Episode 118 – Sugar Substitutes October 11, 2024

Introduction

Excessive sugar consumption is increasingly common, posing a significant risk to general and oral health by contributing to the development of diseases such as diabetes and dental caries. Sugar is cheap and almost universally available worldwide. Free sugar consumption in high- and middle-income countries far exceeds the World Health Organization's (WHO) recommendations. In many low-income countries, sugar consumption is steadily rising. [1] [2]

WHO defines free sugars as all monosaccharides (e.g., glucose, fructose) and disaccharides (e.g., sucrose) added to foods by the manufacturer, cook, or consumer, and sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates. Free sugars provide little or no nutritional value. This definition of free sugars does not include sugars found naturally in fruit, vegetables, and plain milk. [3]

Sugar comes in many forms, such as white sugar, brown sugar, molasses, honey, maple syrup, and corn syrup. Sugars are often added to processed foods to improve flavour, colour, texture, and shelf-life and are listed on food labels under various names, including glucose, fructose, dextrose, maltose, or sucrose. Many sugars consumed today are "hidden" in processed foods.[1] [3] [4]

Sugar substitutes

Sugar substitutes provide an alternative to traditional sugar. They are typically classified as low-intensity sweeteners (e.g., xylitol, sorbitol) or high-intensity sweeteners (e.g., aspartame, sucralose, cyclamate, saccharin, stevia). Low-intensity sweeteners provide a sweet taste with fewer calories than sugar. High-intensity sweeteners are sweeter than sugar and require smaller amounts to achieve the same level of sweetness. The majority of sugar substitutes are high-intensity sweeteners. [1] [5]

Sugar substitutes may also be classified as nutritive or nonnutritive. Nutritive sweeteners (e.g., sugar alcohols) provide minimal amounts of carbohydrates and energy, have fewer calories than sucrose (table sugar), and have negligible effect on blood glucose levels. Nonnutritive sweeteners (e.g., aspartame, sucralose), also called artificial sweeteners, provide minimum or no carbohydrates and energy and do not affect blood glucose levels. [6] [7]

[1]Refer to Episode 86 for additional information on hidden sugars in foods.

In Canada, sugar substitutes are regulated by Health Canada as food additives, subjected to rigorous controls under the Food and Drugs Act and Regulations. Sugar substitutes are only approved once safety assessments are conducted. [8]

Sugar substitutes are chemical or plant-based substances used to sweeten or enhance the flavour of foods and beverages without adding the calories of sugar. They may be used as an ingredient in processed foods and beverages or as a tabletop sweetener. Tabletop sweeteners are high-intensity sweeteners that can be manufactured in liquid, powder, or granular formats and are intended for addition to foods by the consumer (e.g., to sweeten tea or coffee) and are not meant to be used as an ingredient in processed foods. [5] [9]

Sugar substitutes are found in many of the foods and beverages marketed as “light,” “reduced calorie,” “diet,” “sugar-free,” “keto-friendly,” and “low-carb.” Most sugar substitutes are many times sweeter than sucrose, requiring smaller amounts to provide the same level of sweetness. [5] [9] [10]

Approximately 2% of all prepackaged food and beverage products in Canada contain a sugar substitute, and slightly less than 2% contain a sugar substitute and free sugar ingredients, both of which must be listed on the ingredient label. [11]

Sugar substitutes are generally safe for healthy people to consume within the acceptable daily intake (ADI) recommended by Health Canada for each sweetener. [6]

Sugar substitutes are not recommended for infants and children. There is no evidence of harmful effects with the occasional consumption of sugar substitutes. However, due to limited research in this population and specific nutritional requirements for normal growth and development in children, foods and beverages containing sugar substitutes are generally not recommended. [6]

While the use of sugar substitutes during pregnancy and breastfeeding is considered safe, there is limited research on both of these populations. Excessive consumption of products containing sugar substitutes should be avoided during pregnancy for nutritional reasons since these foods could replace more nutritious foods. [6] [12]

Since sugar substitutes have a negligible effect on blood glucose levels, people with diabetes can consume moderate amounts of sugar substitutes to help manage the condition. Sugar substitutes may help increase flexibility in a meal plan, reduce carbohydrate intake from sugar, or support a weight management strategy.[2] [6] [13]

Several sugar substitutes have been approved for use in Canada, including aspartame, advantame, acesulfame potassium, saccharin, cyclamate, sucralose, neotame, thaumatin, monk fruit extract, stevia extract, sugar alcohols (e.g., sorbitol, mannitol, xylitol, erythritol), and polydextrose. [8] [14]

[2] Listen to Episodes 91, 93, and 94 for additional information on diabetes.

