

ABSTRACT

Nutritive and Non-Nutritive Sweeteners

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Non-nutritive sweeteners were introduced in the early 1900's and were used in many different ways with the most notable being a sugar substitute. While nutritive and non-nutritive sweeteners share similar properties, each hold various impacts on the human body. In the first chapter, I will be using primary sources to complete the literature review of my thesis that will explain the similarities and differences in these sweeteners. In the second and third chapters, I will be both conducting and explaining my experimental data found through my scientific research to support my hypothesis. In my scientific research, I will determine the difference between iced coffee and Greek yogurt sweetened with sugar and those made with Splenda. This thesis will conclude by connecting the significance of diet on health, as this thesis is a combination of both my passion for the sciences as well as an eagerness to help my future patients in the dental field.

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NUTRITIVE AND NON-NUTRITIVE SWEETENERS

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By

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CHAPTER ONE

Literature Review and Introduction

Statement of Purpose: the purpose of this research is to determine the difference between iced coffee and Greek yogurt sweetened with sugar and those made with Splenda.

$$H_0: \mu_{\text{splenda}} = \mu_{\text{sugar}} = \mu_{50/50SS}$$

H_a : at least one mean is different

As I begin my research, I explored the specifically nutritive and non-nutritive sweeteners. In this chapter, I will dive into the literature research I have completed prior to my lab work.

First, I will explain the basic similarities and differences between nutritive and non-nutritive sweeteners. Nutritive sweeteners contain glucose, fructose, and sucrose which all are absorbed in the gut at the same rate. These sweeteners cause a glycemic response, in addition to signaling to the brain that the body is satisfied. Examples of nutritive sweeteners are glucose, fructose, and sucrose. Nutritive sweeteners are used in a variety of ways to increase as sweetness, provide energy, and improve the texture of food. On the other hand, non-nutritive sweeteners are a way to savor sweetness, but do not provide any energy or glycemic response¹. Examples of non-nutritive sweeteners are Splenda, Saccharin, and Aspartame. Non-nutritive sweeteners can be used for people with diabetes, obesity, treatment for reduction of dental caries, and much more.

Non-nutritive sweeteners, specifically Splenda, is a high intensity sweetener that is 600 times sweeter than sugar². This allows the person to greatly enjoy the taste of the food, but does not induce a glycemic response.

Starting in the 1930's, non-nutritive sweeteners rose to popularity among middle to upper class women who felt empowered by this new caloric additive⁴. The early uses of non-nutritive sweeteners had a "positive expression of self-determination and a means for women to pursue unrealistic beauty norms"⁴. Women saw non-nutritive sweeteners as a means to lose weight, while at the same time they could enjoy the sweetness in their foods. The magazines and television advertisements also had a positive perspective of non-nutritive sweeteners, endorsing the fact that these sweeteners can help women become slimmer through the use of Saccharin. In the 1940's, there was a decline in the use of sugar among women. Women were experiencing social criticism because "when children and fighting soldiers enjoyed sugar sweets, they were building strong bodies and protecting the nation. When women consumed them, however, they were selfish and indulgent"⁴. This contrasting idea continued to encourage the unrealistic beauty expectations set forth by the emerging media and sugar rations. In addition, during this time "diet" cook books would encourage the use of non-nutritive sweeteners because they could easily take away the calories, yet at the same time retain the sweetness.

In the 1960's-1970's, non-nutritive sweeteners were undergoing FDA studies to ensure their safety for the consumers. Soft drink companies, such as Coca Cola, underwent a new type of advertising due to saccharin: on each of their cans they were

required to say: “This product contains saccharin which has been determined to cause cancer in laboratory animals”. Soon after, they switched this ingredient to Nutrasweet to avoid the public’s criticism of their product. The laboratory studies that were tested proved that the rats were at a risk for bladder cancer at extremely high doses of saccharin. The rat’s intake of low doses for saccharin were shown not to be involved in giving the rats cancer. Non-nutritive sweeteners and cancer have been studied in depth, in fact “a study of more than 16,000 patients has found no link between sweetener intake and the risk of cancer. This supports a previous ruling by the European Food Safety Authority (EFSA)”¹. On the other hand, no long-term study has been conducted so some mainstream experts still hold some questions¹. Today, non-nutritive sweeteners can be used for diabetics who want to enjoy the sweet flavor, without raising their blood glucose levels. In addition, non-nutritive sweeteners can be used to lower caloric intake, while maintaining the gratification of eating something sweet. It is important to note that no nutrients are provided with the use of non-nutritive sweeteners, therefore people can have a tendency to look to satisfy their hunger in other caloric foods.

