1. **Title**

The Effects of Sucralose, Splenda and Splenda Sugar Blend, Used in Place of Sugar and Introduced at a Different Stage in a No-Bake Cookie Recipe

2. **Abstract**

There has been a shift in recent decades away from complex carbohydrate consumption and towards simple carbohydrate consumption. Increased simple carbohydrate consumption has been linked to increases in obesity, diabetes, and dental caries. This experiment attempted to modify a No-Bake cookie recipe using the alternative sweetener Splenda. Both Splenda Granular and Splenda Sugar Blend were substituted for sugar in a No-Bake cookie recipe. Both of the alternative sweeteners used were introduced at the end of the recipe in an effort to avoid molecule breakdown during stovetop heating. The cookies made with both types of Splenda had undesirable taste and texture characteristics and were unlike the No-Bake cookie made with sugar. Conclusions from this study are that Splenda can not be successfully used to substitute sugar in the No-Bake cookie recipe used.

3. **Introduction**

In recent decades, there has been a shift in carbohydrate consumption. The shift has been away from complex carbohydrates, such as starch and fiber, and towards simple carbohydrates, such as sugars and syrups. The majority of simple sugars consumed presently come from caloric soda, sugar cereals, and manufactured baked goods. The annual soft drink production per capita in the U.S., as of 1997, was 570 twelve-ounce cans. The before mentioned number however, includes both non-caloric and caloric soft drinks (Daniel 2005). A recent study of 15, 000 Americans showed that mean intakes of added sweeteners was eighty-two grams of carbohydrate per day and accounted for 16 percent of total energy intake. The study concluded the consumption levels of sweeteners were in excess of the recommended amount for the general U.S. population.
WHO/FAO report states, while sugar is not a direct cause of obesity, high consumption of energy dense foods, including those high in fat and sugar, are believed to promote weight gain (Birkbeck and others 2001). Increased weight gain in turn, increases risk for obesity, Type 2 diabetes, and coronary heart disease (Daniel 2005). High and excessive intakes of sugar may also contribute to insulin insensitivity and increases in blood lipids. In addition and included in the WHI/FAO report, the risk of dental caries increases with intake of sugars, but the risk does not work independently from factors such as oral hygiene. Amylase and bacteria in the mouth, which produce acid and increase the risk of caries, can more easily break down foods containing sugars (Birkbeck and others 2001).

Given the rise in simple carbohydrate consumption and the risks this increase imposes, alternative sweeteners may be used to assist in weight management, control of blood glucose, and prevention of dental caries. A study published in the Journal of the American Dietetic Association concluded that despite the significant doses, more than three-times the maximum recommendation, sucralose did not affect any measure of glucose control evaluated in the trend toward loss of blood glucose control observed (Grotz and others 2003). Another study, published in the American Journal of Therapeutics, concluded that incorporating fat-replacers and no-sucrose sweeteners produced a greater improvement in metabolic and anthropometric variables in well controlled Type 2 diabetic patients when compared with a diet based on American Diabetic Association’s nutrition recommendations (Reyna and others 2003). An article titled “Concept on Sugar-A Review,” states that research shows that people who use foods and beverages sweetened with low-calorie sweeteners consume fewer calories than those who do not, that low-calorie sweeteners do not increase appetite and cravings for sweet foods, and foods and beverages sweetened with low calorie sweeteners do not cause disease (Zakaria and others 2001). An article titled “Dental Considerations in Sucralose Use,” concluded that sucralose does not promote dental caries and fulfills the FDA criteria for non-cariogenicity (Mandel and others 2002).
The following research attempted to replace granulated, or table, sugar with the alternative sweetener, sucralose in a No-Bake Cookie recipe. Sucralose is marketed by the name Splenda. Two forms of Splenda were used in this research, Splenda Granular and Splenda Sugar Blend. Both are marketed as appropriate for baking a cooking. Splenda Granular contains sucralose and small amounts per serving of food ingredients commonly found in other no calorie sweeteners. These provide less than five calories and 1 gram of carbohydrate per serving, which meets the FDA’s standards for no calories. Splenda Sugar Blend, a blend of sucralose and pure sugar, provides full-sugar sweetness with half the calories and carbohydrates. When used in place of sugar, substitution of Splenda Sugar Blend is a 1:1/2 cup ratio: one cup of sugar equals one-half cup of Splenda Sugar Blend (McNeil Nutritionals LLC 2005).