Aspartame

Aspartame has been permitted as a food additive in Canada since 1981 in many processed foods and beverages, including soft drinks, desserts, yogurt, breakfast cereals, and chewing gum and is also available as a tabletop sweetener (e.g., Equal, NutraSweet). Aspartame can also be found in some medicines (e.g., cough drops) and vitamins as a nonmedicinal ingredient. It is 200 times sweeter than sucrose. Aspartame is unstable in heat and should not be used as a substitute for sugar when baking since it loses its sweet taste when heated. Aspartame is made by bonding together the amino acids aspartic acid and phenylalanine, which are normal constituents of proteins, to form a dipeptide which is further esterified with methanol. [9] [15]

Aspartame can be safely consumed by most healthy individuals. However, excessive phenylalanine intake, one of the constituent amino acids of aspartame, can pose a hazard to individuals with phenylketonuria (PKU). PKU is an inherited metabolic disorder characterized by an absence or deficiency of phenylalanine hydroxylase (PAH), an enzyme that breaks down phenylalanine. When PAH is absent or deficient, phenylalanine accumulates and is toxic to the brain, resulting in severe intellectual disability. To prevent intellectual disability, individuals with PKU follow carefully controlled diets low in phenylalanine beginning during the first days of life.[3] The amount of phenylalanine safe to consume is different for each person. [15] [16]

Since phenylalanine is found in all proteins, the PKU diet consists of avoiding meat, dairy, nuts, tofu, and other foods that are high in protein. Aspartame should be avoided as it contains high amounts of phenylalanine. For this reason, the Food and Drugs Act requires all food and beverage products with aspartame to be labelled as containing phenylalanine. [5] [17]

In July 2023, WHO's International Agency for Research on Cancer (IARC) classified aspartame as "possibly carcinogenic to humans." The decision was based on limited evidence for liver cancer in human and animal studies.

However, WHO's Joint Expert Committee on Food Additives (JECFA) determined there was no reason to change their previous conclusion that a daily intake of aspartame at levels up to 40 milligrams per kilogram body weight would not cause adverse health effects, including cancer. For example, an adult weighing 70 kg (154 lb) would need to consume more than 9-14 cans of diet soft drink containing 200-300 mg of aspartame per day to exceed the acceptable daily intake (ADI). The ADI for a child weighing 20 kg (44 lb) is 800 mg of aspartame or two to three cans of diet soft drink a day.

The conclusions between the two organizations conflict because IARC classifies a substance as hazardous based on whether the substance can cause cancer and does not consider the risk based on the level of exposure. JECFA evaluates risk based on the likelihood that cancer will occur because of exposure to a substance. These two approaches contribute to the different conclusions of the two organizations.

[3] In Ontario, a heel prick is used to take a few drops of blood from each infant shortly after birth. The blood is tested for more than 25 treatable diseases, including PKU. A positive screen test result means that more tests are needed to diagnose PKU and does not mean the infant has PKU. [49]

Aspartame is one of the most studied food additives and is approved in many countries. Regulatory and scientific authorities, such as Health Canada, the US Food and Drug Administration (FDA), and the European Food Safety Authority, have evaluated aspartame and consider it safe at the current permitted use levels. [15] [18] [19]

Advantame
Advantame is structurally similar to aspartame but is approximately 70 to 120 times sweeter than aspartame and 20,000 times sweeter than sucrose. In Canada, advantame has been approved as a tabletop sweetener (e.g., Advantame) and is added to packaged food and beverages, such as baked goods, breakfast cereals, breath freshener products, chewing gum, candy, condiments, and yogurt. It is heat stable, making it suitable as a sugar substitute in baked goods. [14] [19] [20]

Acesulfame potassium
In Canada, acesulfame potassium (acesulfame K or Ace-K) is available as a tabletop sweetener (e.g., Equal Original) and is added to packaged food and beverages by food manufacturers. It is 200 times sweeter than sucrose. Ace-K is in various processed foods and beverages (e.g., baked goods, breath freshener products, chewing gum, candy, dessert mixes, yogurt, condiments, soft drinks). [14] [21]