Specifically, I will be conducting my research on sugar and sucralose. I decided to research sucralose as my non-nutritive sweetener particularly because it is very common and widely accepted in most countries, unlike its counterpart saccharin. Additionally, it is “a chlorinated derivative of sucrose” which has shown to be non-carcinogenic through experimentation with animals³. While sugar, or sucrose, is the most prevalent cause of dental caries, sucralose has shown little development of dental

caries in desalivated rats³. The implications of this research demonstrate that non-nutritive sweeteners are extremely unlikely to cause dental caries because they do not provide sugar (which is a main reason why cavities form). This is especially important to note on chewing gum: if the gum contains sugar, the person will be at risk for dental caries. For this reason, it is usual for chewing gum to contain non-nutritive sweeteners. Sucralose can also be found in many different foods such as soda, dairy products, and candy. This product has allowed a reduction in the number of calories via grams of sugar; however, it is important to note that it does not provide any energy or nutritional benefit for the body.

Non-nutritive sweeteners have been very beneficial to our current culture. Their use has allowed diabetics to enjoy the sweet taste without having drawbacks such as raising their blood glucose levels. For non-diabetics, researchers continue to ask the question if non-diabetics use the calories they saved as a justification to eat other calorie-dense foods later in the day⁴. Because non-nutritive sweeteners do not raise blood glucose levels, they do not let the brain know that the body is satisfied. Therefore, after the person is done eating their non-nutritive sweeteners, their body will continue to crave glucose because the brain has not received the signal that it is satisfied. This is the reasoning behind why researchers believe that people can have a tendency to over-eat when using non-nutritive sweeteners.

In my literature research, studies have shown that when sucralose is added to hot coffee, “this study confirmed sucralose’s non-acidogenicity and indicated that it may reduce the acidogenic potential of coffee, although the clinical relevance of this is

unclear”³. Further in my thesis, I will be conducting research using Greek Yogurt and iced coffee to test characteristics of Splenda, when compared with sugar as the control. While I will not be testing the pH in both the coffee and Greek Yogurt before and after adding sugar and Splenda, I hope to verify this in the future.

CHAPTER TWO

Research Methods

In this chapter, I will discuss how I prepared for the research involved in my thesis. First, I began by choosing the exact ingredients I would be using for the research. The Greek yogurt and iced coffee needed to be controlled for extraneous variables, such as added sugars. I chose to use Chobani non-fat Greek yogurt because its ingredient is only cultured pasteurized non-fat milk. This Greek yogurt has no artificial flavors and includes three types of probiotics. The nutrition facts for one cup of this Greek yogurt are: 120 calories, 0 grams of total fat, 9 grams of carbohydrates, 6 grams of sugar, and 22 grams of protein. Because there are no artificial flavorings or any added ingredients with sugar, we can conclude that the 6 grams of sugar come directly from the yogurt's natural ingredients. Next, I chose to use unsweetened Starbucks iced coffee because of its few ingredients and no added sugars. The ingredients in this iced coffee are: water, coffee, and ascorbic acid (to protect the flavor). The nutrition facts for 8 fluid ounces of this iced coffee are: 10 calories, 0 grams of total fat, 2 grams of carbohydrates, 0 grams of sugar, and 1 gram of protein. I chose both of these specific products in order to see a direct relationship between the added sugar/Splenda and the effect on the person.

The nutritive sweetener I will be exploring in this experimental research is cane sugar, while the non-nutritive sugar is Splenda. I added these two components in equal amount to the iced coffee and Greek yogurt in order to see the effects. In order to test

these effects, I selected 10 subjects to participate in my research. I organized the research into two separate days that the subjects were required to come into the lab. The first day was the training session: on this day the subjects were shown how to complete a proper taste test. I instructed the subjects visually and verbally, while handing out their judgement sheet with directions on it (below):

Purpose: sweeteners and different effect on products and how you like them.

