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Strategies to Reduce Sugar Intake:

The Role of Artificial Sweeteners Versus Sugar Alcohols

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The American Sugar Rush

Approximately 70 percent of the U.S. population consumes more than the recommended amount of added sugars [1]. Added sugars are not the sugars that are already present in foods (for example, the sugars found in fruit). Added sugars are sugars that are added to food or beverages during processing or preparation [2]. One of the problems with consuming too much sugar is that it can easily lead to increased calorie intake without adding any nutritional value to the diet.

According to the 2015-2020 Dietary Guidelines, less than 10 percent of a person's calorie intake should come from added sugars. For example, if a person is eating 2,000 calories per day, their diet should contain no more than 200 calories, or 50 grams, of added sugars. Although 50 grams seems like a lot, it can be quickly met by drinking a 16.9 fluid ounce bottle of Coca-Cola, which contains 55 grams of sugar [3]. On average, Americans consume about 71 grams of added sugar per day — more than 1/3 of a cup of sugar, or approximately one large frozen coffee drink from your favorite coffee shop [4].

Strategies to Reduce Sugar Intake

The American Heart Association (AHA), recommends substituting low-calorie or calorie-free sweeteners to reduce sugar and calorie intake [5]. There are many types of low-calorie and zero-calorie sweeteners on the market. They can be sold as packets at the grocery store or can be found in food products in the form of additives. A food additive is an ingredient added to food to boost or enhance flavor.

Low-calorie or calorie-free sweeteners can be used to reduce added sugars without sacrificing sweetness. However, it is important to understand the differences in the low-calorie or calorie-free sweeteners in order to choose the best alternative sweeteners for one's own health, cooking and dining experiences. This fact sheet will discuss two popular types of calorie-free and low-calorie sweeteners: artificial sweeteners and sugar alcohols.

What are Artificial Sweeteners?

Artificial sweeteners are high-intensity, non-nutritive sweeteners (NNS). High-intensity NNS contain no nutritional benefit. They may contain a small number of calories, but by legal definition, they must have less than 2 percent of the calories found in sugar. For example, because one gram of sugar has four calories, one gram of an artificial sweetener cannot have more than 0.08 calories. The FDA has labeled five artificial sweeteners as "Generally Recognized as Safe," or GRAS [5].

Stevia (on the market as Truvia® and PureVia®), a common low-calorie natural sweetener, is not labeled as GRAS, because there is currently insufficient evidence to support its safety or identify its risk [6]. The five FDA GRAS sweeteners are listed below from the lowest to highest sweetness level.
1) Aspartame (NutraSweet® and Equal®)
2) Ascesulfame-K (Sweet One®)

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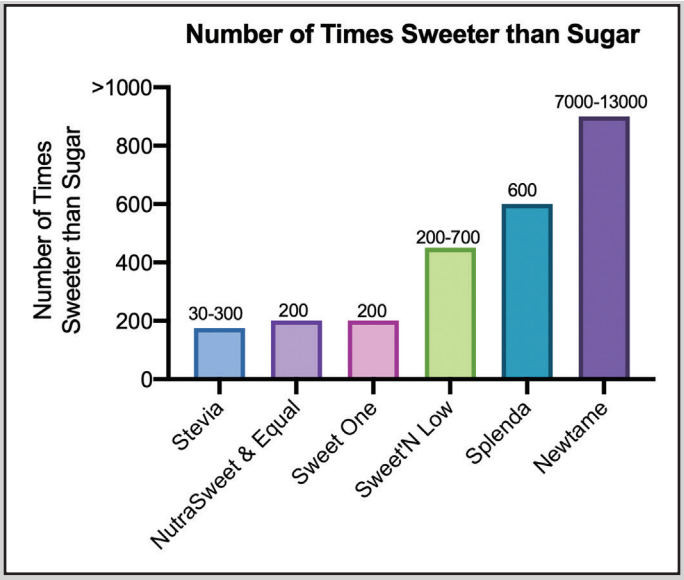
3) Saccharin (Sweet'N Low®)
4) Sucralose (Splenda®)
5) Neotame (Newtame®)

Figure 1 represents the sweetness level of artificial sweeteners compared to sugar. For example, Stevia is 30 to 300 times sweeter than sugar depending on the source of Stevia and Splenda is 600 times sweeter than sugar [7].



The bar graph represents the sweetness of six common artificial sweeteners compared to the sweetness of sugar.

Is It Safe to Consume Artificial Sweeteners?

The U.S. Food and Drug Administration (FDA) states that the five GRAS certified artificial sweeteners discussed throughout this fact sheet are safe to consume in amounts normally consumed by Americans. The FDA determines "a safe amount" based on an Acceptable Daily Intake level. An Acceptable Daily Intake, or ADI, level has been set for each artificial sweetener. The ADI is the maximum amount of sugar substitute that can be safely consumed daily over one's lifetime without any adverse effects.