Saccharin
Saccharin is used in food products in many countries and is 200 to 700 times sweeter than sucrose. In the 1970s, scientific studies raised concerns that saccharin could be carcinogenic in laboratory rats. On this basis, saccharin was delisted as a food additive in Canada, although access to saccharin as a tabletop sweetener was maintained. More recent studies revealed the carcinogenic effect of saccharin in rats is not relevant to humans. In 2016, Health Canada reinstated saccharin as a food additive in certain food products (e.g., breath fresheners, chewing gum, frozen desserts and dessert toppings, canned fruit, soft drinks, jams). It is also available a tabletop sweetener in tablet form (e.g., Hermesetas). [8] [12] [22] [23] [24]

Cyclamate
In Canada, cyclamate is a tabletop sweetener sold in packets, tablets, liquid, and granulated form (e.g., Sucaryl, Sugar Twin, Sweet'N Low). It is 30 times sweeter than sucrose and may leave a metallic taste. It is also used as a nonmedicinal ingredient in drugs and natural health products. It is not a permitted food additive in Canada and cannot be added to packaged foods and beverages. Cyclamates are very heat-stable and can be used when cooking. It is best to cook from recipes designed for cyclamate use to obtain good results, as the flavour may change when heated. Individuals are cautioned to avoid exceeding the ADI. [12] [24] [25]

Sucralose
In Canada, sucralose is available as a tabletop sweetener (e.g., Splenda) and is used in many foods and beverages (e.g., soft drinks, syrups, breath freshener products, chewing gum, candy, desserts, baked goods, canned fruits). It is used in medicines, nutritional supplements, and vitamins as a nonmedicinal ingredient. Sucralose is 600 times sweeter than sucrose. It can be used in baking because it does not lose its sweet

taste at high temperatures. It is best to cook with recipes designed for sucralose use to achieve optimal results. [9] [14] [24]

Neotame
Neotame is available in Canada as a tabletop sweetener (e.g., Newtame) and is added to packaged food and beverages, such as breakfast cereals, yogurt, breath freshener products, chewing gum, condiments, nut and peanut spreads, candy, and baked products. Neotame is 7,000 to 13,000 times sweeter than sucrose. It is heat stable, making it suitable as a sugar substitute in baked goods. [14] [19]

Plant and fruit-based sweeteners
Plant and fruit-based high-intensity sweeteners include thaumatin, monk fruit extract, and stevia. They are sometimes categorized as novel sweeteners. [7] [19]

Thaumatin
Thaumatin is a group of intensely sweet proteins isolated from the West African Katemfe fruit *Thaumatococcus daniellii* and is approximately 2,000 to 3,000 times sweeter than sucrose. Thaumatin is metabolized by the body as any other dietary protein. The substance is often used for its flavour-enhancing properties and less as a sweetener. In Canada, thaumatin is used as a sweetener in breath freshener products, chewing gum, salt substitutes, and flavouring preparations. [14] [19] [26]

Monk fruit extract
Siraitia grosvenorii Swingle, commonly known as monk fruit, luo han guo, or swingle fruit, is a plant native to Southern China. Extract from monk fruit contains varying levels of mogrosides, constituents primarily responsible for the sweetness of monk fruit. In Canada, monk fruit extract has been approved as a tabletop sweetener (e.g., Sweet Monk, Nectresse, Monk Fruit in the Raw, PureLo) and is 300 times sweeter than sucrose. However, other monk fruit ingredients (e.g., monk fruit juice concentrate) are not considered sweeteners but are food ingredients because of their lower mogroside content. [5] [14] [19]

Stevia
Stevia refers to the leaves of *Stevia rebaudiana* Bertoni, a plant native to South America. It is also known as “honey leaf,” “sweet leaf,” or “sweet herb.” The leaves of the stevia plant contain sweetening compounds. Stevia leaf and crude extracts of stevia leaves are considered food ingredients and are not considered food additives. For this reason, there is no mandatory requirement for their review and approval before use in food. Stevia leaves (fresh, dried, or powdered) and its crude extracts are available in Canada for personal culinary use only. Stevia leaves and its crude extracts have been approved by Health Canada as nonmedicinal and medicinal ingredients in certain natural health products. [8] [27]

Purified stevia extract (also referred to as steviol glycosides and commonly known as stevia) is regulated as a food additive in Canada. Steviol glycosides are approved for use as tabletop sweeteners (e.g., Pure Via, Truvia), and are added to packaged foods, such as breakfast cereals, nut and peanut spreads, candy, beverages, condiments,

breath freshener products, chewing gum, canned fruit, and meal replacement and supplement bars. Steviol glycosides are 200 to 400 times sweeter than sucrose and can be used as a substitute for sugar when baking. Steviol glycosides do not raise blood sugar levels or contribute to dental caries. Some people may notice an aftertaste after consuming. [8] [9] [14]

