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USE OF LOW-CALORIE SWEETENERS IN TREATING OBESITY

ZASTOSOWANIE NISKOKALORYCZNYCH SUBSTANCJI SŁODZĄCYCH W LECZENIU OTYŁOŚCI

Patryk Reimisz[1(A,B,C,D,E,F,G)]

[1] Department of Physiology, Biochemistry and Biostructure of Animals, Faculty of Veterinary Medicine and Animal Science, University of Life Sciences, Poznań, Poland

Authors' contribution
Wkład autorów:
A. Study design/planning
zaplanowanie badań
B. Data collection/entry
zebranie danych
C. Data analysis/statistics
dane – analiza i statystyki
D. Data interpretation
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Summary

Reducing body fat through conservative interventions is a frustrating process for obese people, hence the search for additional ways that can help patients persevere with long-term treatment procedures. Although data obtained from scientific studies do not allow for drawing clear conclusions about the use of sweeteners in the treatment of obesity, their appropriate use may prove beneficial. A review of the current literature was conducted to find the answers to the question of where such large discrepancies come from. It allowed for drawing the following conclusions: 1) Obese individuals may differ significantly in their sensitivity to sweet taste and even the sweeteners themselves; 2) The long-term effects of some sweeteners may neutralize the effect associated with short-term sweet appetite relief and even lead to the greater energy intake and/or utilization; 3) Natural sweeteners differ significantly from artificial sweeteners in terms of long-term effects; 4) The psychological effects of the sweeteners use (e.g., the acquiescence effect) may at least partially attenuate their inhibitory effects on food intake. Based on the review, guidance was developed for obesity practitioners and their patients regarding the use of sugar substitutes in fat reduction.

Keywords: natural sweeteners, non-nutritive sweeteners, sweetening agents, obesity

Streszczenie

Redukcja tkanki tłuszczowej przy zastosowaniu interwencji zachowawczych jest dla osób otyłych procesem frustrującym, stąd szuka się dodatkowych sposobów, które mogą pomóc pacjentom w wytrwaniu przy długotrwałym stosowaniu procedur leczniczych. Choć dane uzyskiwane z badań naukowych nie pozwalają na wyciągnięcie jednoznacznych wniosków odnośnie do stosowania słodzików w leczeniu otyłości, to odpowiednie ich wykorzystanie może okazać się przydatne. W poszukiwaniu odpowiedzi na pytanie skąd biorą się tak duże rozbieżności dokonano przeglądu aktualnej literatury. Pozwolił on na wyciągnięcie następujących wniosków: 1) Osoby otyłe mogą znacząco różnić się w kwestii wrażliwości na słodki smak, a nawet same substancje słodzące; 2) Długoterminowe skutki stosowania niektórych substancji słodzących mogą neutralizować efekt związany z krótkotrwałym łagodzeniem apetytu na słodycze, a nawet prowadzić do większego poboru i/lub wykorzystania energii; 3) Naturalne substancje słodzące znacząco różnią się od sztucznych substancji słodzących w kwestii oddziaływań długoterminowych; 4) Efekty psychologiczne stosowania substancji słodzących (np. efekt przyzwolenia) może co najmniej częściowo osłabiać ich hamujący wpływ na pobór pokarmu. Na podstawie dokonanego przeglądu opracowano wskazówki dla osób zajmujących się leczeniem otyłości oraz ich pacjentów odnośnie stosowania zamienników cukru w procesie redukcji tkanki tłuszczowej.

Słowa kluczowe: naturalne substancje słodzące, sztuczne substancje słodzące, substancje słodzące, otyłość

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Address for correspondence / Adres korespondencyjny: Patryk Reimisz, Department of Physiology, Biochemistry and Biostructure of Animals, Faculty of Veterinary Medicine and Animal Science, University of Life Sciences, Wojska Polskiego 28 Street, 60-637 Poznań, Poland, e-mail: patryk-reimisz@wp.pl, phone: +48 61 848 71 04, ORCID: https://orcid.org/0009-0007-5855-892X

Introduction

The reduction of body fat using behavioral interventions is a lengthy and frustrating process for the person undergoing the treatment. Although multiple recommendations, especially when used concurrently, are highly efficacious (e.g., energy restriction, cognitive-behavioral therapy directed at dietary modifications, exercise, limiting sugar intake to <20% of delivered calories), maintaining them for a sufficiently long period of time is difficult for many obese individuals to endure [1,2]. In their case, the solution may be a pharmacological support. Currently, there are 3 drugs registered on the European market for the treatment of obesity. These include liraglutide, naltrexone/bupropion and orlistat [3]. Numerous substances used in the past have been withdrawn due to side effects that are too dangerous for health. Additional ways are being sought to help obese people with long-term treatment procedures. An appropriate use of sugar substitutes may prove useful, but no clear recommendations have yet been developed regarding specific substances and their usage [4]. The characteristics of selected sweeteners are summarized in Table 1.

