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The use and health effects of sugar substitute

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Abstract. Due to the rising prevalence of obesity and the growing emphasis on health consciousness, an increasing number of individuals are opting to manage their weight by reducing their caloric intake through the regulation of sugar consumption. Sugar substitutes are commonly selected as primary alternatives to sugar due to their low caloric content and high level of sweetness. Recent research indicates that sugar substitutes may not be entirely effective in reducing overall calorie consumption. The impact on human metabolism is significant. This paper presents a comprehensive overview of the classification of sugar substitutes, examines the utilization of sweeteners in low-sugar food products available in the market, evaluates recent research findings regarding the safety of sugar substitutes and their effects on metabolism, and proposes potential considerations for individuals when selecting sugar substitutes as well as the future trajectory of the sugar substitute market.

Keywords: sugar substitute, low-sugar foods, obesity, market development.

1. Introduction

Obesity has emerged as a significant global public health concern since the onset of the 21st century. The overconsumption of nutritionally deficient meals that are rich in sugar and calories, particularly in the context of sugary beverages, constitutes a significant contributing factor to the prevalence of obesity. The enhancement of quality of life and optimization of lifespan have prompted a significant emphasis on the management and reduction of sugar intake within a healthy dietary framework. Zero-calorie beverages are commercially available in significant volumes and enjoy widespread demand. The use of sugary foods has become an integral component of individuals' dietary habits. Upon conducting additional research, it was discovered that sugar substitutes are unable to fully supplant sugar and partake in large-scale manufacturing. There exist numerous ongoing debates about the safety of sugar substitutes. Additionally, the taste of individual sugar substitute products is generally regarded as subpar. Further research is required to determine the ideal combination of multiple sugar substitutes. Moreover, there is a significant disparity in production costs between artificial and natural sugars. Several studies have identified a multifaceted association between prolonged use of various dietary items and one's overall well-being [1]. This paper presents a comprehensive examination of the categorization of sugar substitutes, evaluates the utilization of sweeteners in low-sugar food products available in the market, presents recent research findings regarding the safety of sugar substitutes and their effects on metabolism, and proposes future prospects for consumer preferences in selecting sugar substitutes and the potential growth trajectory of the sugar substitute market. This study examines the categorization of sugar

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replacements, the utilization of processed products, and their impact on human health. The findings contribute to the establishment of a theoretical framework for the production and advancement of sugar-related commodities.

2. The application of sugar substitute in food

2.1. Definition and classification

Sugar substitutes refer to compounds that are capable of generating sweet alternatives to sugar, while also possessing a reduced calorie content. The advancement of extraction and synthesis technologies has led to a proliferation of sugar alternatives, including a diverse range of options. These substitutes can be broadly classified into three primary categories [2]. The three types of sweeteners commonly used are sugar alcohols, natural sweeteners, and artificial sweeteners. Sugar alcohols are substances with reduced digestibility that are derived from the conversion of aldehyde or ketone groups in sugar molecules into hydroxyl groups [3]. The aforementioned substances encompass xylitol, erythritol, sorbitol, sorbitol liquids, lactitol, maltitol, maltitol liquids, D-mannitol, and isomaltolose. The predominant composition of natural sweeteners comprises plant extracts, such as stevia, momorrhoea, glycyrrhizin, and somatose. Artificial sweeteners encompass a group of chemically produced or semi-synthetic organic chemicals, such as acesulfameae, aspartame, cyclamate, sucralose, and saccharin sodium. The substance exhibits notable levels of sweetness, minimal thermal intensity, and demonstrates resilience to changes in temperature.

2.2. The application of sugar substitute in confectionery

The selection of candy fillers is determined by the physical and chemical qualities of various sugar alternatives, including solubility, crystallinity, moisture absorption, and sweetness. This is done in order to suit the specific processing requirements of candy production technology and to ensure the desired shelf life of the final product. Sugar alcohols and certain oligosaccharides are employed as alternatives to sucrose for crystal sourcing or as substitutes for starch syrup in order to impede crystal formation, based on their distinct physical and chemical attributes. Sorbitan powder is considered to be a highly effective polyol for the production of sugar-free tablets through compression at a relatively reduced expense. This polyol exhibits the advantageous ability to be directly compressed into compact tablets that include desirable attributes such as hardness, density, and a pleasing texture and flavor. Nevertheless, it is imperative to consider moisture levels during the production process of sorbitol due to its hygroscopic nature. The gel sugar can incorporate sugar alcohol or fiber as a filler, depending on the gel agent's gel strength. According to a study [4], the gel strength of acid-modified starch and gelatin can be greatly strengthened when the concentration of sorbitol is 30% m/m and 5% w/v, respectively. The melting point of isomaltolose is comparatively lower than that of sucrose. However, the viscosity of a solution with an equivalent concentration of isomaltolose is similar to that of sucrose. Consequently, isomaltolose is a viable ingredient for the production of marshmallows at lower processing temperatures. The study conducted by Periche et al. [5] examined the impact of various combinations of isomaltolose and fructose, as well as the quantity of gelatin incorporated, on the overall quality of marshmallow. The findings indicated that the isomaltolose to fructose ratio of 1:1, along with a gelatin concentration of 4g per 100g, resulted in decreased hardness, increased viscosity and elasticity, and improved sensory evaluation.

