in-fat-and-sugar cookies. For chocolate chip cookies, the full-sugar formulation produced the greatest area under the curve by the probe test. The full-sugar and ace-K formulations produced the greatest area under the curve for oatmeal cookies. According to the trained sensory panel, only chocolate chip full-sugar cookies were perceived as orally harder than modified cookies. While the instrumental assessment appears to be more sensitive than human perception and can sometimes help explain sensory results, sensory panels are necessary to determine the practical importance of the findings.

Applications/Conclusions

Numerous health risks, such as diabetes and heart disease, are associated with the consumption of excess fat and sugar. Consumers, however, are gradually purchasing more indulgent products despite a stated desire to improve the quality of their diets. This points to the need for the availability of reduced-in-fat and sugar products that are also reduced in calories, which possess the flavor and texture of their favorite full-fat counterparts. A trained descriptive sensory panel, which can produce a quantifiable product profile, is useful in the process of modifying favorite food products. Trained panelists in this study found that reduced-in-fat oatmeal and chocolate chip cookies prepared with one or more HIS did not result in significant flavor differences. Undesirable aftertastes previously associated with use of HIS either alone or in blends were not found. However, differences in texture were found due to the effect of incorporation of one or more HIS and the accompanying sugar reduction in reduced-in-fat oatmeal and chocolate chip cookies. In general, textural effects of HIS incorporation receive limited attention in the product literature, but often affect consumer acceptability of products (Szczezniak and Skinner, 1973). In this study, physicochemical/instrumental measurements and trained sensory panelists detected similar differences in the cookies, although the instrumental assessment appears to be more sensitive than the sensory panelists. Single HIS and HIS blends also produced similar products. Therefore, factors such as cost, ease of handling, and use in other products could be used to select among the HIS and HIS blends. Because differences were found between test cookies and the control, acceptability of these reduced-in-fat and sugar cookies should be determined by consumers.

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CHAPTER VI

EFFECTS OF HIGH INTENSITY SWEETENERS (HIS) AND HIS BLENDS ON FLAVOR OF REDUCED-IN-FAT COOKIES[1]

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[1]Cardello EE, Swanson RB, Lyon BG and Savage EM. To be submitted to *J Food Sci*.

Abstract

Acesulfame-K (ace-K) and sucralose, high intensity sweeteners (HIS), were used in reduced-in-fat cookie formulations to determine synergistic effects of one or more HIS on cookie flavor profiles and aftertastes/feels intensity. Reduced-in-fat formulations of 2 cookie types were prepared with 50% reduction of sugar and replacement with either ace-K, sucralose, or ace-K/sucralose blend. Eight trained descriptive panelists evaluated flavor attributes and aftertastes/feels using 0-15 cm linescales. PROC MIXED and PDIFF ($p<0.05$) revealed minimal significant flavor or aftertaste/feel effects due to HIS incorporation. Time effects within treatment were found for all aftertastes/feels. All HIS produced similar products. Non-flavor criteria can be used to select HIS in this system.

Introduction

Two high intensity sweeteners (HIS), acesulfame-K (ace-K) and sucralose, are heat stable and suitable for use in baked products, including those that have been reduced in fat to improve their nutrient profiles. These HIS impart sweet character notes. However, flavor profiles do not mimic that of sucrose and aftertastes/feels, in particular bitter and intensely sweet notes, have been reported (Hanger and others 1996; Lim and others 1989). Taste profiles may also be affected by other ingredients in the formulation, such as fat replacers or bulking agents, which are often included when cookies are reformulated to reduce fat content. Wiet and others (1993) reported that the sweetness profile of a food containing HIS can be affected by the amount of fat present. It has also been reported that sweet and bitter profiles of cookies prepared with HIS are altered when polydextrose, a bulking agent, is present (Lim and others 1989).

Combining sweeteners may overcome some of the flavor limitations of using HIS to replace sugar. Synergistic effects between HIS often result in a sweetness profile closer to that of sugar (CCC 2002), and the combination may help to minimize associated aftertastes/feels (Hanger and others 1996; Hutteau and others 1998; Verdi and Hood 1993). Hanger and others (1996) evaluated solutions of acesulfame-K, aspartame, sucralose, saccharin, and cyclamate, each individually and in blends, to determine similarity to 4% sucrose solution. Sucralose, either alone or blended with another sweetener, was found to have a higher sweet aftertaste than the majority of the other sweeteners. Bitter flavor was highest for ace-K, with only cyclamate's bitter aftertaste exceeding that of ace-K. In general, solutions with a combination of two or more sweeteners had sweetness profiles more similar to sucrose due to a decrease in aftertastes typically associated with use of individual sweeteners (Hanger and others 1996).

Cookies, a popular baked product, typically contain 30-75% sugar, 30-60% fat and 7-20% water on a flour-weight-basis (Pyler 1988). Although the incorporated fat may not have a strong or distinctive flavor, it contributes to flavor of a food through its ability to distribute, release, enhance, and affect the intensity of other ingredients' flavors (Bennett 1992; Giese 1996). Fat replacers may only be able to impart some of these flavor effects of fat (Akoh 1998). Similarly, sugar substitutes may be used to successfully replace the sweetness that sugar provides in the product, although the flavor profile may not be easily duplicated and many of the functional properties imparted by sugar are lost. Reformulation of reduced-in-fat products to also lower the sugar content may be facilitated by partially, rather than totally, replacing sugar with HIS to help maintain sensory characteristics. Perry and others (2003) evaluated reduced-in-fat and reduced-in-fat-and-sugar cookies in which dried plum puree and ace-K/dextrose blend replaced half of the fat and sugar, respectively. The flavor profiles produced by these cookies reduced in both fat and sugar were more similar to their full-fat counterparts than to cookies reduced in fat alone.

Currently, there is little information about the use of alternative sweeteners in reduced-in-fat baked products like cookies. The objectives of this study were to (1) produce descriptive profiles and to (2) evaluate intensity of aftertastes/feels of 2 reduced-in-fat cookie types (oatmeal and chocolate chip) prepared with one or more HIS.