The results of the studies comparing the effects of sugar intake and sugar substitutes on indicators such as body weight or glycated hemoglobin (HbA1c) levels in people with diabetes are inconclusive. Long-term studies on the effects of multiple sweeteners on diabetes complications or overall mortality are also lacking [12]. Some publications point to the benefit (in terms of reducing total energy delivered with food) of reaching for low-calorie snacks and beverages sweetened with sugar substitutes between meals [4], while others point to their inclusion in the main meals. Some authors have shown that the consumption of light products leads to a small reduction in body weight only in the obese people who do not follow dietary restrictions, but has no effect for those who remain on a reduction diet [13]. On the other hand, there are reports that the obese people who are more likely to reach for diet drinks eat more and provide more energy in total than the obese people who choose sugar-sweetened beverages [14,15]. In addition, an increased risk of developing complications such as hypertension or type 2 diabetes may be associated with an excessive consumption of both the former and the latter [16]. Children who consume significant numbers of light drinks may also be at higher risk of developing overweight [17]. Hence, some authors consider them mainly as part of diet plans and cite evidence that introducing them into controlled diets moderately aids weight loss [18]. It may be particularly important in diets with a large calorie deficit, where it prevents excessive reductions in palatability that would translate into increased cravings and more frequent abandonment of the menu [19].

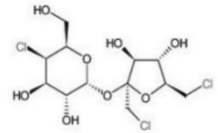
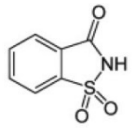
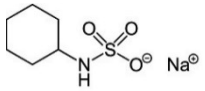
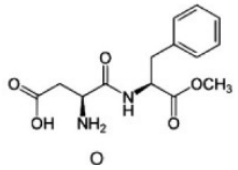
Clarity is also lacking on whether light drinks have any advantage at all in weight loss over consuming pure water. One study reported greater weight reduction in a weight-loss program and improved tissue insulin sensitivity when substituting water for sugary light drinks consumed after a main meal [20]. On the other hand, another study showed an advantage of consuming diet drinks instead of water in both weight reduction (5.95 kg vs. 4.09 kg over a 12-week period) and weight maintenance over the next two years after losing 10 kg (+5.4 kg vs. +9.4 kg) [21].

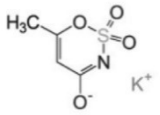
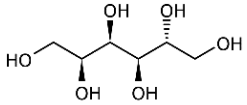
It is worth mentioning that the use of artificial sweeteners during pregnancy may be associated with preterm labor, and should therefore be discouraged, although the evidence for this relationship is described as weak or insufficient [19,22,23]. The cited data do not enable drawing any firm conclusions regarding the use of sweeteners in the treatment of obesity.

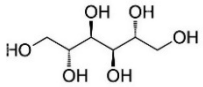
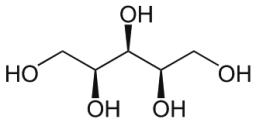
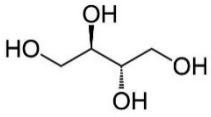
Aim of the study

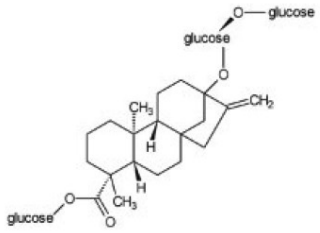
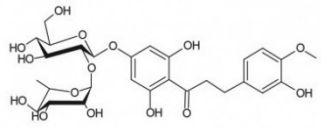
This article attempts to answer the question of why so large discrepancies appear, and to develop clearer guidance for obesity treatment practitioners and their patients on this basis.

