

Majewski Maciej, Chruścicka Izabela, Buchta Justyna, Egierska Dominika, Burzyńska Paulina, Pietruszka Paulina, Perszke Michał, Całkosiński Aleksander. What do we know about sugar substitutes?. Journal of Education, Health and Sport. 2020;10(4):90-98. eISSN 2391-8306. DOI <http://dx.doi.org/10.12775/JEHS.2020.10.04.011>
<https://apcz.umk.pl/czasopisma/index.php/JEHS/article/view/JEHS.2020.10.04.011>
<https://zenodo.org/record/3749848>

The journal has had 5 points in Ministry of Science and Higher Education parametric evaluation. § 8. 2) and § 12. 1. 2) 22.02.2019.


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The authors declare that there is no conflict of interests regarding the publication of this paper.


Received: 20.03.2020. Revised: 25.03.2020. Accepted: 13.04.2020.


What do we know about sugar substitutes?


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Abstract

Sweeteners are widespread primarily in the food industry. An attractive alternative to sugar. Their prevalence was driven primarily by food shortage during the war. The intense sweetener is permitted for consumption by specifying the ratio of ADI. Due to the chemical structure stands out semi-synthetic and synthetic substances. The most common sweeteners are saccharin, acesulfame-K, steviol glycosides, aspartame, xylitol. Sweet taste is guaranteed, have been using a minimum amount of their low calorie. The aim of this review was to describe the most common sweeteners The article emphasizes both advantages and disadvantages of sucrose's substitutes intake.

Key words: Sweeteners; sugar; health; saccharin; acesulfame-K; steviol; glycosides; aspartame; xylitol

Introduction

The mechanisms responsible for sensing sweet taste already appear in utero. Due to the fact that the baby's first food is breast milk containing lactose, infants have a predilection for high-sweetness products. [1]The preference for sweet taste is also caused by socio-cultural factors, such as the habit of giving children sweets as part of a reward for good behavior. [2]

The most famous available sweetener is sucrose, called table sugar. Consumption of high-energy products, mainly containing easily digestible carbohydrates in the form of sucrose and plant syrups is one of the factors causing the obesity epidemic. Their excessive amount in the diet can also lead to the development of civilization diseases such as caries, type 2 diabetes, cardiovascular diseases, sleep apnea syndrome and some cancers. [2]

Table sugar and the mentioned syrups, with time, began to be replaced with sweeteners, both natural and synthetic origin, the consumption of which ensures minimal or zero energy supply.[1]

The main purpose of their use is to give the products a sweet taste, without causing a strong increase in blood glucose levels and not creating conditions for the development of tooth decay. [1] [3]

The use of sweeteners for food production reduces the risk of excessive body weight and carbohydrate disorders, however, it may have a risk of negative health effects.[4]

For a substance to be considered a substitute, it must meet many criteria. It should have sufficient sweetening power, be thermostable, low calorie and inexpensive, it should not cause caries and neoplastic lesions, and should not leave an unpleasant taste in the mouth after eating. [1]

Different intensively sweeteners have different ones the course of sweetness intensity than sucrose and they differ in their sweetening power.[3]

Stevia

Stevia is a natural sweetener and a common sugar substitute used in daily diet as an addition to food and drink.[5] It is a perennial plant from Asteraceae family. Its genus includes 250- 300 species.[6] Originally stevia comes from Brazil and Paraguay. Currently, it is planted in different regions in the world, especially in Asia, in countries like Japan, China and Thailand.[5] Some Indian tribes used stevia's leaves for chewing after a meal, like nowadays we use a chewing gum. It was also used as an addition to herbal infusions.[2] The Guarani Indians have been using stevia for over 1500 years to lower blood pressure, treat digesting and skin disorders and to accelerate wound healing.[5] The sweet taste of stevia is caused by presence of active compounds- steviol glycosides (mainly stevioside and rebaudioside A), which are over 300 times sweeter than saccharose.[7] Stevia rebaudiana, Stevia opata, Stevia ivifolia and Stevia errata are the species, which are said to have a sweet taste, but from all of them Stevia rebaudiana plays the most significant role in the market.[6] Stevia rebaudiana's powdered leaves are 20-30 times sweeter than saccharose. Due to its thermostability, stevia, unlike other sweeteners, can be used in many categories of food. Stevia is a natural substitute for sugar, which can be used in cooking and baking up to 200°C.[8]