Materials and Methods

Sample preparation

Four different formulas of two cookie types (oatmeal and chocolate chip) were prepared: full-sugar control, and three reduced-sugar cookies (ace-K, sucralose, and ace-K/sucralose blend) according to the formulas in **Table 6.1.** All cookies were reduced-in-fat, containing dried plum puree to replace half of the added fat (CDPB 1999). The reduced-fat, full-sugar cookie served as a control. In all other cookie treatments, sugar was reduced by 50%. The sugar reduction was accomplished by replacing half of the sugar with either ace-K/dextrose blend (SweetOne®, Stadt Corporation, Brooklyn, NY), sucralose/maltodextrin blend (Splenda®, McNeil Specialty Foods, New Brunswick,

Table 6.1. Reduced-in-fat oatmeal and chocolate chip cookie formulas (fwb)

	Cookie Type		
Ingredient	Oatmeal	Chocolate chip	Product Information
All-purpose flour	100.0	100.0	ConAgra, Inc, Omaha, NE
Baking Soda	1.3	1.0	Kroger Co., Cincinnati, OH
Salt	1.3	1.8	Kroger Co., Cincinnati, OH
Oats	71.9	-------	Quaker Oats Co., Chicago, IL
Cinnamon	0.5	-------	Kroger Co., Cincinnati, OH
Cloves	0.1	-------	Kroger Co., Cincinnati, OH
Nutmeg	0.3	-------	Kroger Co., Cincinnati, OH
Granulated sugar[a]	45.0	48.6	Monarch Regency, Greenville, SC
Light brown sugar	74.0	35.4	Colonial, Savannah, GA
Vanilla	0.9	1.3	Greinoman's Unified Industry, Cumming, GA
Butter	11.7	36.6	Kroger Co., Cincinnati, OH
Egg	38.0	37.0	Kroger Co., Cincinnati, OH
Shortening	28.0	-------	Proctor and Gamble,Cincinnati,OH
Dried plum puree	27.4	19.8	Sunsweet Growers, Inc., Yuba City, CA
Chocolate chips	-------	64.9	Nestle USA, Solon, OH

[a]In reduced-in-sugar oatmeal cookies, 50% of granulated sugar was replaced by either 1.3% (fwb) Sweet One® (ace-K/dextrose blend, Stadt Corporation, Brooklyn, NY), 2.7% (fwb) Splenda® (sucralose/maltodextrin blend, McNeil Specialty Foods, New Brunswick, NJ), or a combination of 0.6% (fwb) Sweet One® and 1.3% (fwb) Splenda®; in reduced-in-sugar chocolate chip cookies, 50% of granulated sugar was replaced by either 1.5% (fwb) Sweet One®, 2.4% (fwb) Splenda®, or a combination of 0.4% (fwb) Sweet One® and 1.9% (fwb) Splenda®

NJ), or a combination of the ace-K/dextrose and sucralose/maltodextrin blends. These sweetener formulations are available for consumer purchase. Ratios of ace-K/dextrose and sucralose/maltodextrin blends differed between the two cookie types and were based on preliminary work and a review of studies employing blends of ace-K and sucralose (Hanger and others 1996; Hutteau and others 1998). Three replications were produced for evaluation.

All dry ingredients were weighed one day before baking. On the day of baking, the eggs, butter and vanilla were measured. For the oatmeal cookies, eggs and butter were allowed to sit at room temperature for 15 minutes prior to mixing. Eggs and butter for chocolate chip formulations sat at room temperature for 45 minutes prior to mixing. When there were multiple lots of one ingredient, lots were combined and aliquots were taken.

A Kitchen-Aid mixer (model K5SS, St. Joseph, MI) equipped with a paddle beater was used to mix the cookie dough. For oatmeal cookies, flour, soda, salt, oatmeal, sugar, ace-K/dextrose blend and/or sucralose/maltodextrin blend, brown sugar, cinnamon, cloves, and nutmeg were blended for 2 minutes at speed 1. Dried plum puree, butter, shortening, eggs and vanilla were added and mixed for 1.5 minutes at speed 1. For chocolate chip cookies, flour, soda, and salt were combined in a separate bowl. Butter, dried plum puree, sugar, ace-K/dextrose blend, and/or sucralose/maltodextrin blend, brown sugar, and vanilla were blended for 1 minute at speed 1. Beaten egg was added and incorporated for 1 minute at speed 1. Flour mixture was gradually added over a 2 minute period while continuing to mix at speed 2. Chocolate chips were added and mixed at speed 1 for 1 minute. For each cookie type, 18 cookies (6 down, 3 across) were portioned out on a 41.9-cm X 30.5 cm baking sheet lined with parchment paper using a #70 scoop. Cookies were rolled to 1.3-cm thickness (AACC 52-10 1995). Oatmeal cookies were baked for 9 minutes at 176EC (350EF), except those cookies containing sucralose, which were baked for 8 minutes at 176EC (350EF). Chocolate chip cookies were baked for 10 minutes at 190EC (375EF), except those cookies containing sucralose, which were baked for 9 minutes at 190EC (375EF). The manufacturer of the sucralose/maltodextrin blend recommends decreasing baking time for products containing this HIS by 1-2 minutes (Splenda®, 1998). All cookies were baked in a rotary oven (National Manufacturing Co, Inc., Lincoln, NE). Cookies were cooled on wire racks for about 1 hour. Cookies were then placed individually in a sandwich-sized zip-top plastic bag (6.5 X 3.25 in., 1.15 mm thickness, Kroger Co, Cincinnati, OH) and grouped in a zip-top gallon sized plastic bag (10.6 X 11 in., 1.75 mm thickness, Kroger Co., Cincinnati, OH) and stored flat at room temperature for approximately 20 hours until sensory evaluation was conducted.