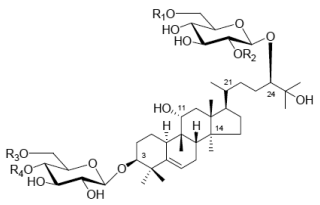
Table 1. Characteristics of selected sweeteners

Name	General characteristics							Regulations		Effect on body
	Chemical classification	Chemical structure	Type*	Source (CS - chemical synthesis)	Sweetness†	Calorific value‡	IG§	EFSA‖	ADI (UE)¶	
Sucralose	Chlorinated sucrose derivative		S	CS	600x	0	0	E955	5	It is absorbed in the intestines at 15%, not metabolized. It may cause disturbances in carbohydrate metabolism. It may cause increased appetite [5].
Saccharin	*O*-sulfobenzoic acid imide		S	CS	300x	0	0	E954	5	As a sweetener usually in combination with cyclamate. It is absorbed in the intestines at 85%, excreted unchanged. It stimulates the bitter taste receptor. It may cause carbohydrate disturbances. It may lead to weight gain [5].
Cyclamate	Amidosulfonic acid salt		S	CS	30-50x	0	0	E952	1	It stimulates the bitter taste receptor. It is not metabolized in the human body and is quickly excreted unchanged, although in individual cases (an individual trait, affects 7 to 11% of the population) it can undergo a harmful transformation to cyclohexylamine under the influence of bacterial microflora [6,7].
Aspartame	Asp-Phe dipeptide methyl ester		S	CS	180-200x	4	0	E951	50	Often in combination with acesulfame K. It is completely digested to amino acids and methanol. It cannot be consumed by people suffering from phenylketonuria. It can cause hyperactivity, antioxidant imbalance, inflammation,

Name	General characteristics							Regulations		Effect on body
	Chemical classification	Chemical structure	Type*	Source (CS - chemical synthesis)	Sweetness†	Calorific value‡	IG§	EFSA‖	ADI (UE)¶	
										intestinal dysbiosis, raises cortisol levels, potentially nephrotoxic and carcinogenic. There are two derivatives on the market – Neotam (sweetness 8000x sucrose, approved in the EU since 2010) and Advantam (20000x sucrose, approved in the EU in 2014) [5].
Acesulfame K	Potassium salt of N-sulfonyl amide		S	CS	200x	0	0	E950	15	Usually in combination with aspartame. It stimulates the bitter taste receptor. It is fully absorbed in the intestines, is not metabolized, and is rapidly eliminated in the urine. It may cause disorders of carbohydrate metabolism. It may cause increased appetite [5].
Sorbitol	Polyhydroxy alcohol		N	Glucose hydrogenation	0.5-0.7x	2.7	9	E420	No limit	It is partially absorbed in the small intestine by diffusion. It is partially digested, partially excreted unchanged in the urine. The unabsorbed portion is fermented in the colon by bacterial flora into volatile fatty acids. It exhibits antitumor activity. In excess, it can cause intestinal discomfort [6].

Name	General characteristics							Regulations		Effect on body
	Chemical classification	Chemical structure	Type*	Source (CS - chemical synthesis)	Sweetness†	Calorific value‡	IG§	EFSA‖	ADI (UE)¶	
Mannitol	Polyhydroxy alcohol		N	Fructose hydrogenation	0.5-0.7x	1.6	0	E421	No limit	It undergoes partial absorption in the small intestine. It is not metabolized, fully excreted by the kidneys. It exhibits antitumor activity. In excess, it can cause intestinal discomfort. It is also used as an osmotic diuretic in pharmacotherapy [6].
Xylitol	Polyhydroxy alcohol		N	Hydrogenation of xylose extracted from birch bark, among others	1	2.4	13	E967	No limit	It is partially absorbed in the small intestine, in the large intestine it is broken down by bacteria (mainly to short-chain fatty acids). Absorbed, it is metabolized mainly in the liver (50-80%), where it is converted to glucose and lactic acid. It exhibits anti-corrosive, anti-cancer, antioxidant, potentially beneficial effects on intestinal microflora. In excess, it can cause intestinal discomfort [8].
Erythrol	Polyhydroxy alcohol		N	Glucose fermentation by the fungus Moniliella pollinis	0.6-0.8x	0.2	0	E968	No limit	It is 90% absorbed in the small intestine. In unchanged form, it is excreted by the kidneys. The unabsorbed portion is partially metabolized by colon bacteria. It exhibits antimicrobial, anticancer, antioxidant, potentially beneficial effects on intestinal microflora. In excess, it can cause intestinal discomfort, but these occur less frequently than with other polyols due to its high absorption rate [8].