Sweetness intensity of high-intensity sweeteners [6] [12] [13] [19] [28] [29]

Sweetener	Times sweeter than sucrose	Common brand names	ADI* (mg per kg body weight per day)
Acesulfame potassium	200 times	Equal Original	15
Advantame	20,000 times	Advantame	5
Aspartame	200 times	Equal, NutraSweet	40
Cyclamate	30 times	Sucaryl, Sugar Twin, Sweet'N Low	11
Monk fruit extract	300 times	Sweet Monk, Nectresse, Monk Fruit in the Raw, PureLo	No ADI
Neotame	7,000 – 13,000 times	Newtame	2
Saccharin	200 – 700 times	Hermesetas	5
Steviol glycosides (stevia)	200 – 400 times	Stevia, Truvia, Krisda, Pure Via	4
Sucralose	600 times	Splenda	9
Thaumatin	2,000 – 3,000 times	Talin	No ADI

*ADIs apply to all age groups because they are based on weight and not age.

Sugar alcohols

Sugar alcohols are a family of sweetening agents, also known as polyols. Sugar alcohols are carbohydrates and do not contain ethanol (alcohol). They occur naturally in small amounts in fruits and vegetables (e.g., berries, apples, plums, carrots). They are manufactured from common sugars for large-scale commercial use.

Sugar alcohols are used as sweeteners and texturizing and bulking agents in foods. Sugar alcohols permitted as food additives in Canada include hydrogenated starch hydrolysates, isomalt, lactitol, maltitol, maltitol syrup, mannitol, sorbitol, sorbitol syrup, xylitol, and erythritol. While they are chemically very similar to sugars, they are less sweet than sugars and have fewer calories per gram. [5] [8] [30]

Sugar alcohols are added to a variety of packaged foods and beverages. They may also be in cough and cold syrups, other liquid medications, and oral care products (e.g., toothpaste, mouthrinse). [14]

Sugar alcohols have been promoted as useful sugar substitutes for individuals with diabetes. Sugar alcohols do not cause significant changes in blood glucose levels because they are converted to energy by processes that require little or no insulin.

People with diabetes should consult their medical provider about sugar alcohols before increasing the amount of foods they eat that contain these substances. [30]

Sugar alcohols are also resistant to metabolism by oral bacteria that break down sugars and starches to produce acids. As a result, sugar alcohols do not promote dental caries. Studies have indicated that xylitol in particular may help to prevent tooth decay. [30]

Overconsuming sugar alcohols (e.g., over 10 grams a day) can cause gastrointestinal (GI) discomfort (e.g., bloating, gas) and laxative effects. GI effects are related to the amount consumed and increase by consuming more than one product containing sugar alcohols. There is a wide variation in sensitivity between individuals. It is possible to develop tolerance by frequent consumption of products containing sugar alcohols and to increase consumption without experiencing adverse effects.[4] [30]

Properties of sugar alcohols [9] [30]

Sweetener	Relative sweetness*	Derived from	Calories per gram
Xylitol	100%	D-xylose	2.4
Sorbitol	50% - 70%	Glucose	2.6
Sorbitol syrup	25% - 50%	Corn, wheat, or potato starch	not available
Mannitol	50% - 70%	Fructose	1.6
Maltitol	90%	High maltose corn syrup	2.1
Maltitol syrup	25% - 50%	Corn, wheat, or potato starch	not available
Lactitol	30% - 40%	Lactose	2
Isomalt	45% - 65%	Sucrose	2
Erythritol	60% - 80%	Glucose	0.2

* Relative sweetness compared to sucrose where sucrose equals 100%.
For comparison, there are 4 calories per gram of sucrose.

Polydextrose

Polydextrose is a compound synthesized from dextrose. Because it has a low digestible energy value, it is used to provide bulk in foods, thereby reducing the caloric content. Polydextrose is not sweet but has a slightly tart taste and thus can add texture to food without adding sweetness. It is often used to replace sugar, starch, and fat in foods such as cakes, candies, pudding, and desserts.