Training of sensory panel members

For this study, 8 sensory panelists with 2-8 years experience and participation in descriptive sensory tests received orientation and training for cookie evaluations. Panelists were familiar with the test conditions, test procedures, and computerized scoring system (Compusense®*five*, release 4.0, Compusense, Inc., Guelph, Ontario, Canada). The Spectrum Method™ was used as the descriptive analysis technique. A lexicon of terms describing cookie flavor and aftertastes/feels was reviewed and specific attributes to be evaluated were identified by assessing a variety of products. The list of terms (**Table 6.2**) was condensed and products which represented the terms were identified as references. The universal flavor scale was applied to all flavor attributes except sweetness and bitterness. When using universal scaling, flavor intensities that panelists have previously experienced in specific products are used as a reference point for the products being evaluated (Meilgaard and others 1999). For example, all panelists agreed that the intensity of cinnamon flavor in Big Red chewing gum was 12 on the 15-point scale. Therefore, during evaluation, panelists could compare the intensity of flavor reference products to the intensity of actual product attributes. The actual flavors present in the reference are unimportant when using the universal flavor scale. Only its relative intensity is considered. Solutions with increasing concentrations of sucrose and caffeine

Table 6.2. Sensory profile attributes, definitions and references used by trained sensory panel to evaluate oatmeal and chocolate chip cookies[a]

OATMEAL	CHOCOLATE CHIP		
Flavor attributes/Basic tastes[c]		***Definitions***:	***Reference samples***[d] ***or solutions***[b]
Cinnamon/ woody	---	Aromatic/taste sensations associated with cinnamon and non-specific spices	0.3 cinnamon/clove/nutmeg mixture
Dried plum puree	Dried plum puree	Aromatic/taste sensations associated with dried plum puree	6.0 g dried plum puree
Grainy/ oatmeal	---	Aromatic/taste sensations associated with non-specific grain/oatmeal	6.5 g old-fashioned oats
---	Chocolate	Aromatic/taste sensations associated with chocolate	18.0 g semi-sweet chocolate chips
Sweet	Sweet	Basic taste on the tongue stimulated by sugars and high potency sweeteners	Sucrose, solution in water 2% (2)---5%(5)---10%(10)---15%(15)
---	Salty	Basic taste on the tongue stimulated by sodium salt, especially sodium chloride	NaCL, solution in water 0.2%(2)—0.35%(5)—0.5%(10)—0.7%(15)
Sour	Sour	Basic taste on the tongue stimulated by acids	Citric acid, solution in water 0.05%(2)—0.08%(5)—0.15%(10)—0.2%(15)
---	Bitter	Basic taste on the tongue stimulated by solutions of caffeine, quinine and certain other alkaloids	Caffeine, solution in water 0.05%(2)—0.35%(5)—0.50%(8.5)—0.7%(15)
Astringency	---	Feeling of drying of the linings of the mouth	Tea bags/1 h soak (6.5)
Aftertastes[c]		***Definitions:***	***Reference solutions***[b]
Sweet	Sweet	See above	See above
---	Sour	See above	See above
---	Salty	See above	See above
---	Bitter	See above	See above

Warm/ cinnamon/ numbing/ tingling	---	Combined effect of chemical feeling factors which cause sensations of warmth, numbing, and/or tingling on the tongue and linings of the mouth, associated with cinnamon and/or cloves combined with other spices, like ginger	
Slick	---	Chemical feeling factor which is perceived as a slippery sensation in the saliva and on the palate	
Astringency	---	See above	See above

[a]All flavor definitions were determined by the trained panel. Basic taste definitions were obtained from Civille and Lyon (1996) and basic taste references were obtained from Meilgaard and others (1999).
[b]Reference products and solutions followed by a number in parentheses indicates intensity of that product or solution on a 15-point scale, with 0=low and 15=high.
[c]The universal flavor scale was applied to all flavor attributes and aftertastes/feels (Meilgaard and others, 1999).
[d]Reference samples were held in closed screw top 3.5 oz. jars. Panelists opened and immediately closed the jars after sniffing as needed during product evaluation.

were used to define reference intensities for sweetness and bitterness, respectively (**Table 6.2**).

Data were analyzed during the training period to monitor the performance of the panelists, to determine the appropriateness of terminology to judge product differences, and to determine redundancy of terms and to assess actual product differences (Powers 1984). Through discussion, panelists identified appropriate terms and eliminated redundant ones. Means and standard deviations of training sessions were used to evaluate the ability of panelists to discriminate.

Sensory descriptive analysis and evaluation of aftertastes/feels

One day after baking, sensory evaluation of cookies was performed by trained panelists (n=8). Each sensory station was equipped with computers and networked for test presentation and retrieval using Compusense®*five* (release 4.0, Compusense, Inc., Guelph, Ontario, Canada). The attribute and 15-point linescales, 0 being absence of the attribute, and 15 being very intense, were presented on the monitor screen. Panelists used a mouse to move the cursor to a point along the line that corresponded to the perceived intensity of the specific attribute in the sample.

Evaluations were performed in individual booths in a sensory laboratory equipped with controlled lighting and charcoal-filtered air. Low pressure, sodium vapor white light (CML-18, Trimble House, Norcross, GA) was used at each work station. During evaluation, jars of aromatic reference samples were available for use by panelists (**Table 6.2**). A reduced-in-fat cookie prepared with margarine instead of butter was used as a warm-up sample to allow panelists to self-calibrate. Following the warm-up sample, panelists were presented with four cookie samples (full-sugar control, ace-K, sucralose, and ace-K/sucralose blend) from one cookie type (oatmeal or chocolate chip) per session. Cookies were coded with a 3-digit random number and order of presentation was balanced. Specific cookie samples were randomly assigned to panelists.

