

# **Splenda Is an Acceptable Substitute for Sugar in Chocolate Chip Cookies**

## **Abstract**

Sugar is a main ingredient in many baked goods and contributes to a lot of empty calories in the American diet. Splenda, a zero calorie sweetener is used in many products to lower the amount of in the product, as well as the amount of sugar; without jeopardizing the sweet flavor. Our study examined three variations of chocolate chip cookies from Whitney Hall. Cookies were either made with 100% Splenda, 100% sugar, or 50% sugar/50% Splenda. We used sensory and objective evaluations to determine whether or not Splenda was an acceptable substitute for sugar. Our sensory method results show that Splenda is an acceptable substitute for sugar by consumers.

## **Introduction**

Sugar consumption is readily increasing in the United States and is a main contributor to such nutritional conditions like Type II Diabetes and obesity. The suggested daily recommendation for sugar intake is about 10 teaspoons a day. The average American consumes about 32 teaspoons per day. Soda is the leading source of sugar intake among American; cakes, cookies and other baked goods follow right behind.

Splenda, a zero calorie sweetener is a popular sugar replacer in the United States. Splenda is the brand name for the ingredient sucralose. Splenda is made through a multi-step process, where regular table sugar is converted into sucralose. The process replaces three hydrogen-oxygen groups on the sugar molecule with three chlorine atoms and in the end you have a product that tastes just as sweet as sugar, but without the calories. Sucralose goes through your body unnoticed, so therefore your body does not treat it like a carbohydrate. The Food and Drug Administration recognizes Splenda as being safe for human consumption and there have been many trials done on the product over the past twenty years ensuring its safety. The consumption of Splenda is safe for children, pregnant women and those who are diabetic. Since Splenda can

give the sweet taste consumers are looking for, it helps aid in a healthy diet, because it doesn't add the empty calories that regular sugar does.

The significance of our study was to find out if we could create a lower calorie cookie using Splenda, that would be accepted by consumers and be without a significant difference in flavor profile from the original. We hypothesized that we would be able to create a cookie using Splenda that tasted just as good as the original and would also be accepted by the consumers. We performed a marketing survey at the beginning of the semester and from the results we were able to draw a conclusion that most people's least favorite place to eat on campus was Whitney Hall. Many people who were surveyed said that Whitney Hall was their least favorite due to the poor taste, poor quality, and poor nutrition of the items that are served. With these results we decided that we wanted to change the chocolate chip cookies that are served at Whitney Hall, and try to come up with a lower calorie version using Splenda in place of the regular sugar used in the recipe.

The first study we reviewed for our research was, "Sensory and Microbial Quality of a Baked Product Containing Xylitol as an Alternative Sweetener." This study conducted an experiment to see if xylitol, an alternative sweetener, could be used as a replacement to sucrose and glucose in baked goods. They wanted to find out whether xylitol can be used as an alternative without changing the quality of products. This study used homemade cookies using the same recipe, but with 3 different sweeteners (sucrose, glucose and xylitol). Samples were measured in height and weight and then stored in different conditions (variations were made to the temperature) for different amount of times. They conducted sensory evaluations on the treatments using untrained panelists. They conducted a duo-trio test to find out if the xylitol cookies were respectively different to the sucrose or glucose cookies. They conducted a 9-point hedonic scale to find out how well all three treatments were accepted by the consumer. They conducted a sweetness intensity scale (9-point) to find out how the sweetness of all three treatments compared.

The main outcome of the study showed that even though xylitol was shown to be as sweet as sucrose in baked products, panelists were still able to tell a difference in the products. The panelists thought that the

cookies with xylitol were as sweet as the ones with sucrose but could still detect the difference. The cookies with xylitol were softer and tenderer than those that were made with sucrose, which turned out to be crunchy and dry. The researchers believe xylitol is a great alternative to sugar; it has fewer calories than regular sugar and can be used by diabetics. This experiment is useful in our research because it shows that xylitol is an acceptable alternative to sugar.

There were several similarities between this study and ours. For example, they used an alternative sweetener to substitute for sugar. They also found no difference in sweetness or overall flavor between the cookie made with sugar and the one made with the alternative sweetener. They conducted a 9- point hedonic test in which they found that the majority of the consumers either liked the altered cookie slightly or moderately. The researchers tested the cookie in terms of its tenderness; they yielded a statistical difference in the tenderness ( $P < 0.01$ ). We also measured our cookies in terms of their tenderness using a penetrometer. We yielded the same exact statistical difference ( $P < 0.01$ ) as they did in their study.