Name	General characteristics							Regulations		Effect on body
	Chemical classification	Chemical structure	Type*	Source (CS - chemical synthesis)	Sweetness†	Calorific value‡	IG§	EFSA‖	ADI (UE)¶	
Stevia	Steviol glycosides		N	Stevia rebaudian leaf extract	200x	0	0	E960	4	It stimulates the bitter taste receptor (leaves a slightly licorice-bitter aftertaste). In the digestive tract, steviol glycosides are not digested, but broken down to steviol and glucose with the participation of bacteria residing in the large intestine. The released glucose is consumed by intestinal bacteria. A small portion of steviol is absorbed and converted in the liver to the glucuronide form, which is quickly excreted in the urine, with the remainder excreted in the feces. It shows potential antiviral, anti-inflammatory, hypotensive effects, potentially beneficial effects on intestinal microflora [5].
Neohesoery-dyne DC	Flavonoid glycoside dihydrochalcone		S	Neohesperidin derivative extracted from *Citrus aurantium*	1000x	0	0	E959	5	The sweet taste sensation persists for a long time. It undergoes little absorption in the small intestine and is subject to rapid elimination. Metabolized by intestinal bacteria. Reduces inflammation induced by a high-fat diet, has a potentially beneficial effect on the microbiome. Also used as a flavor enhancer [9].

Name	General characteristics							Regulations		Effect on body
	Chemical classification	Chemical structure	Type*	Source (CS - chemical synthesis)	Sweetness†	Calorific value‡	IG§	EFSA‖	ADI (UE)¶	
Monk fruit extract	Triterpene glycosides		N	Mogroside V extracted from Siraitia grosvenoria	250-400x	0	0	-	-	It has not been approved for consumption in the EU, due to insufficient data relative to its safety of use. Due to its slight aftertaste, it could find use in masking the bitter aftertaste of steviol sweeteners. It is absorbed in small amounts. It is metabolized by intestinal bacteria. Potential antioxidant and anti-inflammatory effects [10].
Thaumatin	Polypeptide (207 amino acids)		N	Extracted from the fruit of Thaumatococcus daniellii	2000x	4	0	E957	No limit	The sweet taste appears only moments after consumption and lasts for a long time. It undergoes complete digestion and absorption in the form of amino acids [11].

Notes: *N – natural, S – artificial, †With respect to sucrose, ‡kcal/g, §Glycemic Index, ‖E-index assigned by the European Food Safety Authority, ¶Acceptable daily intake – according to the European Food Safety Authority (mg/kg bw/d).

Sensitivity to sweet taste

Obese people may differ significantly in their sensitivity to sweet taste and even sensitivity to sweeteners as such. It has been demonstrated, among others, that different variants of genes encoding taste receptor proteins such as *TAS1R2, TAS1R3, GNAT3* and *TAS2R38* are associated with varying degrees of preference for and intake of sweet foods [21,24]. It may mean that those with a low threshold of sensitivity to sweet taste experience pleasure at relatively low stimulus and therefore are not fond of intensely sweet foods, while those with a high threshold of sensitivity need to be stimulated by a more intense stimulus to experience similar pleasure and therefore prefer sweets [25]. Preference for sweet taste may also depend on the activity of the reward system itself. In this case, it is hypothesized that sweet foods may be specifically sought by individuals who have an enhanced dopaminergic response resulting from eating them [26].

Another issue relates to the considerable chemical diversity of sweeteners, which, by binding to taste receptors at different sites, elicit a different intracellular response. For example, in studies in rats, it was noted that sucralose mainly activates a different secondary messenger (cAMP) pathway than saccharin (IP3) [26]. These differences may translate into different arousal effects. In addition, the two sweeteners may affect different individuals with different intensities, depending on genetic conditions, including variants in the proteins that encode taste receptors [19].

An issue that hinders the study of individual substances is the practice of combining them with each other to obtain the appropriate taste properties and sweetening power [21]. Compounds characterized by an undesirable aftertaste are combined with others that mitigate the aftertaste, and a synergistic effect is used to increase the sweetening power (without exacerbating the undesirable effects) – substances that bind to different receptor sites (e.g., cyclamate and saccharin) are combined. The synergistic effect is not exhibited by substances which binding sites largely overlap (e.g., cyclamate and neohesperidin DC) [27,28].