First, panelists performed descriptive analysis of flavor, followed by evaluation of aftertastes/feels (**Table 6.2**). Six flavor attributes specific to each cookie type were evaluated. Panelists were prompted at 30 second intervals, from 30 seconds post-swallow to 120 seconds post-swallow, to evaluate intensity of aftertastes/feels. Four aftertastes/feels were evaluated for oatmeal cookies and five aftertastes/feels were evaluated for chocolate chip cookies. Upon completion of each sample, a sweet 7.5% solution, carrots, unsalted crackers and carbon-filtered water were available for palate cleansing (Booth 2001). Panelists waited 10 minutes before evaluating the next sample.

Statistical analysis

All results from the sensory and instrumental tests were analyzed using SAS for Windows (version 8.2, SAS, Inc., Cary, NC). Normal data distribution was verified with PROC UNIVARIATE. Mixed model analysis of variance (PROC MIXED) was used to analyze data ($p<0.05$). Least-square means (LS-Means) and standard errors were generated. PDIFF was used for means separation (Littell and others 1996).

Results and Discussion

Sensory flavor attributes for oatmeal and chocolate chip cookies can be found in **Table 6.3.** No significant differences were found in flavor of oatmeal cookies.

Oatmeal cookies were low in dried plum flavor and astringency, moderately low in brown sugar flavor, and had moderate grainy, cinnamon, and sweet flavors.

Chocolate chip cookies did not differ in any flavor attributes during mastication, except for sweetness. The full-sugar control was sweeter than all modified cookies. Modified cookies, however, did not differ from one another in sweetness. Chocolate chip cookies were low in salty and sour flavors, moderately low in bitterness, and moderate in brown sugar and chocolate notes.

The manufacturer of Sweet One® claims that ace-K provides sweetness similar to sugar in baked products, although sweetness onset is more rapid (Peck 1994; Sweet One® 2000). In an experiment conducted by Perry and others (2003), trained panelists produced descriptive flavor profiles of reduced-in-fat cookies prepared with ace-K/dextrose blend. Panelists did not find any flavor differences in sweetness of cookies prepared with this commercially available blend. However, sweetness of ace-K/dextrose chocolate chip cookies evaluated in this study was significantly lower than that of full-sugar cookies. A loss of sweetness intensity was reported by Redlinger and Setser (1987) when ace-K alone was used to completely replace sugar in shortbread cookies. Additionally, use of carbohydrate-based fat replacers, such as citrus peel pectin, to replace 50-75% of fat has been associated with a decrease in sweetness intensity in chocolate chip cookies (Armbrister and Setser 1994). Partial reduction of sugar, coupled with the use of pectin-containing dried plum puree as the fat replacer, may have contributed to the decrease in sweetness (CDPB 1999). However, dried plum puree also contains sorbitol which, when

Table 6.3. LS-means[a] and standard errors for flavor attributes of oatmeal and chocolate chip cookies evaluated during mastication

Attribute	Cookie Type	
	Oatmeal	Chocolate chip
Sweet	5.59±0.13	*sig[b]
Cinnamon/woody	4.30±0.20	------------
Grainy/oatmeal	4.18±0.12	------------
Brown sugar	3.41±0.15	3.64±0.12
Dried plum	2.48±0.33	------------
Astringent	2.40±0.21	------------
Salty	------------	1.89±0.09
Sour	------------	2.30±0.10
Bitter	------------	2.71±0.14
Chocolate	------------	4.53±0.11

[a]LS-means and standard errors are across all cookie treatments. Mixed model analysis of variance (PROC MIXED) was used for data analysis and PDIFF was used for means separation (Littell and others 1996).
[b]* indicates a significant difference ($p<0.05$) between cookie treatments; full-sugar control cookies were significantly sweeter (5.11±0.11) than modified cookies (4.67±0.11).

combined with combined with ace-K, evens out the initial sweetness of this HIS (Bullock and others 1992). Similar effects have not been reported with sucralose.

Splenda® is said to "taste like sugar because it is made from sugar" and leaves no unpleasant aftertaste (Splenda® 1998). Sucralose also has the greatest sweetness potency when compared with other HIS (Wiet and Beyts 1992). In this study, no significant differences in sweet flavor of oatmeal cookies were found during chew, regardless of sweetener system incorporated. However, chocolate chip full-sugar control cookies were sweeter than all modified cookies. Ingredients in the reduced-in-fat system, such as pectin or sorbitol in the dried plum puree, may have minimized the intense sweetness anticipated from the use of the sucralose/maltodextrin blend. Dried plum puree also contains malic acid, which may have moderated the intense sweetness associated with sucralose by enhancing other flavors in the system (CDPB 1999).

Aftertastes/feels did exist for both cookie types (**Tables 6.4 and 6.5**). However, there were no significant differences among treatments, except for astringency in chocolate chip cookies. Time effects within each treatment were found for all aftertastes/feels. The most intense aftertastes/feels were found at 30 seconds post-swallow. Overall, intensity of aftertastes/feels was very low and none rated above 3.5 on the 15-point scale.

Ace-K has been reported to elicit a strong, bitter aftertaste (Ott and others 1991) especially at a sweetness intensity of a 5% sucrose solution (Wiet and Betys 1992). Bitterness associated with use of ace-K, however, was minimized by combining it with another HIS in solution or when used in a food system (Lim and others, 1989; Wiet and Beyts 1992). Time intensity for bitterness in shortbread cookies prepared using combinations of ace-K, cyclamate, aspartame, and saccharin with and without polydextrose was studied by Lim and others (1989). Trained panelists evaluated bitterness intensity every 5 seconds for 85 seconds post-swallow. Sensory descriptive analysis revealed that bitter profiles for cookies that contained ace-K were higher than for cookies prepared with sucrose alone. When polydextrose, a bulking agent often used in reduced-in-fat-or-sugar systems, was present, bitterness further increased for all sweetener combinations. In this study, bitter aftertaste was only evaluated for chocolate chip cookies because panelists did not identify bitterness in oatmeal cookies during lexicon development. Bitter aftertaste among all chocolate