The ADI will change depending on a person's body weight. For example, to consume enough artificial sweeteners to equal the ADI, a 132-pound person would need to consume 23 packets of Splenda (sucralose), 45 packets of Sweet N' Low (saccharin) or 75 packets of NutraSweet or Equal (aspartame) daily [12] (refer to table 1 [7]) . Each individual packet of sweetener contains 1 gram of total product, but only a fraction is made up of the artificial sweetener itself. The majority of the packet contains fillers like maltodextrin, a "bulking agent" made from corn. The bulking agent is added to make the sweetener packet more user friendly for consumers. For example, it is much easier to coat your favorite bowl of strawberries with 1 gram of sweetener granules compared to just a few granules of pure aspartame. In addition, one 12 fluid ounce Diet Coke contains approximately 125mg of aspartame per can [13]. A 132-pound person would need to consume approximately 24 12-ounce Diet Cokes daily to reach the ADI.

During digestion, sugar alcohols are either not absorbed at all or are only partially absorbed, which can cause flatulence, bloating, and an upset stomach. This is because when the sugar alcohols reach the colon, they are broken down by the bacteria in your gut. This process is called fermentation[8]. The FDA has identified alcohol sugars to have a laxative effect (refer to table 2 [8]).

Evidence, Safety, and Uses of Three Common Artificial Sweeteners:

Aspartame (NutraSweet® and Equal®)

Background

Aspartame is one of the most extensively studied food additives in the United States. Remember, a food additive is an ingredient added to food to boost or enhance flavor.

Table 1. Acceptable Daily Intake of Artificial Sweeteners for a 132-Pound Person

Sweetener	Brand Name Sweetener	ADI, Milligrams [14] per Kilogram (kg) or Pound [15] of Body Weight per day	Number of Tabletop Sweetener Packets Equivalent to the ADI for a 132-pound Person
Aspartame	NutraSweet® Equal®	50 mg per kg 22.7 mg per lb	75
Ascesulfame	Sweet One®	15 mg per kg 6.8 mg per lb	23
Neotame	Neotame	0.3 mg per kg 0.13 mg per lb	23
Saccarin	Sweet'N Low®	15 mg per kg 6.8 mg per lb	45
Sucralose	Splenda®	5 mg per kg 2.27mg per lb	23

Evidence

More than 100 scientific studies support the use of aspartame as a general-purpose sweetener [7]. Recently, the safety of aspartame has been challenged. For example, a 2018 review [16] from the Journal of Clinical Neuroscience debates the safety of aspartame as it relates to neurotransmitters, which are used to send chemical messages across the brain. One issue with this review is that most of the studies discussed use aspartame doses above the identified safe dose of daily aspartame consumption. The majority of research showing negative side effects of aspartame use very high doses, use mice or rats and inject or treat cells outside of the body with aspartame when conducting the experiment.

Safety

Aspartame is GRAS certified. Common concerns regarding aspartame consumption are related to the presence of phenylalanine and aspartic acid and the production of methanol in the body. Surprisingly, one consumes more phenylalanine and aspartic acid when eating certain whole foods than when consuming aspartame products. According to an article published by the Academy of Nutrition and Dietetics, 8 fluid ounces of non-fat milk contains nearly six to nine times more phenylalanine, and 13 times more aspartic acid, than an equivalent amount of a beverage sweetened with aspartame. This is because phenylalanine and aspartic acid are amino acids (the building blocks of protein).

A serving of tomato juice produces almost four to six times more methanol than an equal amount of an aspartame sweetened drink such as Diet Coke [12]. People with phylketonuria (PKU) cannot metabolize phenylalanine and should not consume aspartame.

Uses

It is commonly used as a tabletop sweetener, in coffee, fillings and chewing gum. It is not suitable for baking as aspartame is not heat stable and loses its sweetness when heated.

Sucralose (Splenda)

Background

Sucralose is made from sugar, tastes like sugar and contains zero calories [7].

Evidence

Studies have shown that sucralose does not promote dental cavities or a spike in blood sugar [17]. In a 13-week study investigating the effect on blood sugar (glycemic control) in individuals with type 2 diabetes, sucralose was shown to have no effect [18]. Sucralose safety has been studied. However, according to a 2017 critical review of scientific studies by the journal of Food and Chemical Toxicology, sucralose was found to have no negative effects on blood sugar control, body weight, growth, reproduction, dental health, and overall health status [19].

Safety

Sucralose is GRAS certified. More than 110 studies support the safe consumption of sucralose [7]. The FDA established an acceptable daily intake (ADI) for sucralose of 5 milligrams per kilogram (2.2 pounds) body weight per day. The ADI represents an amount 100 times less than the quantity of sucralose found to be safe in research studies. For example, a person weighing 150 pounds (68 kilograms), could safely consume 340 milligrams of sucrolose (the amount found in nine cans of diet soda or more than 28 individual packets of sucralose).