There were several differences between their study and ours as well. They used a different type of sugar substitute than we did. They used xylitol and we used Splenda, which is the brand name for sucralose. Their study assessed storage time and temperature, where we did not. They also assessed the difference in affect on microbial load between the cookies made with sucrose and those made with the alternative sweetener.

Another study we reviewed in our research was, "Functionality of sugars: physiochemical interactions in foods." The study offered us great insight into the chemical properties and reactions of sugars and how they function in the production of foods. Specifically, they discuss sugar replacement in baked goods. When baking, it is important that the sugar-replacement sweetener being used is heat stable. They noted that cookie dough which was studied resulted in a harder, more dense cookie when sugar was removed. It informed us that sugars play an important role in the structure and texture, as well as the sweetness of foods. They help control the heat-transfer characteristics in heated products. They affect the emulsion-stabilizing properties, protein denaturation, and starch gelatinization. From this article we were

able to understand that there could be a great affect on our product's texture, mouth-feel, and flavor by substituting the sugar with Splenda.

## Methods and Materials

The objective of our experiment was to replace the sweetener used in the chocolate chip cookie recipe from Whitney Hall. The recipe uses 100% table sugar/sucrose. We will be replacing the sucrose with Splenda, which will create a lower calorie cookie. We hypothesize that if we replace the sucrose with Splenda in the Whitney Hall chocolate chip cookie, we will create a lower calorie cookie that will be accepted by the consumer because Splenda is an acceptable substitute for sugar.

In this experiment our independent variable was the amount of sucrose or Splenda (sucralose) used in the preparation of the cookies. There were three variations all with different amounts of sucrose or Splenda. Our dependent variable was the acceptance rate of our modified cookies and results from our objective method (tenderness of each cookie). We measured consumer acceptance using a 9 point hedonic scale for untrained consumers and qualitative descriptive analysis for trained panelists. We measured our objective method using a penetrometer.

The characteristics of our experiments are displayed in the table below:

| TREATMENT | % SUCROSE | % SPLENDA |
|-----------|-----------|-----------|
| 1         | 100       | 0         |
| 2         | 50        | 50        |
| 3         | 0         | 100       |

Our main goal was to create a lower calorie cookie that would still be accepted by consumers. Upon evaluation of the nutritional content of each cookie, we realized there was a slight difference in caloric content among the three variations. The 100% Splenda cookie contained 136 calories, 7.5 g fat, and 7.6 g

sugar. The 50% Splenda/50% Sucrose contained 140 calories, 7.5 g fat, and 8.7 g sugar. The 100 % Sucrose has 145 calories, 7.5 g fat, and 9.7 g sugar. So the cookie made with Splenda instead of sucrose was 9 calories less. This was not a huge difference; in order to really lower the caloric content in the future we could investigate replacing other ingredients like butter, or oil. We obtained this nutrition information by looking up the values for each ingredient on the website [calorieking.com](http://calorieking.com).

We used the standard cookie method to prepare our cookies. The margarine, oil, brown sugar, sugar/Splenda and instant pudding were added together until fluffy. We then add the eggs and vanilla to the mixture and mixed them together on medium speed. We then blended the flour, salt, baking soda, baking powder and oats and mixed everything together on low speed, until everything was blended. Lastly, we added the chocolate chips and cornflakes and mixed on low until all the ingredients all combined. The cookies baked at 176 degrees Celsius, until golden brown.

To obtain a uniform sample each time we tried to follow this procedure exactly each time. We made small changes in preparation techniques during the beginning of our experimentation (i.e. standardizing cooking temperature, and blending in the corn flakes). Everyone did the same job each time to avoid changes in the product. If we were to do this experiment again we believe it would be necessary to have a standard cookie size, because the samples tended to look different at times.