Table 6.4. Oatmeal cookies: LS-Means[a] and standard errors for aftertastes/feels at 30, 60, 90, and 120 seconds post-swallow

		Cookie Treatment				
Aftertaste/ feel	Time[b]	Full-sugar control	Ace-K[c]	Sucralose[d]	Ace-K/ sucralose[e]	Standard error
Sweet	30	3.50a	2.97a	3.30a	3.30a	0.24
	60	2.00b	1.92b	2.63a	2.44b	0.24
	90	1.21c	1.47bc	1.43b	1.42c	0.24
	120	1.05c	0.88c	1.52b	1.42d	0.24
Warm/ Cinnamon	30	1.72a	1.93a	1.75a	1.69a	0.24
	60	1.35ab	1.32ab	1.40ab	1.32ab	0.24
	90	1.07ab	0.83b	0.94bc	0.81ab	0.24
	120	0.82b	0.65b	0.68c	0.70b	0.24
Slick	30	0.42a	0.61a	0.69a	0.58a	0.16
	60	0.21a	0.34a	0.40a	0.17a	0.16
	90	0.21a	0.19a	0.21a	0.02a	0.16
	120	0.10a	0.22a	0.21a	0.14a	0.16
Astringent	30	2.21a	2.09a	2.22a	1.96a	0.24
	60	1.30b	1.27b	1.21b	1.30b	0.24
	90	0.69c	0.56c	0.98bc	0.55b	0.24
	120	0.69c	0.37c	0.51c	0.44c	0.24

[a]LS-Means within a column (treatment) followed by different letters are significantly different ($p<0.05$). Mixed model analysis of variance (PROC MIXED) was used for data analysis and PDIFF was used for means separation (Littell 1996)).

[b]Panelists (n=8) evaluated intensities of aftertastes/feels at 30, 60, 90, and 120 seconds post-swallow on a 15-point linescale; 0=absence of aftertaste/feel and 15= very intense aftertaste/feel.

[c]Acesulfame-K substitutions: 4.0 grams Sweet One®(ace-k/dextrose blend) for 75 grams of sugar (4.0 grams for 50% of the sugar in the control).

[d]Sucralose substitutions: 7.5 grams Splenda® (sucralose/maltodextrin blend) for 75 grams of sugar (7.5 grams for 50% of the sugar in the control).

[e]Ace-K/sucralose substitutions: 50% of granulated sugar replaced by a blend of Sweet One® (ace-K/dextrose blend) and Splenda® (sucralose/maltodextrin blend).

Table 6.5. Chocolate chip cookies: LS-Means[a] and standard errors for aftertastes/feels at 30, 60, 90, and 120 seconds post-swallow

		Cookie Treatment				
Aftertaste/ feel	Time[b]	Full-sugar control	Ace-K[d]	Sucralose[e]	Ace-K sucralose[f]	Standard error
Sweet	30	2.44a	2.60a	2.44a	2.24a	0.19
	60	1.79b	1.37b	1.38b	1.44b	0.19
	90	0.79c	0.92bc	0.92bc	0.87c	0.19
	120	0.54c	0.56c	0.63c	0.52d	0.19
Sour	30	1.11a	1.22a	1.21a	1.35a	0.14
	60	0.47b	0.58b	0.67b	0.63b	0.14
	90	0.30bc	0.34bc	0.49bc	0.21c	0.14
	120	0.18c	0.20c	0.17c	0.14c	0.14
Bitter	30	1.83a	1.94a	1.79a	1.86a	0.13
	60	1.10b	1.45b	0.98b	0.83b	0.13
	90	0.86bc	0.86c	0.70b	0.75b	0.13
	120	0.63c	0.55c	0.62b	0.67b	0.13
Astringent[c]	30	1.47a	1.63a	1.56a	1.57a	0.14
	60	1.02b	1.23b	1.12b	1.25ab	0.14
	90	0.36c	0.81c	0.61c	0.93b	0.14
	120	0.32c	0.51c	0.26c	0.41c	0.14
Salty	30	0.71a	0.57a	0.56a	0.29a	0.10
	60	0.17b	0.26b	0.10b	0.09ab	0.10
	90	0.00b	0.05b	0.00b	0.08ab	0.10
	120	0.00b	0.08b	0.11b	0.00b	0.10

[a]LS-Means within a column (treatment) followed by different letters are significantly different ($p<0.05$). Mixed model analysis of variance (PROC MIXED) was used for data analysis and PIDFF was used for means separation (Littell and others 1996)).
[b]Panelists (n=8) evaluated intensities of aftertastes/feels at 30, 60, 90, and 120 seconds post-swallow on a 15-point linescale; 0=absence of aftertaste/feel and 15= very intense aftertaste/feel.
[c]Modified cookies were significantly more astringent than full-sugar control cookies.
[d]Acesulfame-K substitutions: 50% of granulated sugar replaced by Sweet One® (ace-k/dextrose blend).
[e]Sucralose substitutions: 50% of granulated sugar replaced by Splenda® (sucralose/maltodextrin blend).
[f]Ace-K/sucralose substitutions: 50% of granulated sugar replaced by a blend of Sweet One® (ace-K/dextrose blend) and Splenda® (sucralose/maltodextrin blend).

cookies was very low (<1.94). Bitterness in all four treatments decreased significantly as time post-swallow increased. However, bitter aftertaste cannot be attributed to incorporation of ace-K/dextrose blend because there were no significant differences in bitterness among treatments. The chocolate may have contributed to the very low bitter aftertaste. Chocolate liquor, found in chocolate, is known to have a bitter flavor (Stauffer 1996). No significant differences were found for the remaining aftertastes/feels in chocolate chip cookies prepared with either ace-K or ace-K/sucralose. Time effects, however, were found. For all cookies containing ace-K, intensity of all aftertastes/feels decreased with time.