Similar to sugar alcohols, overconsuming polydextrose may cause GI discomfort and diarrhea. GI issues increase with the consumption of more than one product containing polydextrose and/or sugar alcohols. Frequent consumption of polydextrose may lead to a tolerance lessening GI effects. [8] [30]

[4] Note: Xylitol is toxic for dogs. Within 10 to 60 minutes of consuming xylitol, depending on body weight and the amount consumed, a dog could experience a rapid release of insulin, causing a sudden decrease in blood glucose, resulting in hypoglycemia. Untreated hypoglycemia can quickly turn life-threatening. Symptoms of xylitol poisoning include vomiting, followed by symptoms of hypoglycemia (e.g., decreased activity, weakness, staggering, incoordination, collapse, seizures). People who think their dog has eaten a product containing xylitol should immediately call a veterinarian, emergency clinic, or animal poison control centre. Hospitalization may be needed to monitor the dog because hypoglycemia and other serious adverse effects may not occur for up to 12 to 24 hours. [50] [51]

Sugar substitutes and healthy eating
Individuals may rely on sugar substitutes to decrease the sugar they consume. However, sugar substitutes are not needed to make healthy eating choices. Eating foods sweetened with sugar substitutes can make healthy eating more difficult because foods and beverages with sugar substitutes may replace more nutritious foods. In addition, regularly eating sweet-tasting foods can lead to a preference for sweet foods.

Consuming unsweetened foods and beverages is especially important for children. Foods consumed early in life can influence their taste preferences and lifelong eating habits. Foods and beverages that contain sugar substitutes are often low in nutrients and may negatively impact optimal growth and development during infancy, childhood, adolescence, and pregnancy. [6] [31]

Non-sugar sweeteners in weight control
High intake of free sugars is associated with overweight and obesity, which affects nearly 40% of the global adult population and millions of children. High body mass index (BMI) is responsible for millions of deaths a year. Obesity is also a risk factor for many noncommunicable diseases (NCDs), including cardiovascular diseases (CVDs), type 2 diabetes, and certain types of cancer. NCDs are the leading cause of death globally. In response to the impact of free sugars, the WHO issued recommendations in 2015 to reduce the intake of free sugars. [32]

The guideline recommends adults and children reduce their daily intake of free sugars to less than 10% of daily total energy intake and ideally to less than 5% or roughly 25 grams (6 teaspoons) per day to achieve additional health benefits. Evidence indicates keeping intake of free sugars to less than 10% of total energy intake reduces the risk of overweight, obesity, and dental caries. [3] [33]

Since the release of the WHO free sugar intake guidance, interest has increased in non-sugar sweeteners (NSS) to reduce sugar intake. NSS are generally marketed as aiding weight loss or maintaining a healthy weight and are frequently recommended as a means of controlling blood glucose in individuals with diabetes. NSS undergo toxicological assessment to establish safe levels of intake (i.e., ADI). However, there is no clear consensus on whether NSS are effective for long-term weight control or if they are linked to other long-term health effects at habitual intakes within the ADI. Therefore, WHO reviewed the evidence to provide guidance. [32]

In May 2023, the WHO released a new guideline on non-sugar sweeteners (NSS), recommending against their use to control body weight or to reduce the risk of noncommunicable diseases. The recommendation is based on the findings of a large systematic review, which suggests NSS use does not confer any long-term benefit in reducing body fat in adults or children. Replacing free sugars with NSS does not help with weight control in the long term. Other ways need to be considered to reduce free sugars intake, such as consuming food with naturally occurring sugars (e.g., fruit, unsweetened food and beverages).

Long-term use of NSS may cause undesirable effects, such as increased risk of type 2 diabetes, CVDs, and mortality in adults. NSS are not essential and have no nutritional value. Individuals should reduce the sweetness of their diet starting early in life.

The recommendation includes all synthetic and naturally occurring or modified nonnutritive sweeteners in manufactured foods and beverages, or sold on their own to be added to foods and beverages, such as aspartame, saccharin, sucralose, stevia, and stevia derivatives.

The recommendation does not apply to individuals with pre-existing diabetes. NSS are frequently recommended as a means of controlling blood glucose levels in individuals with diabetes. Providing guidance on diabetes management in individuals with pre-existing diabetes was beyond the scope of the NSS guideline.

The guideline does not apply to personal care and oral hygiene products containing NSS, such as toothpaste and medications, or to low-calorie sugars and sugar alcohols (polyols), such as xylitol, which are sugars or sugar derivatives containing calories and are not considered NSS. [32] [34]

Steffen et al. (2023) showed long-term artificial sweetener intake was related to greater adipose tissue volume. The research team examined participants' regular dietary intake over 20 years. They found long-term consumption of aspartame, saccharin, and diet beverages were linked to increased fat stores in the abdomen and fat within muscle. This was found even after accounting for other factors, including diet quality and caloric intake. These outcomes underscore the importance of finding alternatives to artificial sweeteners in foods and beverages, especially since these added sweeteners may have negative health consequences. [35]

Cardiovascular effects

Sugar substitutes have become a widespread way to reduce sugar and calorie intake. Regulatory agencies consider sugar substitutes to be safe. However, little is known about their long-term health consequences. Several studies recently investigated the cardiovascular effects of sugar substitutes, particularly erythritol and xylitol.