1. How to evaluate

- swish around and let sit for a little pause so you can taste it and swallow
- rinse out with water and go to next sample

2. Directions

- 3 samples of iced coffee
- 3 samples of Greek yogurt
 - Scale of 1 to 5
 - Follow the directions on the chart of how to rate each characteristic

3. Taste your samples

- Iced Coffee
- Greek Yogurt

Iced Coffee Characteristic	Sample A	Sample B	Sample C
Color Appeal 1 = dark brown 3 = tan 5 = yellow			
Texture 1 = course 3 = smooth 5 = heavy/thick			
Olfactory 1 = unsweet 3 = pleasing 5 = too sweet			
Flavor 1 = unsweet 3 = pleasing 5 = too sweet			
Aftertaste 1 = none 3 = slight 5 = distinct			
Greek Yogurt Characteristic	Sample A	Sample B	Sample C
Color Appeal 1 = creamy 3 = white 5 = yellow			
Texture 1 = course 3 = smooth 5 = heavy/thick			
Olfactory 1 = unsweet 3 = pleasing 5 = too sweet			
Flavor 1 = unsweet 3 = pleasing 5 = too sweet			
Aftertaste 1 = none 3 = slight 5 = distinct			

The scale in which the subjects used, varied based on the product they were testing. As seen with the color appeal, the scale varied based on the product. For example, the iced coffee was based on a dark brown to yellow scale, while the Greek yogurt was placed on a creamy to yellow scale. The texture was the same with both products, as the subjects had a scale to fit each quality their product could have been. Each scale consisted of an ideal number, three, in order to read the results accurately. In addition, I included olfactory, flavor, and aftertaste to see the effect on the iced coffee and Greek yogurt.

I mixed together three separate samples of the Greek yogurt with the cane sugar, Splenda, and $\frac{1}{2}$ portion of each. The recipe I used for the cane sugar sample was 1 cup of Greek yogurt to $\frac{1}{2}$ cup of cane sugar. For sample two, I used 1 cup of Greek yogurt to $\frac{1}{2}$ cup of Splenda (one tablespoon of Splenda is equal to one tablespoon of cane sugar). For the third sample, I mixed 1 cup of Greek yogurt with $\frac{1}{4}$ cup of cane sugar with $\frac{1}{4}$ cup of Splenda.

For the iced coffee, I prepared three different samples for the subjects. The first sample was 16 ounces of iced coffee with $\frac{1}{2}$ cup of cane sugar. Next, the second sample was 16 ounces of iced coffee with $\frac{1}{2}$ cup of Splenda. Finally, the last sample was 16 ounces of iced coffee with $\frac{1}{4}$ cup of Splenda and $\frac{1}{4}$ cup of cane sugar.

I set up the samples on two different tables with a four-way divider in between each station so that the subjects would have no distractions. I conducted a blind taste test; the samples were labeled A, B, or C so that the subjects did not know which sample

they were testing, but recorded their results under the appropriate category. On the first day the subjects came into the lab the samples were the following:

Sample A: Splenda

Sample B: $\frac{1}{2}$ Splenda and $\frac{1}{2}$ cane sugar

Sample C: cane sugar

On the other hand, I wanted to control for any outside factors on the second day, so I chose to mix around the samples. The samples were put in this order for day two:

Sample A: $\frac{1}{2}$ Splenda and $\frac{1}{2}$ cane sugar

Sample B: Splenda

Sample C: cane sugar

The ten research participants came in and followed the directions involved with this research. The extraneous variables were the brands of iced coffee and Greek yogurt that I used. The dependent variable was the sweeter quality of the iced coffee and Greek yogurt themselves, while the independent variable was the sugar, Splenda, and $\frac{1}{2}$ sugar and $\frac{1}{2}$ Splenda. In the next chapter, I will further explain my results and conclusions.