While it is a fact that people differ in their preference for sweet taste, it has not been clearly established whether this preference can be altered by the provision of artificial sweeteners. Some studies indicate that it remains unchanged [29], while others indicate that it may intensify – especially if the amount of sweeteners consumed is high [21]. It has been postulated that the potential change may be due to both the altered expression of taste receptors [21] and a reduced ability of the nervous system to relate taste sensations to the amount of the delivered energy [19].

The long-term effects of some sweeteners

The long-term effects of some sweeteners may neutralize the effect associated with short-term relief of sweet cravings and even lead to greater energy intake and/or utilization. Short-term side effects of the selected sweeteners are summarized in Table 2.

Table 2. Short-term side effects of selected sweeteners within ADI*

Sweetener:	Was rebound effect observed?	Are gastric disorders often observed?	Does it cause adverse gustatory sensations?
sucralose	YES	NO	NO
saccharin + cyclamate	ID†	NO	YES
aspartame + acesulfame K	ID†	NO	YES
xylitol	ID†	YES	YES
erythrol	ID†	NO	YES
stevia	ID†	NO	YES

Notes: *Acceptable Daily Intake, †Insufficient data.

The majority of studies indicate that a short-term use of all approved artificial sweeteners is safe. The effects of a long-term use are different for various substances and often not fully recognized. The need for more detailed research in this regard is being indicated [26,30]. In general, these effects are mainly due to reactions occurring within the digestive system. None of the approved sweeteners are bioaccumulative. Those that undergo more intensive absorption in the small intestine (such as acesulfame K or saccharin) are quickly eliminated by the kidneys, usually in an unchanged form [5]. Others, such as sucralose, which are absorbed only slightly, are also subject to rapid elimination [5]. Aspartame is the only artificial sweetener to be completely digested into amino acids and methanol, which, as small molecules, are further metabolized in the same way as if they came from natural foods [5].

Some artificial sweeteners can only inhibit cravings for a short time, producing a "rebound" effect afterwards. The studies comparing brain arousal after sucrose and sucralose delivery have shown differences in the activity of MCH neurons of the lateral hypothalamic nuclei, resulting in a reduced dopamine secretion in the striatum. It is likely that this neuronal debt is more than repaid shortly thereafter, through a stronger motivation to provide energy-rich food [31]. In the case of saccharin, the processes associated with food reward in rats are also altered, but it is unknown whether a similar effect can be observed in humans [26]. It is worth noting that in the cited studies, the sweetener was taken up without energy compounds. In humans, such a situation occurs, for example, when consuming a "zero" drink between meals. However, if such a drink is consumed with a meal, or the caloric content of the product was only reduced by replacing sugar with a low-energy sweetener, the "rebound" effect may not occur. Some sweeteners bind with varying affinity to the domains of taste receptor subunits (T1R and T2R) of the gastrointestinal tract (min. the VFD domain of the T1R1 and T1R3 subunits). Stimulation of these receptors affects the activity of incretins (e.g. GLP-1), leading to the release of insulin in the so-called cephalic phase (CPIR), which in the long term can induce or exacerbate existing carbohydrate disorders [21,26,32]. Such a property has been demonstrated by saccharin, sucralose and acesulfame-K [19]. Studies have observed increased appetite after long-term exposure to each of these substances [21].

It has been postulated that an adverse change in the composition of intestinal bacteria, observed, among others, with saccharin or sucralose, may also be responsible for impaired carbohydrate metabolism [21,26,33]. The dysbiosis caused by artificial sweeteners and their metabolites can in turn affect the density of taste receptors, exacerbating metabolic disorders [21]. It has also been postulated that taste receptor density may be related to the tightness of the intestinal barrier. An exposure to sucralose, saccharin or aspartame (in amounts obtainable in the human diet) can lead to an increased intestinal permeability and consequently increased inflammatory processes in the body. The mechanism of this change in the case of aspartame is likely to be related to an increased production of reactive oxygen species, which cause internalization of the epithelial adhesion protein claudin family (CLDN3) [32].