2.3. The application of sugar substitute in beverage

In contemporary times, individuals commonly opt for beverages as a means to satiate their thirst. However, in conjunction with the consumption of water, there is a notable presence of sugar, hence augmenting the overall caloric intake. The reduction of sugar in beverages is a crucial strategy for managing daily sugar intake. Traditional solidified yogurt is known for its nutritional value; however, it is important to note that it also contains high levels of sugar and calories. This high sucrose content and calorie density can potentially contribute to the development of obesity and other associated health

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conditions. Hence, sweeteners possess the potential to serve as substitutes for a portion of the sugar content in yoghurt. Momordica glycosides possess a low caloric content, exhibit high sweetness, and demonstrate beneficial health properties. The utilization of Momordica glycosides as a sugar substitute in yogurt has several benefits, including reduced sugar content, lower caloric value, and potential health advantages. This particular attribute renders it highly appealing to a diverse range of individuals, particularly those with diabetes. Polyglucose, a non-nutritive sweetener, is generated through the random condensation of glucose molecules. It can serve as a viable substitute for sucrose in the manufacturing of beverages. The polyglucose solution has a comparable viscosity to sucrose and offers a smooth and delicate flavor reminiscent of fat. Consequently, it can be employed in the manufacturing of low-fat ice cream and other chilled beverages. Polydextrose is employed as a substitute for sucrose in orange juice beverages using AK sugar [6]. Through a thorough examination of the texture and taste, it was determined that the substitution of sucrose with a combination of polyglucose and AK sugar had no discernible impact on the inherent quality attributes, including texture, taste, and flavor, of the orange juice beverage. Additionally, it significantly decreases the amount of sugar and calories included in the product.

3. Health effects of sugar substitutes

3.1. Effects of sugar substitutes on metabolism

Various sources of sugar replacements can elicit diverse impacts on human metabolism. Certain artificial sugar substitutes as well as certain naturally occurring sugar substitutes have the potential to facilitate the regular release of insulin, hence contributing to the regulation of sugar metabolism. Certain types of sugars, such as aspartame, xylitol, erythritol, aloxulose, tagose, and somatose, exhibit properties that prevent their digestion and absorption within the human body. Additionally, these sugars do not stimulate the release of insulin and are ultimately eliminated from the body through urine excretion. Numerous literature sources indicate that the consumption of sugar replacements has the potential to disrupt the equilibrium of intestinal flora, leading to adverse effects such as diarrhea or sugar intolerance. Both saccharin and sucralose have been found to have detrimental effects on the composition and diversity of gut microbiota. Table 1 presents the impact of partial sugar replacements on human metabolism [7]. The introduction of non-nutritive sweeteners in human subjects resulted in noticeable alterations in both the makeup and function of the microbiome, as well as several plasma metabolites. This indicates that the presence of non-nutritive sweeteners may elicit a response from specific bacterial species and their associated functions [8]. The replacement of sugar is anticipated to have an impact on the microbial ecosystem within the human body, thereby altering metabolic processes and influencing human physiological functions.

Table 1. The effects of partial sugar substitutes on human metabolism [7].

Sugar substitute name	Insulin secretion	Effects on intestinal flora
Saccharin	facilitate	negative
Cyclamate	facilitate	positive
Acesulfame	facilitate	uninfluential
Aspartame	Not promote	uninfluential
Sucralose	facilitate	negative
Xylitol	Not promote	positive
Erythritol	Not promote	uninfluential
Aloxulose	Not promote	positive
Tagatose	Not promote	positive
Maple sugar	facilitate	positive
Agavose	facilitate	uninfluential
Stevioside	facilitate	uninfluential
Momordica glycosides	facilitate	uninfluential
Thaumatin	Not promote	uninfluential

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3.2. Effects of sugar substitutes on obesity