CHAPTER THREE

Results

After conducting the research, I am able to draw some conclusions about the difference between cane sugar and Splenda in iced coffee. Below are the charts with the results of the judges of their blind taste test with standard deviation. These ten subjects came in to this taste test on two separate occasions, and the two-day results were averaged together and are displayed on Table 1 and Table 2. Each characteristic test was on a scale of one through five, with three being the most pleasing characteristic.

Table 1:

Iced Coffee Characteristic	Splenda	½ sugar with ½ Splenda	Cane Sugar
Color Appeal 1 = dark brown 3 = tan 5 = yellow	1.00 ± 0.00	1.10 ± 0.14	1.40 ± 0.56
Texture 1 = course 3 = smooth 5 = heavy/thick	2.85 ± 0.35	2.75 ± 0.07	3.05 ± 0.10
Olfactory 1 = unsweet 3 = pleasing 5 = too sweet	2.25 ± 0.21	2.40 ± 0.42	2.45 ± 0.33
Flavor 1 = unsweet 3 = pleasing 5 = too sweet	2.90 ± .16	2.90 ± 0.59	3.60 ± 0.28
Aftertaste 1 = none 3 = slight 5 = distinct	3.15 ± 0.39	2.60 ± 0.24	2.55 ± 0.71

Table 2:

Greek Yogurt Characteristic	Splenda	½ sugar with ½ Splenda	Cane Sugar
Color Appeal 1 = creamy 3 = white 5 = yellow	2.00 ± 0.55	2.25 ± 0.32	2.20 ± 0.78
Texture 1 = course 3 = smooth 5 = heavy/thick	3.65 ± 0.49	3.65 ± 0.08	2.85 ± -0.07
Olfactory 1 = unsweet 3 = pleasing 5 = too sweet	2.25 ± 0.31	2.15 ± 0.63	2.15 ± 0.43
Flavor 1 = unsweet 3 = pleasing 5 = too sweet	2.65 ± 0.32	2.75 ± 0.10	3.05 ± 0.43
Aftertaste 1 = none 3 = slight 5 = distinct	2.45 ± 0.05	2.30 ± 0.13	2.25 ± 0.06

To begin, the results for the color appeal of iced coffee (see Table 1) were rated on a scale of 1 through 5. The scores are based on the following: 1 = dark brown, 3 = tan, and 5 = yellow. The Splenda and the ½ sugar with ½ Splenda were close to 1.00 and 1.10 respectively, while sugar was a 1.40. Therefore, the sugar in the iced coffee seemed to have an effect on the color, changing it to a slightly lighter brown than just the Splenda. The next test was the texture. In this texture test the scale was 1 = course, 3 = smooth, and 5 = heavy/thick. The results are as follows: Splenda received a 2.85, ½ sugar with ½ Splenda was 2.75, and the sugar was a 3.05. Through this test, it is obvious that the sugar with iced coffee created the smoothest liquid texture, while the subjects

seemed to find a coarser texture with the Splenda. Another test conducted was olfactory; the subjects were instructed to smell each of the three samples. The scale was set to the following: 1 = unsweet, 3 = pleasing, and 5 = too sweet. The subjects judged the Splenda with an average score of 2.25, the $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar was 2.40, and the cane sugar was a 2.45. These results suggest that the sugar was sweeter than the Splenda in the iced coffee. Likewise, the flavor test was judged on a scale of 1 = unsweet, 3 = pleasing, and 5 = too sweet. Similarly, the subjects found the sugar to be the sweetest of the three samples. The results were as follows: Splenda received a score of 2.90, the $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar got a 2.90, and the sugar was a 3.60. The subjects found the cane sugar to be the sweetest of the three samples both in their olfactory and flavor test. Finally, the last test was the aftertaste which was scored 1 = none, 3 = slight, and 5 = distinct. The scores were the following: Splenda was a 3.15, the $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar was a 2.60, and the sugar was a 2.55. This follows the hypothesis that Splenda leaves an aftertaste in one's mouth, while sugar does not.