Witkowski et al. (2023) investigated erythritol and atherothrombotic disease risk. Erythritol is a popular sugar substitute. Erythritol is found in various fruits (e.g., melon, watermelon, pears, grapes) and fermented foods (e.g., cheese, soy sauce). The human body produces low amounts of erythritol naturally. Researchers studied over 4,000 participants in the US and Europe. They found those with higher blood erythritol levels were at elevated risk of experiencing a major adverse cardiac event such as heart attack, stroke, or death. They also examined the effects of adding erythritol to whole blood and isolated platelets. Results revealed that erythritol made platelets easier to activate and form a clot. The authors note the importance of additional research to confirm their findings in the general population. The study had several limitations, including that clinical observation studies demonstrate association and not causation, and participants in the observational cohorts showed a high prevalence of CVD and risk factors. [36]

In 2023, the FDA reviewed the study by Witkowski et al. (2023) and determined the cited observational studies in the paper did not establish a causal link between consuming erythritol and the observed effects. FDA will continue to monitor and review new information on erythritol and other sweeteners as it becomes available. [19] [37]

A 2024 study by Witkowski et al. examined the association between xylitol and thrombotic risk. Xylitol is found in small amounts in fruit and vegetables (e.g., strawberries, bananas, carrots, onions), and the human body produces it (e.g., 5-15 g/day in a healthy person). It is a common sugar substitute in sugar-free candy, gums, baked goods, and oral care products such as toothpaste.

The researchers studied more than 3,000 participants in the US and Europe over three years and found participants with the highest amount of xylitol in their plasma were at an elevated risk of major adverse cardiovascular events. To confirm the findings, the research team conducted preclinical testing and found xylitol caused platelets to clot and heightened the risk of thrombosis. They also tracked platelet activity from 10 healthy participants who ingested a xylitol-sweetened drink (30 g xylitol in 300 ml water within 2 minutes) versus a glucose-sweetened drink. They found every measure of clotting ability significantly increased immediately following ingestion of xylitol but not glucose.

The authors note further studies assessing the long-term cardiovascular safety of xylitol are warranted. The study had several limitations, including that clinical observation studies demonstrate association and not causation, and most participants had a high burden of CVD and risk factors (e.g., hypertension, coronary artery disease, myocardial infarction, average age 65, average BMI 28.4 indicative of overweight). [10]

A third study by Witkowski et al. (2024) evaluated the impact of erythritol versus glucose consumption on platelet responsiveness in 20 healthy participants (10/group). The researchers found the average erythritol level after consuming 30g of erythritol mixed in water increased over 1,000 times in the group that consumed erythritol compared to their initial levels. Results also revealed participants showed a significant increase in platelet activity after ingesting erythritol. No change was found in the participants who consumed glucose (30g glucose in water).

The study had several limitations, including small study size and long-term changes in platelet function after erythritol consumption were not tested. Further research is required on the effects of erythritol on cardiovascular health. [38]

Sun et al. (2024) investigated the association between sugar-sweetened beverages (SSB), artificially sweetened beverages (ASB), and pure juice (PJ) consumption with the risk of atrial fibrillation (AFib). Researchers reviewed data from dietary questionnaires and genetic data for 201,856 adults free of AFib at the time they enrolled in the UK Biobank between 2006 and 2010. During the nearly 10-year follow-up period, there were 9,362 cases of AFib among the study participants.

The analysis found a 20% higher risk of AFib among people who said they drank two litres or more per week of artificially sweetened drinks. The risk was 10% higher among people who said they drank similar amounts of sugar-sweetened beverages. In contrast, consuming ≤1 L/week of pure unsweetened juice (e.g., orange or vegetable juice) was associated with a modestly lower risk of AFib. The associations between consuming these beverages and AFib risk persisted after adjustment for genetic susceptibility for atrial fibrillation.