The information relating to aftertastes associated with sucralose conflicts. An intense sweet aftertaste has been found with the use of sucralose in sweetener solutions. Combining sucralose with ace-K was found to minimize the sweet aftertaste (Hanger and others 1996). Wiet and Beyts (1992) found the taste profile of sucralose to be very similar to that of sucrose when sensory characteristics of sucrose, sucralose, aspartame, saccharin and acesulfame-K in an aqueous system were studied. Trained panelists evaluated the taste profiles for each sweetener using category scaling procedures. No significant differences were found among sweeteners for sweet aftertaste 20 seconds post-swallow (Wiet and Beyts 1992). In this study, no significant differences in sweet aftertaste were found for cookies prepared with sucralose or ace-K/sucralose. Little information is available about the use of sucralose in a reduced-in-fat cookie system. All other aftertastes/feels decreased as time increased. The only significant difference was found for astringent afterfeel, or drying of the linings of the mouth. Modified chocolate chip cookies were significantly more astringent than full-sugar control cookies. Similar results were found when several HIS, including sucralose, were evaluated at 4% sucrose equivalence (Hanger and others 1996). Astringent aftertaste 120 seconds post-swallow was assessed. Use of a single HIS resulted in a greater degree of astringency than sucrose. Blends of HIS, however, were similar to sucrose in astringency (Hanger and others 1996).

Conclusions

Use of HIS reportedly produces flavor profiles that differ from sugar and, in addition, results in strong or lingering aftertastes. However, reduced-in-fat cookies prepared by partially replacing sugar (50%) with ace-K, sucralose, or a combination of the two HIS, resulted in minimal flavor effects. Additionally, strong or lingering aftertastes/feels were not introduced by use of one or more HIS to partially replace sugar. Therefore, selection of a sweetener system in these reduced-in-fat cookies may be based on criteria other than flavor because there were minimal flavor effects and aftertastes/feels associated with use of one or more HIS.

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CHAPTER VII

CONCLUSIONS

The risk for numerous health problems, such as diabetes and heart disease, has become a major concern as obesity and overweight among Americans continues to increase (CDC, 2001; NIDDK, 2001). Among other factors, an increase in the marketing of snack food (CDC, 1999), paralleled by an increase in consumption of foods containing most of their calories from fat and sugar, including cookies (Tippett and Cleveland, 1999), have contributed to the obesity epidemic. While many Americans have adopted strategies to decrease their intakes of calories and fat, there is a need for more acceptable and convenient reduced-in-fat and reduced-in-calorie products to assist with compliance with a healthier diet (Harvey-Berino, 1998; Peterson and others,1999).

High-calorie, high-fat, and high-sugar foods, such as cookies, are an easily identified target for modification because of their popularity. In this study, reduced-in-fat oatmeal and chocolate chip cookies were prepared by replacing 50% of the fat with dried plum puree. These cookies have previously been found to be acceptable by consumer sensory panelists (Perry, 2001). Half of the sucrose present in these reduced-in-fat cookies was replaced with either a single high intensity sweetener (acesulfame-K/dextrose blend or sucralose/maltodextrin blend) or a combination of high intensity sweeteners (acesulfame-K/dextrose blend and sucralose/maltodextrin blend). The blends are commercially formulated and are available to consumers as Sweet One® (ace-K/dextrose blend) and Splenda® (sucralose/maltodextrin blend). Flavor and texture profiles were developed, intensity of aftertastes/feels was assessed, and consumer acceptability was evaluated.

Reduction of sugar and replacement with HIS in reduced-in-fat cookies was expected to alter the perception of flavor. Sugar imparts sweetness (Alexander, 1998) and contributes to a good flavor through nonenzymatic browning (Penfield and Campbell, 1990). Use of ace-K in shortbread cookies has been reported to decrease the sweetness intensity of the cookies (Redlinger and Setser, 1987). However, trained panelists in a study conducted by Perry and others (2003) found no significant differences in sweetness of reduced-in-fat and sugar oatmeal or chocolate chip cookies, prepared with a fruit-based fat replacer and the HIS ace-K/dextrose blend, when compared with the full-fat and sugar control. Limited information is available about the flavor effects of sucralose in a reduced-in-fat cookie. In solution, sucralose has been found to elicit a potent sweetness when compared with other HIS and sugar (Wiet and Beyts, 1992). In this study, trained panelists found the flavor profiles of modified oatmeal and chocolate chip cookies to be similar to that of the full-sugar control. Full-sugar chocolate chip cookies, however, were sweeter than all modified cookies.

Aftertastes, specifically intensely sweet and bitter, were expected to be present in modified cookies. It has been reported that ace-K produces a strong bitter/metallic aftertaste in cookies prepared both with polydextrose and without polydextrose (Lim and others, 1989). Sucralose has been shown to posses a very sweet aftertaste in solution (Hanger and others, 1996). Combining these sweeteners with each other or with one or more different HIS and/or sucrose has minimized these effects (Lim and others, 1989; Hanger and others, 1996). In this study, sweet aftertaste existed in both cookie types, although no significant differences among treatments was found. Similarly, a bitter aftertaste existed in all chocolate chip cookies, however, there were no significant differences among treatments. Trained panelists found few differences in the overall flavor profile of these reduced-in-sugar cookies when compared with the full-sugar control. Therefore, advantages of HIS blends, such as achieving a flavor profile like that of sugar, may not be applicable to reduced-in-fat cookies.

According to the trained panelists, partial replacement of sugar with one or more HIS in reduced-in-fat cookies had a greater effect on texture than flavor. Typically, sugar functions to incorporate air, provide bulk, and tenderize a product (Bullock and others, 1992; Sugar Association, 2000). Reduced-in-fat cookies tend to be thicker, chewier, softer, and more cake-like than a full-fat cookie. When compared to the reduced-in-fat full-sugar control, reduced-in-fat and sugar cookies were expected to be thicker and harder. Trained panelists, however, found that oatmeal control cookies were more fracturable and cohesive than cookies prepared with sucralose or ace-K/sucralose blend. The ace-K oatmeal cookie did not differ significantly from any other treatment, including the control. Full sugar control chocolate chip cookies were more fracturable, rough, cohesive, hard and chewy than modified cookies, but modified cookies did not differ from each other. Use of dried plum puree as the fat replacer may have prevented expected textural changes due to sugar replacement. Previously, reduced-in-fat and sugar chocolate chip and oatmeal cookies prepared with dried plum puree and ace-K/dextrose blend resulted in cookies with a textural profile similar to that of the full-fat and sugar cookies (Perry, 2001). In this study, only modified chocolate chip cookies were chewier and more rough than full-sugar cookies. Therefore, texture does not change dramatically with reduction of sugar and replacement with HIS in cookies already reduced-in-fat.