Splenda’s sweetness is 650 times that of pure sugar. It is a synthetic carbohydrate (Daniel 2005). Splenda is made from sugar and taste profiles have concluded it also retains many of the characteristics associated with sugar. It is manufactured in a patented multi-step process that starts with and selectively replaces three hydrogen-oxygen groups on the sugar molecule with three chlorine atoms (McNeil Nutritionals LLC 2005).

Figure 1a. Chemical Structure of Sucralose and Sucrose
Chlorine is a natural element present in many of the foods and beverage humans consume. In Splenda, the substitution of chlorine atoms to sucrose renders it inert so that the body, for energy, does not metabolize it. This makes sucralose free of calories and does not elevate short-term or long-term blood glucose or serum insulin levels. The chlorine also makes the sucralose molecule stable enough to withstand the rigors of cooking and baking without losing its sweetness. Eighty-five percent of consumed sucralose is not absorbed and passes through the gastrointestinal unchanged. The other fifteen percent of consumed sucralose is passively absorbed and because it is highly water soluble, it is distributed to essentially all tissues. Splenda is not lipophilic and does not bioaccumulate. It is also not transported across the blood-brain barrier, the placental barrier, or mammary gland. Since the body does not recognize sucralose as a carbohydrate, it is not broken down for energy and does not contribute any calories. There is also no breakdown of the molecule to its component monosaccharide-like derivatives. Most of the ingested sucralose is eliminated unchanged in the stool with no gastrointestinal effects. Of the sucralose that is absorbed, most is eliminated in the urine within twenty-four
hours. Based on findings from more than one hundred scientific studies, sucralose has been determined safe and an essentially inert ingredient with no toxicity, carcinogenicity, neurotoxicity, and carcinogenicity. Splenda is safe for consumption by pregnant and nursing women, children, and patients with diabetes (McNeil Nutritionals 2005).

The purpose of the current research experiment was to see how replacing sugar with sucralose and a blend of sucrose and sucralose would affect the taste and texture of a No-Bake cookie recipe. Since previous experiments have concluded direct substitution of sucralose in the No-Bake cookie recipe used did not produce a desirable cookie, the current research attempted to replace sucralose and a blend of sucrose and sucralose at the end of the recipe where the alternative sweeteners would not be subjected to stovetop heating and possible breakdown of the molecule. See this experiment, Trial 1, in Appendix 1. The dependent variables in this experiment are taste and texture. Dependent variables will be measured both objectively, using the texture analyzer and water activity machine, and subjectively, using the triangle test and a hedonic rating scale. The independent variables in this experiment are Splenda Granular introduced at the end of the No-Bake cookie recipe and Splenda Sugar Blend introduced at the end of the No-Bake cookie recipe. I will use sugar introduced at the designated time in the No-Bake cookie recipe as the control.

4. Methods

The No-Bake cookie recipe used in trials 2 and 3 of this experiment was obtained from www.allrecipes.com. It was submitted by Sherry T. and was titled “No Bakes.” Variable 1 was the control cookie, sugar introduced at the designated time in the cookie recipe. Variable 2 introduced Splenda Sugar Blend at the end of the cookie recipe. Variable 3 introduced Splenda Granular at the end of the cookie recipe. To perform this experiment, the ingredient amounts were converted to metric units. The recipe is as follows:

No Bakes
16g unsweetened cocoa powder 400g white sugar
120mL milk
115 g butter
245g quick oats
130 g crunchy peanut butter
15mL vanilla extract

Procedure for Variable 1:
1. Heat cocoa, sugar, milk, and butter over medium heat. Boil these very slowly.
   When they reach boiling point, boil no longer than 90-120 seconds.
2. Stir together oats, peanut butter, and vanilla with a big wooden spoon. Pour
   the hot mix over the oatmeal mix and drop onto wax paper.

Modified Procedure for Variables 2 and 3:
1. Heat cocoa, milk, and butter over medium heat. Boil these very slowly.
   When they reach boiling point, boil no longer than 90-120 seconds.
2. Stir together oats, peanut butter, vanilla, and Splenda with a big wooden
   spoon. Pour the hot mix over the oatmeal mix and drop onto wax paper.

Yield: 2 dozen cookies

Since Splenda Sugar Blend is to measured in a 1:1/2 cup ratio when used
in replace of sugar, 1 cup of Splenda Sugar Blend was used for Variable 2. Since
Splenda Granular is measured in a 1:1 cup ratio when used in replace of sugar, 2
cups of Splenda Granular was used for Variable 3. With respect to brand names
for the ingredients, the same brand name of ingredients for each variable and
throughout all trials was consistent. Splenda Granular and Splenda Sugar Blend
were the only alternative sweeteners used in this experiment.