Uses

Sucralose can be used in a variety of products. It is heat stable, so it is suitable for baked goods. It is also used in frozen dairy products, beverages and chewing gum.

Stevia (Truvia® and PureVia®)

Background

Steviol glycosides, or Stevia, is a natural sweetener with a slightly bitter aftertaste obtained from the Stevia rebaudiana plant.

Evidence

In healthy adults, Stevia has been shown to improve the body's response to sugar (glucose), resulting in decreased blood sugar levels and improved insulin release [6]. A 2003 Clinical Therapeutics study indicated that Stevia may also help lower high blood pressure [20]. It is important to remember, however, that there is a lack of evidence compared to other artificial sweeteners.

Safety

It is not labeled as GRAS because there isn't currently sufficient evidence to support its safety or identify its risk [5].

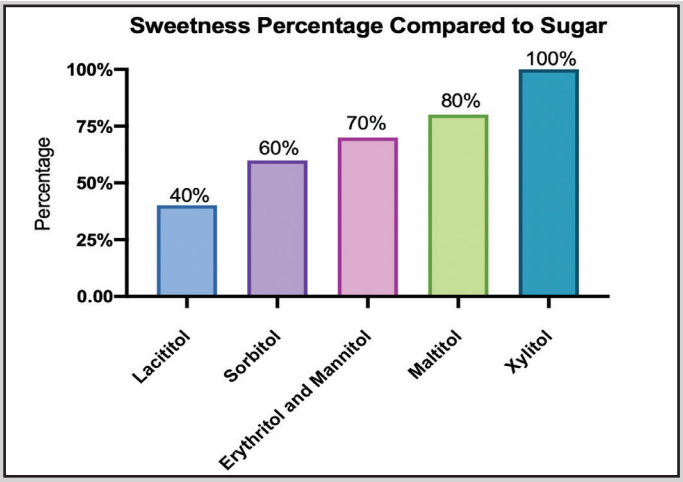
Uses

It is a zero calorie, heat stable, and a good sugar substitute because of its heat stability [6].

The safety of artificial sweeteners was further validated in a recent meta-analysis. A meta-analysis is a scientific paper that looks at data from many different studies of the same subject matter to determine an overall trend or association. This meta-analysis looked at the trends between artificial sweeteners and weight, hunger, and cancer risk. The paper found that people who consumed

artificial sweeteners did not have an increased cancer risk, did not weigh more, eat more or have increased hunger levels when compared to those who did not eat artificial sweeteners [21].

Figure 2 represents the sweetness level of alcohol sugars compared to sugar [8]. For example, lactitol has 40 percent the sweetness of sugar and xylitol has the same sweetness as sugar (100 percent).



The bar graph represents the sweetness percentage of five common sugar alcohols compared to sugar.

What are Sugar Alcohols?

Sugar alcohols, unlike artificial sweeteners, provide a small number of calories and are not as sweet as sugar [8] (refer to figure 2 and table 2). Despite the word "alcohol," sugar alcohols do not contain any ethanol, the compound in alcoholic beverages that causes intoxication [9]. Sugar alcohols are carbohydrates. Sugar alcohols naturally occur in foods such as apricots, grapes, mushrooms and cauliflower, but are also commercially produced from sugar and starch [10]. This fact sheet will discuss six common sugar alcohols found in beverages and food products [11]:

1) Lacitol 2) Sorbitol
3) Erythritol 4) Mannitol
5) Maltitol 6) Xylitol

How Many Carbohydrates Come From Sugar Alcohols?

If you are counting carbohydrates you can subtract half of the sugar alcohol grams from the total carbohydrates in grams on the nutrition facts panel. This is because sugar alcohols are poorly absorbed in the gut, so not all of them enter the body.

For example, let's say you have purchased a protein bar advertised as "low sugar" that lists "Total Carbohydrate 30g" and "Sugar Alcohol 16g" on the nutrition label. To accurately count the carbohydrates, you will follow the equation below [11]:

$$\text{Total Carbohydrates on Label} - \frac{\text{(Sugar Alcohol grams)}}{2} = \text{Net Carbohydrate Total}$$

Erythritol is an exception to this rule. If erythritol is the only sugar alcohol in the product, instead of dividing the grams of sugar alcohol by 2, subtract all of the grams of sugar alcohol from the total carbohydrates listed [11].

Evidence, Safety, and Uses of Three Common Sugar Alcohols

Erythritol

Background

Erythritol is arguably the most popular sugar alcohol because it is the only sugar alcohol that contains zero calories, it does not increase blood sugar or insulin, and it does not have a strong laxative effect [10]. This is because the small intestine quickly absorbs it and the body dumps the majority of erythritol into the urine and it is excreted unchanged, making it the best sugar alcohol choice for people suffering from diabetes, obesity or sugar alcohol sensitivity [22].