For our Qualitative Descriptive Analysis we used a trained panel of testers. The sample size was varied between 8 and 12 panelists. We conducted this type of experiment several times to get an average of numbers. Each panelist was given each type of variation of cookie labeled with a random three digit number and asked to rate its qualities. We then got numerical data from these ratings by measuring where they had made a mark on the scale that we gave them. Once we obtained numbers we were able to analyze the data using excel. Below is a chart listing each characteristic that was tested and what was being tested for.

|                                  |                          |
|----------------------------------|--------------------------|
| <b>Appearance: Color</b>         | <b>Light – Dark</b>      |
| <b>Aroma: Buttery</b>            | <b>Not at all – Very</b> |
| <b>Sweet</b>                     | <b>Not at all – Very</b> |
| <b>Flavor: Sweet</b>             | <b>Not at all – Very</b> |
| <b>Texture/Mouthfeel: Chewy</b>  | <b>Not at all – Very</b> |
| <b>Crumbly</b>                   | <b>Not at all – Very</b> |
| <b>Residual/Affertaste: Oily</b> | <b>Not at all – Very</b> |
| <b>Sweet</b>                     | <b>Not at all – Very</b> |
| <b>Texture: Moistness</b>        | <b>Dry – Moist</b>       |
| <b>Density</b>                   | <b>Airy – Dense</b>      |

For our 9 point hedonic test we used the following scale:

- Like extremely (9)
- Like very much (8)
- Like moderately (7)
- Like slightly (6)
- Neither like nor dislike (5)
- Dislike slightly (4)
- Dislike moderately (3)
- Dislike very much (2)
- Dislike extremely (1)

This scale was given to each untrained panelist along with a small sample of each variation, also labeled by random three digit numbers. They were asked to rate each variation. We then obtained numerical

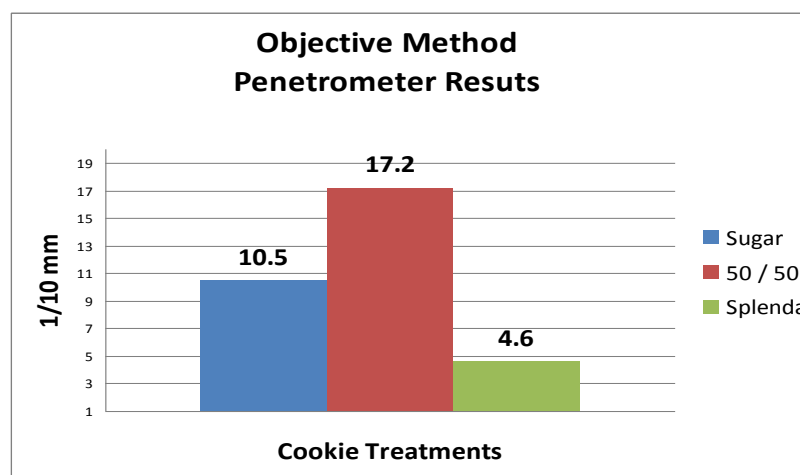
data by assigning a number 1-9 to each rating and plugging these values into excel. From this data we were able to obtain averages. This type of test was very successful for us, 50 + untrained panelist showed up to take part in this survey. With the data we received we were able to analyze consumer acceptance.

For our data analyses we used the Qualitative Descriptive Analysis, 9-point hedonic scale, and penetrometer. Our results found that there was a significant difference in tenderness among all three variations. There was also a significant difference among color and density; none of which affect the flavor of the cookies.

## Results and Discussion

### *Objective Methods Results*

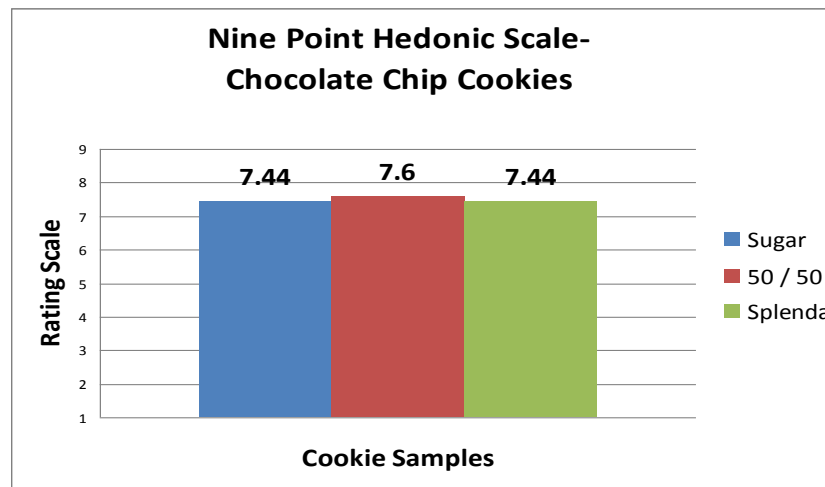
The results of our objective methods, determined by the penetrometer results we collected, showed that all of our treatments varied in tenderness. The 50% sugar/50% Splenda treatment was the most tender, whereas the 100% Splenda treatment was the least tender, and the 100% sugar treatment fell in between. We hypothesized that the most tender treatment would be the most favored by the panelists and consumers, which led us to believe the 50/50 treatment would be the most accepted from. Although there was quite a bit of variation in our penetrometer readings from the nine tries (likely due to human error and variation in the spots tested), we perceived through our tastings of the treatments that the 50/50 treatment was the most tender. Therefore, we felt the penetrometer results were an accurate representation of the true ratios of tenderness between the treatments. All treatments showed significant difference from one another.