Trained sensory panels provide useful information. During the initial steps of product development, instrumental tests may be used to alleviate the time and cost associated with a trained sensory panel. However, human responses must be accurately reflected by the instrumental methods because consumer acceptance is the ultimate factor in determining success of a product (Gaines, 1994; Meilgaard and others, 1999). Trained sensory panelists may be used to verify results obtained from instrumental tests (Gaines, 1994; Meilgaard and others, 1999). Previously, probing has been found to be an appropriate instrumental method to assess texture of reduced-in-fat and reduced-in-fat and sugar cookies. Area under the curve, indicative of oral hardness, chewiness and cohesivenss, was found to correlate best with sensory evaluation of texture (Perry and others, 2003). In this study, probing revealed that full-sugar cookies and those prepared with ace-K were harder than cookies containing sucralose and ace-K/sucralose blend. Sucralose and ace-K/sucralose cookies were also more tender than other cookies. Panelists found similar results.

During product development, trained panelists evaluate flavor and texture characteristics and report intensities of specific attributes. While panelists may note differences between the control and modified products, acceptability of the modified product should be assessed by consumer panelists. In this study, consumers evaluated acceptability of reduced-in-fat and sugar cookies. Consumers also described their "ideal" oatmeal and chocolate chip cookies, providing a guide for continued product modification (Szczesniak, 1975).

Consumer panelists found differences in flavor and texture of modified cookies when compared to the full-sugar control and to the "ideal." Modified cookies were more similar to one another and to the "ideal" than to the control in both flavor and texture. In terms of overall acceptability, modified cookies did not differ from the full-sugar control, but were less acceptable than the "ideal." The attributes most affected by use of HIS were salty, buttery, off-flavors and brown sugar flavor. Textural attributes affected included crispness, hardness and chewiness.

Overall, partial replacement of HIS in reduced-in-fat cookies did not drastically affect texture, flavor or overall acceptability. While use of HIS blends has previously been reported to minimize undesirable effects caused by use of a single HIS, use of HIS blends in these reduced-in-fat cookies did not result in a superior product. Therefore, when choosing a HIS for use in reduced-in-fat cookies factors other than flavor, such as cost and ease of handling, may be considered.

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CHAPTER VIII

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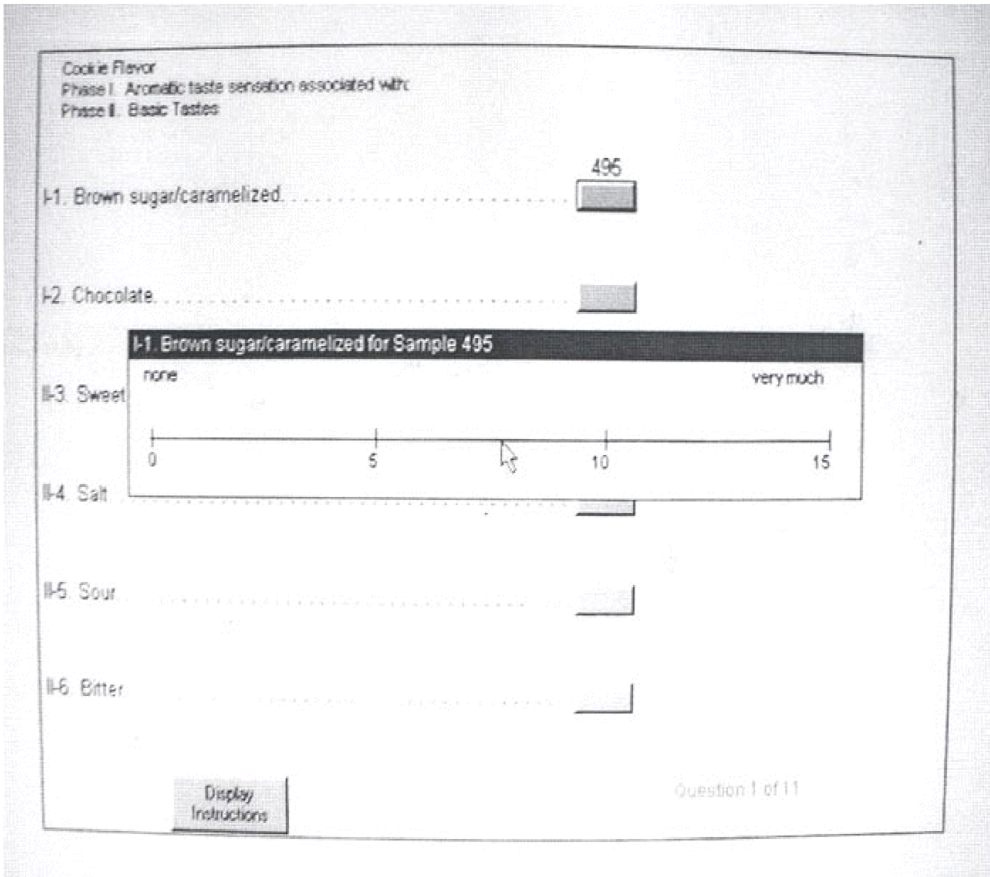
APPENDIX A

EXAMPLE OF A COMPUTERIZED 15-POINT LINESCALE USED BY TRAINED SENSORY PANELISTS DURING SENSORY DESCRIPTIVE ANALYSIS OF OATMEAL AND CHOCOLATE CHIP COOKIES