Evidence

Compared with other alcohol sugars, studies have shown erythritol to be beneficial for oral health. In a study looking at candies sweetened with erythritol, the consumption of the erythritol candy greatly lowered plaque and bacteria levels compared with xylitol or

Table 2. Characteristics of Common Alcohol Sugars

Alcohol Sugar	Calories per Gram	Sweetness (% of Sucrose or Table Sugar)	FDA Laxative Effect Required Statement
Erythritol	0.2	70	No
Lactitol	2.0	40	Yes
Maltitol	2.1	70-90	Yes
Xylitol	2.4	100	Yes
Mannitol	1.6	70	Yes, if product amount > 50g
Sorbitol	2.6	50-70	Yes, if product amount > 50g

sorbitol candies [23]. If substituted for sugar, erythritol may be beneficial for weight loss. A study looking at erythritol compared to sugar consumption in lean and obese volunteers found that erythritol resulted in higher hunger suppressing hormone release with no effect on glucose when compared to sugar [24].

Safety

Erythritol is GRAS certified. Little side effects are reported, but if erythritol is consumed in large amounts it can act as a laxative resulting in flatulence or intestinal discomfort [10]. Official guidelines for erythritol are not available, but in general most people can handle 0.45 grams per pound of body weight. For example, a 160 pound person can consume approximately 47 grams of erythritol per day [22].

Uses

Erythritol has many advantages as it does not have any aftertaste. It tastes similar to table sugar, gives off a strong cooling effect, and is in the form of a white powder. It is commonly mixed with artificial sweeteners such as aspartame and stevia [22].

Sorbitol

Background

Sorbitol provides 2.6 calories per gram which equals about half the calories of sugar. It is used to sweeten products like gum, but it also is a powerful laxative that draws water into the colon to soften stool and relieve constipation [25].

Evidence

Similar to erythritol, sorbitol has been shown to not cause tooth decay or to significantly raise blood sugar levels [17]. It is important to note that sorbitol is a powerful laxative and has been associated with gastrointestinal (GI) discomfort, especially in individuals who are sensitive to sugar alcohols. A study of people who were unable to properly digest sorbitol (sensitive to sugar alcohols) found that reducing sorbitol decreased their levels of abdominal discomfort. It is common for individuals who experience frequent GI discomfort to benefit from the removal of sorbitol from their diet [26].

Safety

Sorbitol is GRAS certified, but it does not have an ADI. It takes as much as 50 grams per day of sorbitol to meet the laxation threshold (the amount of sweetener that can be consumed before abdominal discomfort sets in). Studies have shown that 20-30 grams of sorbitol per day can lead to abdominal pain and a single dose of 50 grams per day commonly results in diarrhea [10, 25].

Uses

Sorbitol is used as an artificial sweetener, to improve texture or to replace fat in products such as basked good, candies, shredded coconut, chewing gum, diet soft drinks and nutrition bars. Sorbitol is also used as a sweetener in products such as mouthwash, toothpaste, vitamins and minerals [8].

Xylitol

Background

Xylitol is found in yellow plums, strawberries, raspberries and is even produced in small amounts in the human body. It produces a strong cooling sensation in the mouth and is commonly used in breath mints and hard candies [8].

Evidence

There is some evidence that has linked xylitol containing gum to cavity prevention and remineralization of broken-down cavity areas, although further research is needed to validate these claims [27]. Xylitol also stimulates the growth of good bacteria in the gut. This bacterium produces a fatty acid called butyric acid that is beneficial for the cells lining the colon [28].

Safety

Currently, xylitol is not GRAS certified, but has been placed in the highest safety category by the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives. Xylitol has been shown to cause temporary laxative effects and GI discomfort such as bloating and stomach pains. It causes GI discomfort because it is passed through the large intestine partially unabsorbed and is fermented by bacteria producing short-chain fatty acids and gas. Xylitol can be well tolerated at 50-70 grams per day in healthy adults (tolerance intake range) [29].

Uses

Xylitol has the same sweet taste as sucrose with a strong cooling effect. It is used in products such as chocolate, ice cream, cookies, sugar-free honey and diet soda [8].

Conclusion

Artificial sweeteners and sugar alcohols are commonly used as sugar substitutes because they enhance the sweetness flavor of a food product and contain fewer calories than sugar. Artificial sweeteners may be consumed in moderation in the midst of a calorie-controlled diet and within the recommended Adequate Daily Intake [30] determined by the FDA. Sugar alcohols are safe to consume and shouldn't be counted as total carbohydrates. An ADI has not been established, but if sugar alcohols are consumed above the ranges of the identified tolerance or laxation level, adverse GI effects may occur.

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