Next, the Greek Yogurt was tested for the same five characteristics as the iced coffee (see Table 2). First test, the color appeal, was rated on this scale: 1 = creamy, 3 = white, and 5 = yellow. The Splenda, $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar, and sugar samples received a 2.00, 2.25, and a 2.20 respectively. These results suggest that the Splenda may have had a color influence on the Greek yogurt. Next was a texture test, the scale was a 1 = coarse, 3 = smooth, and 5 = heavy/thick. Both the Splenda and the $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar had a score of 3.65, while the sugar had a score of 2.85. These results show that the Splenda may have reacted with the yogurt to produce a heavier/thicker texture,

while the sugar may not have blended with the yogurt creating a coarser texture. The olfactory test was based on a scale of 1 = unsweet, 3 = pleasing, and 5 = too sweet. The Splenda received a score of 2.25, while both the $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar received a score of 2.15. This olfactory data suggests that the Splenda in the Greek yogurt had a little sweeter smell than the actual sugar itself. The flavor test was based on a scale where 1 = unsweet, 3 = pleasing, and 5 = too sweet. The data for the Splenda, the $\frac{1}{2}$ Splenda with $\frac{1}{2}$ sugar, and sugar received a 2.65, 2.75, and 3.05 respectively. This data shows that the sugar was the most pleasing to the subjects, and the Splenda was not. The final taste test was the aftertaste test where the scale was 1 = none, 3 = slight, and 5 = distinct. The Splenda had a score of 2.45, the $\frac{1}{2}$ sugar with $\frac{1}{2}$ Splenda had a score of 2.30, and the sugar had a score of 2.25. This data supports the idea that Splenda leaves an aftertaste in the mouth, while sugar does not.

CHAPTER 4

Conclusions

Through the literature and experimental research, the data shows my alternative hypothesis to be true.

$$H_0: \mu_{\text{splenda}} = \mu_{\text{sugar}} = \mu_{50/50SS}$$

H_a : at least one mean is different

By testing both a liquid and yogurt, it is evident that Splenda and sugar do not have the same effects on the selected food products.

First, the iced coffee results showed a difference between the Splenda and sugar when tested for the five characteristics I examined. First, the sugar had a color effect on the iced coffee. The difference between the Splenda and the sugar was 0.40, and the change in color could be due to adding a nutritional component (sugar). The molecules of the nutritional component combine with the molecules of the iced coffee, and will produce a change in color in the iced coffee when they come together. Additionally, the subjects found the texture of the iced coffee was more smooth using the sugar, rather than the Splenda. This smooth texture is due to the sugar molecules dissolving in the iced coffee, rather than dispersing. Therefore, this will create a smoother texture for the iced coffee.

Furthermore, the sugar was the closest to the most pleasing olfactory smell, while Splenda and the ½ Splenda with ½ sugar had a less pleasing smell. The flavor for

the iced coffee was much sweeter with the sugar sample (received an average score of 3.60), while the Splenda sample was given the score of a 2.90 which is closest to 3 (the most pleasing). From my literature research I found Splenda to be 600 times sweeter than sugar. Although sugar is not as sweet as Splenda, it diminishes bitterness much more so than its non-nutritional counterpart. Another difference between Splenda and sugar when added to the iced coffee is that Splenda disperses, while sugar dissolves. Through sugar dissolving in the iced coffee and combining with the iced coffee molecules, it has a greater sweetening potential, thus explaining these results for both the olfactory smell and flavor. The final test was aftertaste. As the results demonstrate, the Splenda sample left a slight aftertaste, while the sugar left very little aftertaste. This is conclusive with the literature research, as Splenda has been proven to leave a bitter aftertaste.