The authors caution that the associations do not necessarily imply causation; beverage consumption was self-reported, so bias is inevitable, and the questionnaires did not capture if the SSB and ASB were caffeinated. The study does not demonstrate that consuming SSB and ASB alters AFib risk, but consuming SSB and ASB may predict AFib risk beyond traditional risk factors.[5] [39]

Strategies to reduce sugar intake without sugar substitutes

Individuals can get used to less sweetness in their food and beverages by:

- Choosing water instead of sugar-sweetened beverages.
- Reducing the amount of sugar added to tea and coffee.
- Choosing unsweetened foods.
- Reading the ingredient list to find sources of sugars and choose foods with little to no added sugars and without sugar substitutes.
- Sweetening foods naturally by using fruits for example in plain yogurt and oatmeal.
- Using ingredients such as cinnamon, nutmeg, or vanilla extract to add flavour. [31]

Dental caries prevention

Controlling carbohydrate intake is important to prevent dental caries.[6] Excessive sugar consumption is common, posing a significant risk to oral health by contributing to the development of dental caries. Sugar substitutes provide an alternative to traditional sugar. [1]

Xylitol and other sugar alcohols are not readily metabolized by oral bacteria and, thus, are considered noncariogenic sugar substitutes. Xylitol is available in many products including gums, gummies, candies, mints, chewable tablets, lozenges, toothpaste, mouthrinse, and oral wipes. Some evidence shows a 30% to 80% decrease in caries incidence with xylitol consumption (five to 10 grams three times per day). However, frequencies less than three times a day (less than 3.44 g/day) yielded no protective effect. [40]

Some studies report the chewing process stimulates saliva production, which enhances the caries inhibitory effect. This can be a confounding variable when evaluating the efficacy of xylitol gum as a primary prevention agent. [40]

The impact of xylitol on preventing caries by interrupting the transfer of cariogenic microorganisms from parent/caregiver to child is inconclusive. These studies have been

[5] Refer to Episodes 79, 80, and 81 for additional information on cardiovascular diseases.
[6] Refer to Episodes 86 and 87 for additional information on dental caries.

performed with xylitol intake ranging from four to 15 g/day divided into three to seven consumption periods, with higher daily doses yielding significantly better results. [40]

A 2015 Cochrane review found some evidence suggesting fluoride toothpaste containing xylitol may be more effective than fluoride-only toothpaste for preventing caries in the permanent teeth of children, and there were no adverse effects from these toothpastes. The effect estimate should be interpreted with caution due to high risk of bias and two of the studies were conducted by the same authors in the same population. The remaining evidence was insufficient to determine whether any other xylitol-containing products can prevent caries in infants, older children, or adults demonstrating the need for more randomized controlled studies to address these uncertainties. [41]

A systematic review and meta-analysis by Luo et al. (2024) examined the effect of sugar substitute consumption on caries prevention in permanent teeth of children and adolescents. Results indicated consuming xylitol or sorbitol is potentially effective in preventing dental caries in permanent teeth of children and adolescents. Currently, no clinical evidence is available on the role of high-intensity sweeteners in dental caries prevention. [1]

A systematic review by Pienihäkkinen et al. (2024) assessed the dental caries-preventive effects of xylitol chewing gums and candies in children. The review evaluated randomized controlled clinical trials and controlled clinical trials published between 1974-2022 that investigated the efficacy of xylitol-containing chewing gums and candies in preventing dental caries in children aged ≤18 years.

The findings suggest adding xylitol chewing gum to the daily diet of children at high or moderate caries levels has a dental caries-reducing effect. The surface-specific analyses suggest xylitol gum use could offer the most benefit in children with active incipient caries lesions on the buccal or lingual surfaces of teeth. A caries-reducing effect could not be demonstrated for xylitol candies, but more research is needed on this topic, especially in children at high-caries risk. The authors highlight that xylitol is one component in caries prevention, and should be used in conjunction with dietary changes (e.g., reduced sugar intake) and fluoride toothpaste in those at risk of dental caries. [42]

The American Academy of Pediatric Dentistry (AAPD) released a policy in 2024 on xylitol use in pediatric oral healthcare. The AAPD:

- Supports the use of xylitol and other sugar alcohols as noncariogenic sugar substitutes.
- Recognizes there is a lack of consistent evidence showing a significant reduction in *S. mutans* and dental caries in children.
- Recognizes that the large dose and frequency of xylitol used in clinical trials may be unrealistic in clinical practice.
- Supports further research to clarify the impact of xylitol delivery vehicles, exposure frequency, and optimal dose to reduce caries and improve pediatric oral health. [40]