Graph 1: Objective Method Penetrometer Results. Shows three cookie treatments and their mean penetrometer result of nine tries, measured in 1/10 mm.

### *Sensory Methods Results*

The nine-point hedonic scale results showed all treatments to be acceptable, almost on an exact scale when comparing their means. Consumers rated all three treatments on average between “like moderately” to “like very much”, which is similar to what we found in the literature results (“like slightly” to “like moderately”) in substituting with xylitol. Consumers found the 100% Splenda and 50/50 cookies to be just as acceptable as the 100% sugar cookie; if not slightly more acceptable (50/50 treatment). This supports our hypothesis that Splenda is an acceptable substitute for sugar in chocolate chip cookies. Although we only tested 50 students, we feel that these results are a good representation of consumer acceptance on campus and would hope to find similar results in a larger sample. Substituting Splenda for sugar in these cookies will help lower calorie intake while keeping taste comparable and acceptance high.

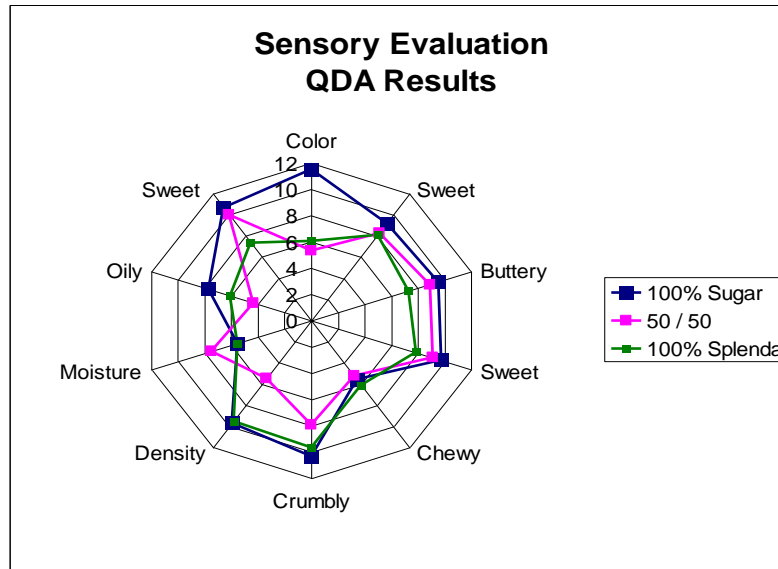


Graph 2: Cookies were rated on a 1-9 scale. 9 being that they 'Like extremely' and 1 being that they 'Dislike extremely'. The consumers were not able to taste the difference between the control and the altered cookies.

We chose 10 attributes from the list of characteristics proposed by the trained panelists to describe our cookies in the sensory evaluation QDA. Most attributes showed relative similarity between treatments. Color and density showed significant difference between one of the treatments. For color, the 100% sugar treatment was significantly different, being much darker than the others. For density, the 50/50 treatment



was significantly different, being much less dense than the other two. The similarity of the other attributes supports our hypothesis even more by showing that Splenda is an acceptable substitute by producing similar responses to the different treatments.



Graph 3: Spider graph showing the relationship of how each attribute of the different treatments related to one another. Color and density show significant difference.

### *Statistical Significance*

Our group found statistical significance in our penetrometer results and in two attributes of the quantitative data analysis (QDA). For the penetrometer results, we found that all treatments were significantly different from each other, with a p-value of 0.013672, meaning it was statistically significant. In the sensory evaluation, there were two attributes that were statistically significant. For color, the 100% sugar cookie was significantly different with a p-value of 0.000108, being much darker. For density, the 50/50 cookie was significantly different with a p-value of 0.046421, being much less dense. The fact that these three factors (tenderness, color, and density) were the only significant differences between the treatments proves even further that Splenda is an acceptable substitute for sugar in chocolate chip cookies. The Splenda cookies offer a slightly healthier (5 calories lower) option to the regular cookies served on campus, but our results show they are equally tasty and acceptable to consumers.