Cookie Flavor
Phase I. Aromatic taste sensation associated with:
Phase II. Basic Tastes
495
I-1. Brown sugar/caramelized
I-2. Chocolate
II-3. Sweet
II-4. Salt
II-5. Sour
II-6. Bitter
I-1. Brown sugar/caramelized for Sample 495
none
very much
0
5
10
15
Display Instructions
Question 1 of 11

APPENDIX B

OATMEAL CONSUMER SENSORY PANEL: CONSUMER PROFILE BALLOT FOR THE "IDEAL" AND 4 COOKIE SAMPLES AND QUESTIONNAIRE

Judge________ Sample________

Oatmeal Cookie Scorecard

This is a list of terms often used to describe the texture and flavor of cookies. Please describe your _______ oatmeal cookie using the terms given. Please check the box beside each term which best indicates the degree to which you feel your _______ oatmeal cookie has that characteristic.

TEXTURE (How the cookie feels in the mouth	Not at all					Very much so
Crisp	☐	☐	☐	☐	☐	☐
Greasy/ Oily	☐	☐	☐	☐	☐	☐
Chewy	☐	☐	☐	☐	☐	☐
Hard	☐	☐	☐	☐	☐	☐
Bad	☐	☐	☐	☐	☐	☐
Crumbly	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Rough surface	☐	☐	☐	☐	☐	☐
Soft	☐	☐	☐	☐	☐	☐

FLAVOR (How the cookie tastes throughout chewing)	Not at all					Very much so
Sweet	☐	☐	☐	☐	☐	☐
Salty	☐	☐	☐	☐	☐	☐
Bland	☐	☐	☐	☐	☐	☐
Molasses-like	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Off-flavors detected	☐	☐	☐	☐	☐	☐
Buttery	☐	☐	☐	☐	☐	☐
Strong	☐	☐	☐	☐	☐	☐
Bitter	☐	☐	☐	☐	☐	☐
Brown-sugar like	☐	☐	☐	☐	☐	☐

QUESTIONNAIRE

1. **Gender**: _________Male _________Female

2. **Please check your age category:**
   _________18-27
   _________28-35
   _________36-43
   _________44-51
   _________52-61
   _________62 or over

3. **How often do you eat cookies?**
   _________Several times a week
   _________Several times a month
   _________Once a month
   _________Several times a year
   _________Never

4. **How often do you eat reduced-calorie or reduced-fat baked goods?**
   _________All the time
   _________Most of the time
   _________Half of the time
   _________Several times a year
   _________Never

5. **How often do you eat reduced-sugar or sugar-free baked goods?**
   _________All the time
   _________Most of the time
   _________Half of the time
   _________Several times a year
   _________Never

6. **Do you eat reduced-fat or fat-free cookies?**
   _________Yes
   _________No

   If yes, how often?
   _________Several times a week
   _________Several times a month
   _________Once a month
   _________Several times a year
   _________Never

7. **Do you eat reduced-sugar or sugar-free cookies sweetened with artificial sweeteners?**
   _________**Yes**
   _________No

   If yes, how often?
   _________Several times a week
   _________Several times a month
   _________Once a month
   _________Several times a year
   _________Never

APPENDIX C

CHOCOLATE CHIP CONSUMER SENSORY PANEL: CONSUMER PROFILE BALLOT FOR THE “IDEAL” AND 4 COOKIE SAMPLES AND QUESTIONNAIRE

Judge_________ Sample________

Chocolate Chip Cookie Scorecard

This is a list of terms often used to describe the texture and flavor of cookies. Please describe your ______ chocolate chip cookie using the terms given. Please check the box beside each term which best indicates the degree to which you feel your ______ chocolate chip cookie has that characteristic.

TEXTURE (How cookie feels in the mouth)	Not at all					Very much
Crisp	☐	☐	☐	☐	☐	☐
Greasy/ Oily	☐	☐	☐	☐	☐	☐
Chewy	☐	☐	☐	☐	☐	☐
Hard	☐	☐	☐	☐	☐	☐
Bad	☐	☐	☐	☐	☐	☐
Crumbly	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Rough surface	☐	☐	☐	☐	☐	☐
Soft	☐	☐	☐	☐	☐	☐

FLAVOR (How the cookie tastes throughout chewing)	Not at all					Very much so
Sweet	☐	☐	☐	☐	☐	☐
Salty	☐	☐	☐	☐	☐	☐
Bland	☐	☐	☐	☐	☐	☐
Chocolate	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Off-flavors detected	☐	☐	☐	☐	☐	☐
Buttery	☐	☐	☐	☐	☐	☐
Strong	☐	☐	☐	☐	☐	☐
Bitter	☐	☐	☐	☐	☐	☐
Brown-sugar like	☐	☐	☐	☐	☐	☐

QUESTIONNAIRE

1 **Gender**: __________Male __________Female

2. Please check your age category:

_________18-27
_________28-35
_________36-43
_________44-51
_________52-61
_________62 or over

3. How often do you eat cookies?

_________Several times a week
_________Several times a month
_________Once a month
_________Several times a year
_________Never

4. How often do you eat reduced-calorie or reduced-fat baked goods?

_________All the time
_________Most of the time
_________Half of the time
_________Several times a year
_________Never

5. How often do you eat reduced-sugar or sugar-free baked goods?

_________All the time
_________Most of the time
_________Half of the time
_________Several times a year
_________Never

6. Do you eat reduced-fat or fat-free cookies?

_________Yes
_________No

If yes, how often?

_________Several times a week
_________Several times a month
_________Once a month
_________Several times a year
_________Never

8. Do you eat reduced-sugar or sugar-free cookies sweetened with artificial sweeteners?

_________**Yes**
_________No

If yes, how often?

_________Several times a week
_________Several times a month
_________Once a month
_________Several times a year
_________Never