One batch of cookies was made for each variable in each trial. After each
variable was prepared, all utensils and equipment used were washed, dried and
used again for the next variable. A thermometer and timer was used to monitor
the temperature of the hot mixture for each variable and throughout each trial.

The objective tests used in trials 2 and 3 measured cookie texture. The
cone probe on the texture analyzer was used to measure the peak force, in grams,
of each cookie variable. Each variable throughout trials 2 and 3 was measured
twice and the average was recorded. The peak force measurement is related to
product hardness, cohesiveness, chewiness, and gumminess (Weaver and others
2003).
The other objective test in trials 2 and 3 used the water activity machine. Water activity is based on dew point. A thermocouple detects the condensation temperature on a cooled mirror (Weaver and others 2003). Each variable throughout trials 2 and 3 was measured twice and the average recorded. The water activity measurement is related to moisture in the product and is an indication of free water in a product (Weaver and others 2003). Attached are the original data sheets and a blank data sheet used in trials 2 and 3.

The subjective tests in trials 2 and 3 measured both taste and texture. Throughout trials 2 and 3 variable 1 was designated 923, variable 2 was 517, and variable 3 was 886. A triangle test was performed on nine panelists for each trial. For each trial, one variable was the designated the “different” cookie three times. Throughout the trials small white paper plates were used to display the cookies and the cookies were placed in a triangle fashion on the plate. Effort was made to make each cookie on a single plate relatively the same size. The number of correct identifications was recorded into scorecards throughout trials 2 and 3.

The other subjective test used in trials 2 and 3 was a nine point hedonic rating scale. The lowest ranking was “dislike extremely”, rank point 1, and the highest ranking was “like extremely,” rank point 9. For trials 2 and 3, each variable was rated nine times. Again each cookie was plated singly on a small white paper plate throughout trials 2 and 3. Attached are sample scorecards for both the triangle test and hedonic rating scale that were used in trials 2 and 3. The average rating for each variable was recorded throughout trials 2 and 3.

5. Discussion

As can be seen from Table 2a and Graph 2a, the highest average peak force was measured in variable 1 and the lowest average peak force was measured in variable 3 for trials 2 and 3. Observation of the cookie variables agreed with these measurements. Neither variable 2 nor 3 hardened like variable 1, independent of the time the variables were allowed to set. Overall, variables 2 and 3 were less cohesive and more chewy and gummy than variable 1. A possible source of error for these measurements may be due to the non-uniform nature of
the cookie itself. The cookies contained bits of nuts and oatmeal surrounded by a chocolate mixture, all with a unique texture.

As can be seen from Table 2b and Graph 2b, the measured water activity was highest for variable 3 and lowest for variable 1 for trials 2 and 3. Again, observation of the cookie variables was consistent with these measurements. Both variable 2 and 3 did not produce the crispness associated with a cookie and seen in variable 1. Overall, variables 2 and 3 were contained more moisture than variable 1. Possible sources of error for these measurements may be contaminated holding cups and/or equipment and again, the non-uniform nature of the cookie.

As can be seen from Table 2c and Graph 2c, the average hedonic ratings were highest for variable 1 and lowest for variable 3. Overall, variables 2 and 3 did not produce a cookie with the same characteristics, taste and texture, that are associated with the accepted control cookie variable. In addition to neither variable hardening to the same degree as variable 1, both variables 2 and 3 left a different aftertaste in the participants’ mouth. In addition, variable 2 had a grainy texture, contributed to the non-dissolved sugar.

As can been seen from Table 2d and Graphs 2di and 2dii, all participants in the triangle tests throughout trials 2 and 3 were able to correctly identify the “different” cookie variable for both taste and texture. Each cookie variable produced a uniquely characterized cookie and was distinguishable from the other variables. An almost certain source of error for the subjective measurements was the inexperience of the participants in the taste panel. None of the participants had been educated on proper panel tasting techniques.

Conclusions from trials 2 and 3 were that neither Splenda Granular nor Splenda Sugar Blend can be successfully substituted for sugar in the No-Bake cookie recipe used. Cookies using Splenda as an alternative sweetener produce cookies that are less hard and cohesive and more moist, chewy, and gummy. Both types of Splenda produce a cookie with a different and undesirable taste and the sugar in Splenda Sugar Blend does not completely dissolve adding a gritty texture to the cookie characteristics.
Future research could include experiments using other commercial alternative sweeteners marketed for baking and cooking such as Equal Sugar Blend, made with sugar and aspartame. Another possible alternative sweetener to test may be neotame, which is heat stable and may be able to withstand the stovetop cooking the No-Bake cookie recipe requires. Another research possibility is using half sugar, introduced at the designated time in the cookie recipe, and half alternative sweetener introduced at the end of the cookie recipe.