Table 1: Subjective evaluation of preference, color, density, and sweet flavor of chocolate chip cookies.\*

| Treatment           | Preference (1)          | Color (2)               | Density (3)             | Sweet Flavor (4)       |
|---------------------|-------------------------|-------------------------|-------------------------|------------------------|
| <b>100% sugar</b>   | 7.44 ± 1.1 <sup>a</sup> | 11.6 ± 1.8 <sup>a</sup> | 9.5 ± 3.4 <sup>a</sup>  | 9.7 ± 3.2 <sup>a</sup> |
| <b>50/50</b>        | 7.6 ± 1.2 <sup>a</sup>  | 5.3 ± 2.8 <sup>bc</sup> | 5.4 ± 2.2 <sup>b</sup>  | 9.1 ± 2.7 <sup>a</sup> |
| <b>100% Splenda</b> | 7.44 ± 1.1 <sup>a</sup> | 6.0 ± 2.9 <sup>c</sup>  | 8.4 ± 3.7 <sup>ab</sup> | 9.7 ± 3.5 <sup>a</sup> |

(1) Preference Score: 1 = dislike very much, 9 = like very much

(2) Color Score: 1 = light, 15 = dark

(3) Density Score: 1 = airy, 15 = dense

(4) Sweet Flavor Score: 1 = not sweet, 15 = very sweet

All values are mean ± standard deviation. Different subscripts within the column indicate significant differences, analysis of variance,  $p \leq 0.05$

The hypothesis of this study was to replace the sucrose with Splenda in the Whitney Hall chocolate chip cookie to create a lower calorie cookie that will be accepted by the consumers. The results from this study showed similar acceptance rate for Splenda as a substitute sugar for sucrose in the chocolate chip cookies. The only differences between the treatments were color, density and the sweetness of flavor; those may have played a role in the acceptance rate of each cookie even though there were no huge differences shown in the results.

In the previous and similar study where Xylitol was used as an alternative sweetener also showed that there was no overall difference in sweetness or flavor of the product. A 9-point hedonic test result also showed that the sugar substitute was very well accepted by consumers. This study also used a penetrometer to examine the differences in effects on tenderness of the product which also showed a significant difference.

The difference between the previous study and this study is the type of sugar that was used (Splenda vs. Xylitol). The previous study examined the storage time and temperature effects on its product and the effects on microbial load which this study did not include. The reason for these differences is that this study mainly focused on the acceptance of Splenda as a substitute and did not include storage time/temperature effects on product or microbial load as the previous study.

Limitations in this study included accuracy and precision of the penetrometer, bake time and temperature, consistency of ingredient measurements, human error, palate of panelist and panelist training. The objective tests results may have been inaccurate due to minor errors of the person measuring and the different textures in certain areas of the product which may have skewed the results. The product bake times were not exactly consistent with each trial during the study. Most of the bake times and temperatures varied due to the differences of temperature from using different ovens and baking each treatment in different ovens each time. Consistency of ingredient measurements may have affected product outcomes and therefore skewing study results. During the study, there could have been some human error which may include judgment of ingredient measurements, procedures, data interpretations and other minor errors. Palate of panelists and panelist training were also limitations because the every individual has different opinions of what is sweet, not sweet enough or too sweet. Panelist training only included 8-12 which could have also affected study results and the types of attributes which were included in the study.

## **Conclusion**

Overall, this study showed that Splenda was accepted by consumers as a substitute for chocolate chip cookies from Whitney Hall. Although there were no significant differences detected in flavor of the product, Splenda did affect the color and density of product. The product made with Splenda also had lower calories.

Future recommendations for further research on this topic would include strict methods of product preparation. The consistency of ingredient measurements should be done by the same person to ensure accurate data and results of the study. Baking time of the product can be more consistent by using the same oven for each treatment and cooking the same amount of product(s) each time. In this study, the product was

baked in different ovens and different times which may have lead to inaccurate results. The size of the cookies should also be the same for consistent and accurate results. This study included product sizes that varied in sizes which may have affected product outcome and results. The more strict the methods, the more accurate and least error the results will contain.

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