Other important compounds which can be found in this plant are vitamins from the group B and minerals like magnesium, calcium, potassium, silicon, iron, manganese, zinc and selenium. It also contains lipids and proteins. The biggest amount of microelements is found in young stevia's leaves. It is proved that stevia contains more iron, copper, manganese and zinc than cereals, potato tuber, lamb's lettuce and also leaves and roots of beetroots. The amounts of copper and iron is higher in stevia's young and old leaves than in lettuce. Stevia rebaudiana contains more microelements than other South American plant- quinoa.[9] Stevia leaves contain much more microelements than processed stevia- in form of tablets. Obviously, using stevia as a sweetener will not provide full demand of microelements for human's organism, but it is an important, additional source of these minerals. [2] Other valuable components of Stevia rebaudiana's fresh leaves are L- ascorbic acid (vitamin C), chlorophyll A and B and carotenoids.[6]

Stevia is recommended for patients with diabetes, because steviosides inhibits the absorption

of glucose in the small intestine.[2] Therefore, stevia does not cause glycemia increase. Moreover, steviol glycosides reduce development of insulin resistance and help in insulin secretion in pancreatic β - cells, which effects in glycemia decrease. [10] According to research published during Internation Diabetic Federation congress, regular intake of stevia, even in small amounts, normalizes blood sugar level without any side effects.[5]

Other disease, in which stevia can be used, is hypertension due to rebaudioside's mild hypotensive effect. However in patients with regular blood pressure this effect wasn't observed.[11]

Stevioside is one of cariostatic factors and can be used in prevention of dental caries development. Unlike majority of carbohydrates, stevia can't decomposed into acids, which cause erosion of enamel. Stevia contains also antibacterial substances which decrease proliferation of harmful bacteria and changes the oral cavity microflora. [10] This saccharose substitute has a positive impact on wound and burn healing.[5] Other positive features of stevia are antifungal and antidiarrheal action.[12][13]

Due to presence of selenium, zincum and vitamin C, use of stevia can be helpful during treatment of coryza.[5]

The last interesting feature of *Stevia rebaudiana* is its potential use in treatment of osteoporosis, which is still being tested. [5]

Xylitol

Polyols are a group of semi-synthetic sweeteners, also known as polyalcohols, sugar or hydroxyl alcohols. The polyols include such alcohol as xylitol, sorbitol, lactitol, maltitol, mannitol or isomalt. They occur naturally in plants and fruits, including in plums, pears, peaches, apples, olives, figs, strawberries, and raspberries. as well as in mushrooms and the human body.[1]

Sugar alcohols have a much lower sweetness than sucrose, so they can be used in food in larger quantities than intense sweeteners. The same energy value was assumed for all polyols, which is 2.4 kcal / 1 g (10 kJ). This represents only 60% of the energy value of glucose or fructose. [2]

Polyols have many beneficial properties and are readily used by food producers. They increase the volume of the product, thus reducing its unit energy value. They are indifferent to enzymes and are difficult to ferment. Consumption of polyols, even in relatively large quantities, does not pose a serious threat to human health. [2]

Xylitol is a representative of polyhydric alcohols, referred to as birch sugar [2] because initially, the raw material for its production was birch wood. [1] However, both in wood and in birch bark, xylitol is absent. Nevertheless, there are xylans. To obtain xylitol from xylans, it is necessary to hydrolyze polysaccharides into single molecules of xylose, aldopentose, called wood sugar, and then reduce it to xylitol. The human digestive system does not produce enzymes capable of digesting xylans that would make it possible to benefit from the sweetness of wood sugar. The current method of obtaining xylitol is microbial fermentation of hemicelluloses. Xylan hydrolysis is carried out by microorganisms. Often, fungi *Saccharomycetales* (*Candida*) and *Saccharomyces cerevisiae* are used for this purpose. New strains of bacteria and fungi are still being sought, which will be characterized by higher efficiency and greater resistance to the secondary metabolites of the process. On an industrial

scale, waste from agriculture (e.g. corn pods, cereal straw) or the wood industry (bark, chips) is most often used. [14]