6. Results

The following contains the tables and graphs from trials 2 and 3. Variable 1 was the control variable, sucrose introduced at the designated time in the cookie recipe. Variable 2 was the first independent variable, Splenda Sugar Blend introduced at the end of the cookie recipe. Variable 3 was the second independent variable, Splenda Granular introduced at the end of the cookie recipe. Trial 1 is not included in this section because the methodology used in it was different. Trial 1 is included in Appendix 1.

Table 2a. Average Peak Force (grams) for Trials 2 & 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average T2</th>
<th>Average T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=923</td>
<td>482.55</td>
<td>638.25</td>
</tr>
<tr>
<td>2=517</td>
<td>101.50</td>
<td>54.05</td>
</tr>
<tr>
<td>3=886</td>
<td>397.40</td>
<td>236.95</td>
</tr>
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</table>

Graph 2a. Average Peak Force of No-Bake Cookie Variables in Trials 2 & 3
Table 2b. Water Activity for Trials 2 & 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average T2</th>
<th>Average T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=923</td>
<td>0.797</td>
<td>0.793</td>
</tr>
<tr>
<td>2=517</td>
<td>0.817</td>
<td>0.775</td>
</tr>
<tr>
<td>3=886</td>
<td>0.810</td>
<td>0.827</td>
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Table 2c. Average Hedonic Rating (Scale 1-9) of Trials 2 & 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average T2</th>
<th>Average T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=923</td>
<td>7.9</td>
<td>7.8</td>
</tr>
<tr>
<td>2=517</td>
<td>5.8</td>
<td>3.8</td>
</tr>
<tr>
<td>3=886</td>
<td>4.2</td>
<td>2.5</td>
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</table>
Table 2d. Percentage of Correct Identifications of No-Bake Cookie Variables for Texture and Taste for Trials 2 & 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>% Correct T2</th>
<th>% Incorrect T2</th>
<th>% Correct T3</th>
<th>% Incorrect T3</th>
</tr>
</thead>
<tbody>
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<td>1=923</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2=517</td>
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<tr>
<td>3=886</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
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</table>

Graph 2c. Average Hedonic Rating of No-Bake Cookie Variables in Trials 2 & 3

Graph 2di. Total Percentage of Correct Identifications for Taste and Texture Using Triangle Test for Trial 2
Graph 2dii. Total Percentage of Correct Identifications for Taste and Texture Using Triangle Test for Trial 3
References
Appendix 1

The methodology in trial 1 of this experiment was different than that of trials 2 and 3, and therefore appears in Appendix 1. While sugar introduced at the designated time in the No-Bake cookie recipe was used for the control and Splenda Granular introduced at the end of the No-Bake cookie recipe was one of the independent variables, the other independent variable was Splenda Granular introduced at the designated time in the No-Bake cookie recipe. The subjective measurements recorded for the latter independent variable were very low. Therefore, a new independent variable, Splenda Sugar Blend introduced at the end of the No-Bake cookie recipe was used in trials 2 and 3.

Table 1a. Average Peak Force (grams) for Trial 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=923</td>
<td>164.75</td>
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<tr>
<td>2=517</td>
<td>145.05</td>
</tr>
<tr>
<td>3=886</td>
<td>65.15</td>
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</table>

Graph 1a. Average Peak Force of No-Bake Cookie Variables in Trial 1
Table 1b. Water Activity for Trial 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=923</td>
<td>0.776</td>
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<tr>
<td>2=517</td>
<td>0.796</td>
</tr>
<tr>
<td>3=886</td>
<td>0.848</td>
</tr>
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</table>

Graph 1b. Water Activity of No-Bake Cookie Variables in Trial 1

Table 1c. Average Hedonic Rating (Scale 1-9) of Trial 1

<table>
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<th>Average T1</th>
</tr>
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<tbody>
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<td>8.4</td>
</tr>
<tr>
<td>2=517</td>
<td>5.3</td>
</tr>
<tr>
<td>3=886</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Graph 1c. Average Hedonic Rating of No-Bake Cookie Variables in Trial 1
Table 1d. Percentage of Correct Identifications of No-Bake Cookie Variables for Texture and Taste for Trial 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>% Correct T1</th>
<th>% Incorrect T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=923</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2=517</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>3=886</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Graph 1d. Total Percentage of Correct Identifications for Taste and Texture Using Triangel Test for Trial 1