It seems that, if sugar substitutes not providing energy can affect carbohydrate metabolism, they affect mainly indirectly, through an impact within digestive system. Such an effect can be revealed as a result of long-term exposure, therefore, measurements taken shortly after the consumption of such substances as aspartame, saccharin or steviosides, showed no changes of the level of glucose in the blood [34]. In metabolic terms, an effect of its delivery in the form of aqueous solution is similar to the one caused by water [35]. An exception can be sucralose because in some tests, there were changes of the level of insulin, shortly after consumption [36]. Such an effect was not observed in other tests [34]. A 7-day test of consumption of high doses of sucralose (75% ADI) showed no effect on the level of glucose in the blood [37]. Whereas, promising results were obtained in the tests based on steviosides. Healthy rats who ate such a substance showed an improvement in the glycaemia control [38]. Dysbiosis may have another adverse consequence – leading to the increased utilization of nutrients contained in food. Indeed, some studies have reported increased body weight despite no difference in energy intake [26].

Aspartame is the most objectionable of all artificial sweeteners. Its elevated intake has been linked, among others, to neurodegeneration, hyperactivity, nephrotoxicity or an increased likelihood of carcinogenesis [39,40]. The breakdown of this substance is associated with the production of oxygen free radicals, which lead to damage to cell membranes [41]. In addition, the phenylalanine released in this process, competing with tyrosine and tryptophan in cellular blood-brain barrier transport systems can disrupt the metabolism of biogenic amines leading to the development of neuropsychological disorders [41]. This effect may be further exacerbated by elevated cortisol levels, which are noted after aspartame consumption [41]. The carcinogenicity of aspartame has been studied primarily in rodents and remains controversial. While some researchers maintain that it is negligible [42], others present evidence of an increased risk of cancer in test animals [43].

Natural sweeteners

Natural sweeteners differ significantly from artificial sweeteners in terms of long-term effects. The use of natural sweeteners such as xylitol, erythrol and steviol glycosides is less controversial. They seem to be a good alternative to both sugar and artificial sweeteners. Xylitol and erythrol belong to a group of polyols (polyhydroxy alcohols) called sugar alcohols, which are natural components of numerous fruits and vegetables, but are also formed during technological processes, including wine and beer production [6,44].

Of the two, xylitol was the first to find use in nutrition. This substance is absorbed to some extent in the small intestine and enters energy metabolism pathways, making it provide some energy (about 2.4 kcal/g) [more]. It has the same sweetness as sucrose and a low glycemic index (GI=8). The long-term use of xylitol improves glucose tolerance, so it can be used by people suffering from insulin resistance [6]. Xylitol is not metabolized by oral bacteria and exhibits antitumor effects. Instead, it undergoes bacterial breakdown in the large intestine, contributing to the growth of probiotic bacteria [19]. Xylitol has antioxidant effects [more] and effectively stimulates the immune system – it has been shown to be effective, among others, in relieving respiratory infections [45]. In addition, it is credited with anticancer activity [11]. Like most polyols, it is osmotically active, so when consumed in amounts greater than 50 g/d it can cause diarrhea [6].

Erythrol is another polyol that is gaining popularity as a sweetener. It is characterized by 60-80% of the sweetness of sucrose. It is more intensely absorbed in the small intestine than xylitol, making it less likely to cause bloating and diarrhea [6]. In addition, it provides a transferable amount of energy – 0.2 kcal/g [19]. In the body, it is rapidly eliminated in the urine, mostly in unchanged form. About 1% of erythrol undergoes esterification before elimination. Although the health effects of erythrol metabolites have yet to be determined, they are likely to be neutral [8]. Erythrol, like xylitol, increases insulin sensitivity, stimulates the immune system and exhibits antioxidant activity [46]. In addition, it shows protective effects against liver cells in animals with induced non-alcoholic steatosis of this organ. This is explained either by immunomodulation and an increase in short-chain fatty acids [46] or by the effect of antioxidant properties (reduced endoplasmic reticulum stress, translating into lower lipid accumulation) [47].