Xylitol in Europe is known as a food additive (E967) safe for use by both adults and children. Due to the rare and few side effects of xylitol, mainly from the digestive system (abdominal pain, discomfort, bloating, diarrhea), the dose of acceptable daily intake (ADI) has not been established. [1][3]

This substance looks similar to sugar, because it is a white, crystalline powder, without smell. It has a sweetness comparable to sucrose, without any unpleasant aftertaste, but it provides 40% fewer calories (2.4 kcal/g). [4] In addition, it exhibits synergism of sweetening power over other polyols, including sorbitol. [1]

Xylitol is a low-calorie sugar substitute, especially for people with diabetes as well as those on a diet. It is recommended for diabetics because it is metabolized without insulin.[3] It is partly absorbed in the digestive system due to passive diffusion. This process is relatively slow, so it does not cause a rapid increase in blood glucose and insulin secretion by pancreatic β cells. [2] Its glycemic index is 13. [15]

Xylitol is also a probiotic, which, unlike sugar, supports the development of beneficial intestinal bacterial flora. [1]

In the food and pharmaceutical industry, it is most often used as a low-calorie sweetener, but also as an emulsifier, stabilizer, humectant, and thickener. It has also been shown to have a positive effect on the sensory characteristics of low-fat cheeses. [1][16]

It is one of the most commonly used substitutes, which is available in many forms. Sugar - xylose is the equivalent. [17]

Several clinical studies have demonstrated the effectiveness of xylitol in reducing the incidence of caries. [18] [19]

It is not fermented in the mouth, therefore it cannot be converted to acids by the bacteria that live in the mouth, including *Streptococcus mutans*. It reduces plaque formation, enamel demineralization, bacterial adhesion and inhibits the growth of *Streptococcus mutans*. These effects are probably the result of bacteria not fermenting xylitol. [17][20] In addition, it was found that it restores the proper alkaline-acid balance in the mouth, and the alkaline environment is not conducive to the development of pathogenic bacteria. [19]

Based on clinical studies, it was also found that the use of xylitol by mothers significantly reduces the incidence of caries in their children aged 19-31 months. [21]

The presence of other polyols enhances its anticaries effect, as does the increase in its dose. [19]

Xylitol meets the conditions necessary to call it a sugar substitute, and also leaves the mouth feeling cool and fresh. For this reason, it is the most common sweetener in chewing gums. Regular chewing of such gums reduces the amount of plaque and increases the amount of saliva. [17]

Mentioned increase in salivation occurs both in healthy people and those suffering from xerostomia, i.e. dryness of the mucous membranes within the mouth. Therefore, the consumption of xylitol is particularly desirable in this group of patients. [2]

According to research by Ly et al., Xylitol works most effectively when it is used 3 to 5 times a day, and the total dose is from 6 to 10 g. However, consuming more than 10 g of this alcohol does not translate into increased effectiveness. [22]

For preventive purposes, it is recommended to chew gum or dragees with xylitol after meals, especially those with added sugar. [1]

Xylitol has many attractive properties desired by producers and consumers, which is why it is used in both the food and pharmaceutical industries as well as in the prevention and therapy of human diseases. [1]

Artificial Sweeteners

Artificial sweeteners are a large group of chemical compounds. They are synthetic sugar substitutes. It is characteristic of them to have a sweet taste in low concentrations. These compounds do not have nutrients and they also do not have calories. There are some more features of these sweeteners:

- thermally resistant in the range of $-30 + 260^{\circ} \text{C}$,
- stable in the range of pH 2.5-8,
- neutral, do not react with food ingredients,
- quickly excreted from the body,
- economical,
- well soluble [23]

Due to their properties, especially lack of calories, artificial sweeteners are considered effective agents used to help people with obesity and overweight, as well as to support treatment in diabetes and tooth decay. They have similar applications as natural sweeteners. In contrast, studies have shown many of the negative effects of consuming artificial sweeteners. [24]