Periodontal disease
Prevention is as important as the treatment of periodontal disease. Many factors impact the progression of periodontal disease, including food choices. Foods high in carbohydrates adhere to the oral cavity and serve as nutrients for bacteria, contributing to pathogen growth and exacerbating periodontal disease. An *in vitro* study by Prashant et al. (2012) showed artificial sweeteners have antibacterial effects on *Porphyromonas gingivalis and Aggregatibacter actinomycetemcomitans*, keystone pathogens of periodontal diseases. However, the effect of artificial sweeteners in foods on periodontal disease is largely unknown. [43] [44]

Shinohara et al. (2022) investigated the *in vitro* effects of ace-K, aspartame, saccharin, and sucralose on *P. gingivalis* growth and biofilm formation. These sugar substitutes are commonly used in foods for the elderly or people with dysphagia (difficulties swallowing). The researchers found *P. gingivalis* growth was inhibited by ace-K, aspartame, saccharin, and sucralose. In addition, these food additives showed bactericidal activity for planktonic *P. gingivalis.* Also, biofilm formation was inhibited by acesulfame K, aspartame, saccharin, and sucralose.

Moreover, the same concentration of these food additives without aspartame killed *P. gingivalis* in the biofilm. Ace-K and saccharin showed cytotoxicity to human cell lines at concentrations that affected *P. gingivalis.* However, aspartame and sucralose did not show cytotoxicity to human cell lines at concentrations that affected *P. gingivalis.* To solve this problem, the researchers want to study the effect of combining two or more food additives on *P. gingivalis*. The mixture may synergistically affect the biofilm and may affect *P. gingivalis* at low concentrations without cytotoxicity.

The authors note the *in vitro* results cannot be extrapolated directly to *in vivo* or clinical practice. However, the food additives in the study are in foods used for people with dysphagia, who are at high risk of aspiration pneumonia. These findings may help clarify the effects of food additives on periodontopathogenic bacteria. [43]

Air polishing
Erythritol is used for subgingival air polishing. Erythritol powder is low-abrasive and water-soluble and can be safely used on restorative materials and dental implants, and for the debridement of periodontal pockets. Compared to glycine powder, erythritol produces a smoother surface when used on dentin. Also, significant improvements in plaque index scores, bleeding on probing, and probing depths have been seen with subgingival air polishing with erythritol powder.[7] [45] [46] [47]

Environmental impact
Sucralose (e.g., Splenda) is resistant to breakdown by microorganisms. As a result, the human gut is unable to process the sweetener. Sucralose is so stable it escapes wastewater treatment processing and has been detected in drinking water and aquatic environments. A recently published study by Westmoreland et al. (2024) investigated how sucralose affects the behaviour of cyanobacteria (an aquatic photosynthetic

[7] Refer to Episode 35 for discussion on air polishing.

bacteria) and diatoms, microscopic algae that account for more than 30% of the primary food production in the marine food chain. Researchers collected soil and water from a freshwater and a brackish water[8] site in Florida.

They exposed the samples to different sucralose concentrations and measured photosynthesis and microbial respiration. Compared to the control group, the concentration of freshwater cyanobacteria increased when samples were exposed to sucralose, but the concentration of brackish cyanobacteria spiked and then crashed when dosed. There is the potential that the freshwater communities might be mistaking sucralose for a nutrient.

Both freshwater and brackish diatoms exposed to sucralose displayed an overall decrease in population compared to a control group. Sucralose's ability to increase and decrease microbial populations could threaten a balanced ecosystem as the diatom community could disappear or completely overtake everything else. More research is needed to understand sucralose and its impact on aquatic environments. [48]

Take home messages

- Evidence shows no definitive risks or benefits for healthy adult populations who consume sugar substitutes.
- Foods and beverages containing sugar substitutes often have low nutritional value and may impact the growth and development of children and youth.
- Consuming foods or beverages with sugar substitutes may displace more nutritious foods. Eating a balanced diet, including fruits, vegetables, proteins, and whole grains, is essential. Clients should be encouraged to follow Canada's food guide to help minimize sugar and sugar substitute intake. Clients with diabetes and other cardiometabolic conditions can be referred to a registered dietician.
- Drinks with sugar substitutes can lessen sugar consumption but often are high in acid, contributing to enamel erosion. Water is the best choice to quench thirst and stay hydrated without adding extra calories.
- Noncariogenic sugar substitutes used in products such as candies, mints and chewing gum may reduce the risk of dental caries but should be used in conjunction with reduced sugar intake, good oral hygiene, and fluoride toothpaste.
- Sugar substitutes such as xylitol have a role to play in preventing dental caries because of their noncariogenic nature and saliva stimulatory effect.
- Ongoing research is required to determine the long-term benefits and consequences of sugar substitutes.

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