After reviewing the results for the Greek yogurt, I conclude that there is a substantial difference between the Greek yogurt sweetened with sugar and Splenda. The first test was the color appeal. It seems as though the Greek yogurt sample with the sugar kept the white color of the yogurt based on the Table 1 results. On the other hand, there was a slight color difference, as the Splenda results demonstrated to be a creamier color. The difference in the color of Greek yogurt is due to the sugar molecules actually combining with the yogurt molecules, while the Splenda simply disperses. Next, the texture of the Greek yogurt had a different texture with the different samples of sweeteners. The sugar sample received the closest rating to the ideal texture of “smooth”, while the Splenda and the ½ Splenda and ½ sugar received

the exact same score that was closer to a heavy/thick texture. Next the olfactory scores were very close in rating; however, the Splenda had a 0.10 rating closer to the pleasing smell. The subjects found the flavor of the sugar to be the closest to pleasing, while the flavor of the Splenda was much lower. This shows that in the Greek yogurt, the judges found the sugar to be the most ideal sweetener. Finally, an aftertaste was present in the Splenda samples, while it was less present in the sugar samples. This supports the literature research which claims that Splenda tends to leave a bitter aftertaste in the mouth, while sugar does not.

CHAPTER FIVE

Further Implications

As a conclusion, I have found that there is a substantial difference in the nutritive and non-nutritive sweeteners. During my experimental research, I decided to test two different types of food: a liquid and a solid. Through doing tests on both, I could accurately describe the effects of the sugar and the Splenda. Overall, I found that the subjects preferred the sugar, rather than the Splenda, both in the iced coffee and Greek yogurt.

In the first chapter, I found that Splenda is a non-nutritive sweetener because it has no nutritional component or glycemic index; it is composed of sucralose. Therefore, Splenda cannot signal to the brain that it is satisfying because it is not glucose, nor can it be converted to glucose. Splenda had similar effects in the iced coffee and Greek yogurt, even though one is a liquid and one is a solid. For example, in both Splenda dispersed throughout both the liquid and solid. Through dispersing, rather than actually combining with the molecules, the Splenda could not have an effect on color. In addition, Splenda only diminished the bitterness in the smell and flavor, as demonstrated in the results showing that Splenda was not as sweet as the cane sugar. Splenda can only lessen the bitterness by spreading out through the iced coffee and Greek yogurt molecules. Although Splenda is 600x sweeter than sugar, it solely decreases the bitterness so it will come across as overall less sweet than its counterpart,

sugar. As supported in the results, the Splenda and sugar had a noticeable difference in their effect on the color appeal, texture, smell, and flavor of both the iced coffee and Greek yogurt.

On the other hand, sugar is made up of a combination of glucose and fructose, therefore it has a glycemic index/nutritional value. The glucose and fructose will signal to the brain that it is satisfied. Sugar had similar effects both in the iced coffee and Greek yogurt. Because it is made up of nutritional components, sugar will combine with the molecules of the iced coffee and Greek yogurt when added. Due to this combination, the sugar molecules will have an effect on the color appeal, texture, smell, and flavor. The color changes as the sugar molecules combine with the iced coffee and Greek yogurt, which explains the discrepancy between the color differences using the Splenda verses the iced coffee. Because the sugar will combine with the iced coffee and Greek yogurt and molecules, the flavor and smell will transform from a bitter taste to a sweet taste. As shown with these results, Splenda and sugar have a substantial difference in the five characteristics tested by the judges.

Nutritive and non-nutritive sweeteners have substantial differences, so they are both used for various purposes. Because non-nutritive sweeteners are not glucose, it is very helpful for Type I diabetics. These people use these non-nutritive sweeteners in order to get a sweet taste and enjoy their food, while not compromising their health simultaneously. In addition, non-nutritive sweeteners (typically sugar alcohols) can be found in gum. This is a benefit for one's oral health because sugar alcohols do not cause dental caries, and this is why many gum companies have switched from using sugar to

these non-nutritive sweeteners. Gum that is made with real sugar causes dental caries because the sugar gets caught in the gum pockets and is the food source for the bacteria in the mouth, thus beginning the tooth decay process. Overall, Splenda has many benefits in a niche environment that sugar itself cannot fulfill.

After completing literature and experimental research, my conclusion is that there is a noticeable difference between Splenda and sugar. Through testing the different effects on two different types of substances (iced coffee and Greek yogurt), there is a noticeable difference in their resulting effects on color appeal, texture, olfactory sense, flavor, aftertaste, and functional advantage. These differences are a result of the sugar having a nutritional component, while the Splenda is non-nutritive. Therefore, both of these sweeteners react differently with the iced coffee and Greek yogurt.

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