The most common artificial sweeteners are saccharin, acesulfame k and aspartame. [24]

Saccharin

It is the first artificial sweetener used in food production. It is sweeter than sucrose about five hundred times. However, after eating it leaves bitter aftertaste which limits applications. Saccharin is slightly soluble in water, therefore in use are sodium saccharin or calcium saccharin. This substance is added to nonalcoholic drinks, and it is in every other one. [24]

Scientists have shown a carcinogenic effect, but only concerning one animal species (rat) and when it is administered in high doses. [25] The bladder cancer formation in male rats is caused by sodium levels and high urinary pH which harms urothelium. Saccharin does not bond with DNA. [26] In humans observed, only a few cases of intoxication, catarrhal kidney disease, proteinuria, high blood urea and allergic reactions. [25]

Acesulfame K

It is an acetic acid derivative which is two hundred times sweeter than sucrose. The feeling of sweet shows quick and disappear slowly. Like saccharin, it has a slightly bitter aftertaste, especially at high concentrations. It has a synergistic effect, therefore it is blended with other sweeteners to use. It is almost in every dietetic drink. [24]

Acesulfame K is potentially carcinogenic. Researchers have found that in mouse acesulfame K in high concentrations interacts with DNA, which leads to cell damage. [27] Side effects of chronic use include digestive system disorders, central nervous system disorders, bronchitis and liver diseases. [28]

Aspartame

It is the most popular artificial sweetener in the world. It is two hundred times sweeter than

sucrose. Aspartame is used to sweeten the products and also as a fixative for fruit aromas in foods. [7]

It is a substance one of the above which in the digestion process is broken down into aspartic acid, phenylalanine and small amounts of methanol. Phenylalanine is not metabolized by people with phenylketonuria. A high level of phenylalanine in blood in this group of patients can be very toxic and can lead to brain damage. The product with aspartame must be signified that contains a source of phenylalanine.[24] Another product of metabolism is methanol. This substance is oxidized to toxic formaldehyde and formic acid. [7]

Exposure of cells to this sweetener activates the lipid peroxidation process and, as a consequence, increases the concentration of superoxide dismutase. Therefore, processes involving free radicals that destroy cells of the human body. Aspartame also increases the expression of genes that activate cell apoptosis and induces a significant decrease in the antiapoptotic Bcl-2 marker. It is therefore clear that long-term exposure to aspartame may change the antioxidant status of cells and promote their programmed death. [29]

Administration of aspartame to mice suggests a significantly higher risk of lymphoma, leukemia, bladder cancer, and ureter. But the carcinogenic effect in humans has not been clearly confirmed. [30] However, after consuming aspartame, various reactions of the nervous system may occur in the human body, such as headaches, epileptic seizures, impaired perception, states of excitement, frustration, depression and general body disorder. [24]

Artificial sweeteners	Positive effects on the human body	Negative effect on the human body (chronic consumption or large doses)
Saccharin	Sweeteners replacing sugar (sucrose) -contribute to the weight loss of overweight and obese people -support the treatment of diabetes and dental caries	-intoxication, -catarrhal kidney disease, -proteinuria -high blood urea -allergic reaction
Acesulfame K		-digestive system disorders, -central nervous system disorders, -bronchitis -liver diseases
Aspartame		-headaches, -epileptic seizures, -impaired perception, -states of excitement, -frustration, -depression

Summary

Both natural and artificial sweeteners described in this article perform also other function than just the sweetening one. Stevia nad xylitol make a positive impact on human's health. Their biggest advantages are cariostatic function and normalizing glycemia level in patients with diabetes. Stevia is also a rich source of other substances like: vitamins, chlorophyll A and B, carotenoids and minerals like magnesium, calcium, potassium, silicon, iron, manganium, zincum and selenium. These substances are also necessary for the proper functioning of

human's organism. Artificial sweeteners also have some positive features- lack of calories, support of treatment of diabetes and tooth decay. Unfortunately, chronic use of artificial sweeteners has side effects, which are: carcinogenicity, include digestive system disorders, central nervous system disorders, headaches, epileptic seizures, impaired perception etc

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