Sweeteners based on steviol glycosides, called steviosides, are also gaining popularity. They are extracted from a plant called *Stevia rebaudiana* and have 50-400x the sweetness of sucrose [44]. Although stevia is a relatively recent discovery for "Westerners", it has been used as a sweetener for hundreds of years in various parts of the world, including South America. Like xylitol and erythrol – stevia has been shown to have a beneficial effect on intestinal microflora [26]. It promotes the growth of probiotic bacteria and inhibits the growth of pathological bacteria (e.g. Escherichia coli) [19]. In in vitro studies, it also exhibits immunomodulatory, anti-inflammatory, anti-diabetic, hypotensive and antiproliferative effects on certain cancers (e.g. of breast and pancreas) [4,19]. Steviol glycosides are not absorbed in the small intestine. In the large intestine, they undergo

bacterial breakdown to glucose (which is excreted in the feces) and steviol – which is absorbed to some extent. Steviol is then converted in the liver to the glucuronide form, which is rapidly excreted in the urine [48].

Additionally, it is worth mentioning two more compounds characterized by high sweetness – thaumatin and monk fruit extract. The former is a polypeptide extracted from the fruit of *Thaumatococcus daniellii*, which is probably the sweetest substance of natural origin (2000x sweeter than sucrose). The sweet taste in the case of thaumatococcus appears only moments after consumption and persists for a long time. The substance is considered fully safe for health, is completely digested and absorbed as amino acids [11]. On the other hand, monk fruit extract is extracted from a plant called *Siraitia grosvenorii*. Its sweet taste is provided by the presence of triterpene glycosides called mogrosides (mogroside V) showing 250-400x greater sweetness than sucrose. This substance has not yet been approved for consumption within the European Union due to insufficient data with regard to safety of use, but it is already available, among others, on the US market. Due to its slight aftertaste, mogroside V will probably be able to find use for masking the bitter aftertaste of other sweeteners, such as steviol glycosides. The compound is absorbed in small amounts in the small intestine and is metabolized by colon bacteria. It is attributed with antioxidant and anti-inflammatory effects [49]. The safety of long-term use of selected sweeteners is characterized in Table 3.

Table 3. Safety of long-term use of selected sweeteners within ADI*

Sweetener	Was higher energy consumption observed as a result of long-term use?	Do they bioaccu-mulate?	Do substances or their metabolites cause health controversies?	Was increased risk of the development of metabolic disorders observed?	Was there negative impact on the microbiota and tightness of intestines observed?	Risk of remote adverse effects
sucralose	YES	NO	NO	YES	YES	INCREASED
saccharin + cyclamate	YES	NO	YES	YES	YES	INCREASED
aspartame + acesulfame K	YES	NO	YES	YES	YES	INCREASED
xylitol	NO	NO	NO	NO	NO	LOW
erythrol	NO	NO	NO	NO	NO	LOW
stevia	NO	NO	NO	NO	NO	LOW

Notes: *Acceptable Daily Intake.

The psychological effects of the sweeteners use

The psychological effects of sweeteners (e.g., the "acquiescence effect") may at least partially undermine their inhibitory action on food intake. It has been observed that people who reach for beverages described as "light" are more likely to allow themselves to consume high-calorie products, justifying this by their previous choice of diet food [50]. This mechanism, referred to in psychology as rationalization, is based on the creation of such a personal narrative that allows one to trivialize the accepted rules of behavior without experiencing unpleasant emotional consequences (such as guilt). This unconscious procedure may not only lead to an equalization of the amount of energy supplied compared to the choice of a full-calorie beverage, but even to a significant excess. A similar effect is observed when an entire meal is described as having reduced calories. In one study, participants took in 42-81 kcal more when informed that a dish was dietary, compared to those who were told it was a filling one [51].

Conclusions

Sugar substitutes are a chemically heterogeneous group of compounds that are characterized by different effects on the body, so they should be considered separately, or at least with a distinction between artificial and natural substances. It does not appear that simply replacing sugar with any of its substitutes translates into a significant weight loss.

More tests are required to be performed on sweeteners, especially with reference to the rebound effect, understood as a short increased appetite as a result of consumption. Such an effect was observed in the event of sucralose [31].

If it turns out that natural sweeteners such as xylitol, and especially erythrol and steviosides, do not increase appetite neither with reference to sweets nor food products of different properties, then, they would be recommended as fully safe sugar substitutes for obese people. Nevertheless, their specific sensorial properties (in the event of erythrol – feeling of cold connected with negative heat of dissolution, in the event of steviosides – bitter aftertaste resulting from stimulation of bitter taste receptors) cause that they are not always preferred by the consumers. We can hope that a substance that has all the properties of an ideal sugar substitute will soon be discovered or synthesized (Figure 1).

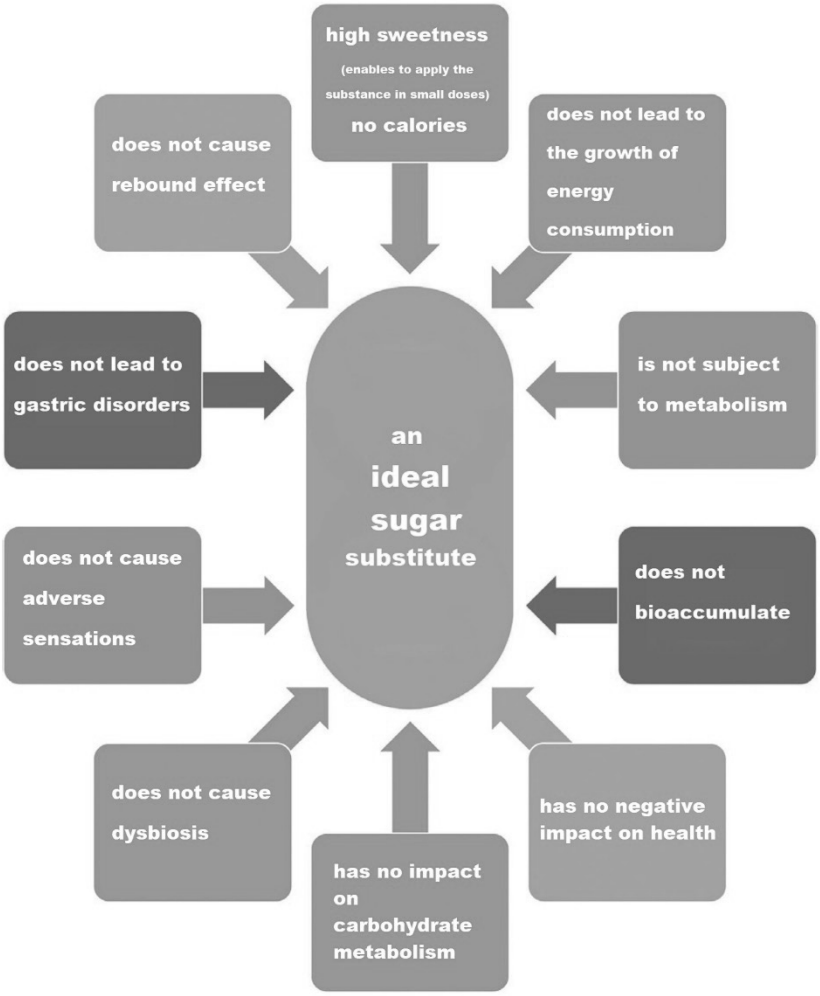


Figure 1. An ideal sugar substitute

The main candidate seems to be the monk fruit extract, which is characterized by similar properties as steviol glycosides, but has no adverse aftertaste [49]. Nevertheless, this substance needs to be thoroughly examined.

Summing up, adults struggling with obesity, having a high preference for sweet taste, who have undertaken a dietary treatment, may derive some benefit from the proper use of sweeteners, provided the following recommendations are followed:

- moderate consumption of sweeteners – as a dietary supplement, may be justified when following reduction diet rules (with a certain caloric content), with a low glycemic index (reduced sugars). Simultaneous consumption of high-sugar products and sweetened with sugar substitutes can lead to a weight gain;
- while on a reduction diet, try to use sugar substitutes in moderation, in greater amounts than needed to achieve a perceptible improvement in the taste of the meal;
- when choosing sweeteners and low-calorie products, pay attention to the type of sweetener. Consume artificial sugar substitutes and products sweetened with them occasionally, and if you are pregnant, lactating, suffer from epilepsy or migraine – it is best to exclude them entirely [4]. Choose natural sweeteners such as xylitol, erythrol or stevia and sweetened with them products for regular consumption;
- you are likely to benefit more if you drink a light drink with a meal that provides energy (such as dinner), rather than between meals. Chances are that it will alleviate your craving for sweets and will not involve more energy consumption later on;
- remember that the use of sweeteners or light drinks does not justify consuming high-calorie foods. Do not give up following the calorie recommendations you set – otherwise you will gain weight instead of supporting the weight loss.

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