Splenda has hundreds of times fewer calories and hundreds of times more sweetness than sucrose, so non-nutritive sweeteners can help people lose weight easily. But some studies have shown that non-nutritive sweeteners can increase the secretion of gastrin, leading to an increased appetite, which leads to a search for more food and obesity. A 4-year cohort of 78,286 people in the Netherlands, after adjusting for relevant confounders, showed that increasing consumption of sugar substitute beverages by 150 mL per day was associated with an annual increase in body weight of 0.06kg and waist size of 0.11cm. The incidence of overweight/obesity was increased by 8% (95%CI: 6%-11%) and the incidence of abdominal obesity was increased by 5% (95%CI: 2%-7%). Substitution analysis found that beverage intake was negatively associated with body weight (−0.05kg year −1) and waist circumference (−0.08cm year −1), and the incidence of overweight/obesity was reduced by 9% (95%CI: 3 to 14%), while replacing sugar-sweetened beverages with an equivalent amount of sugar-replaceable beverages was associated with a 6 percent increase in the incidence of overweight/obesity (95%CI: 2 to 10%) [9]. Hence, it is imperative to avoid excessive consumption of both sugar, which plays a crucial role in human metabolism, and non-nutritional sweeteners. The recommendation is not just based on the low calorie content, but more on the need of regulating the quantity of sugar consumed. It is advisable to either maintain or decrease the intake of sugar products and consider substituting sugar with sugar substitutes.

3.3. Effects of sugar substitutes on oral cavity

The primary bacterial species responsible for dental caries include Streptococcus mutans, Lactobacillus, and Actinomyces. The consumption of food containing sugar can lead to the accumulation of sugar in the inaccessible areas of the teeth. Bacteria present in the oral cavity utilize sugar metabolism to generate organic acids, which can subsequently cause the demineralization of tooth enamel, ultimately culminating in the development of dental caries. Certain non-nutritive sweeteners possess the ability to evade bacterial utilization of sugar metabolism for the production of organic acids, owing to their lack of participation in biological metabolic processes. Certain non-nutritive sweeteners, such as saccharin and aspartame, have the ability to impede the activity of actinomycetes and lower the pH in the oral cavity, hence restraining the proliferation of plaque. Xylitol and erythritol have been identified as potentially significant contributors to the prevention of dental caries by their ability to decrease saliva flow and plaque acid, hence inhibiting the proliferation of oral bacteria [10].

4. Market development

The utilization of sugar replacements originated in Europe and several other nations, and is presently proliferating throughout Asia. Currently, numerous European nations have initiated the evaluation of the safety of sugar substitute goods, suggesting a decrease in their usage, and implementing various categorizations. In certain developing nations, the objective of encouraging widespread consumption of beverages while simultaneously ensuring their nutritional value and healthiness has led to the prevalent utilization of sugar substitutes like "aspartame" and "erythritol". These substitutes possess minimal caloric content while retaining a sweet flavor, making them ideal for the large-scale production of sugar-free beverages. The utilization of sugar substitutes has been prevalent within the beverage sector, leading to the displacement of traditional sugar in beverages and the emergence of novel prospects. The underlying motivation driving this behavior is a desire to engage in consumption from the perspective of demand. The burgeoning sugar-free beverage sector is progressively encroaching upon the market dominance of the conventional sugar-sweetened beverage industry, which represents the largest consumer of sugar within the beverage sector. While the efficacy of sugar substitutes is currently under scrutiny, their presence in the market signifies a notable market presence.

The demand for sweeteners among residents has shifted from a preference for single sweeteners to a preference for health-oriented sweetener supplements. This trend has gained popularity and is expected to continue in the future [11]. The growing nutritional consciousness among consumers is expected to result in a decline in consumer demand for sugary foods. Hence, it is imperative for food makers to

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expeditiously devise food products that effectively satiate individuals' hunger while concurrently preserving the regular metabolic processes of the human body and the balance of intestinal microbiota.

5. Conclusion

Obesity has emerged as a prevalent issue in contemporary society, exerting its influence on an increasing number of individuals. Following the discovery of the low-calorie and high-sweetness properties of sugar substitutes, subsequent investigations have revealed their ability to disrupt the regular metabolic processes of the human body, potentially leading to the development of obesity. The present study centers its attention on the utilization and physiological impacts of sugar replacements. This study aims to explore the classification of sugar substitutes and its implications for the selection and combination of sugar substitute goods. This analysis aims to examine the potential impacts of various sugar replacements on the human body and elucidate the underlying reasons for these effects, examine the appropriate utilization of sugar replacements for promoting a healthy lifestyle, enhance overall human well-being and promote optimal physical health while mitigating the prevalence of obesity.

Although many experiments in mice have been calculated to reach the conclusion that sugar substitutes harm health, but the specific problem should be specific analysis, there are many kinds of sugar substitutes, people's physical conditions are different, different people use different sugar substitutes, the effect is not the same. To look at and make good use of sugar substitutes objectively and reasonably. Understand how sugar substitutes are metabolized after entering the human body and what effects they have on which parts of the human body. This can then provide different groups with more targeted, healthy sugar replacement products. Food is no longer just a source of energy to meet the human body's growth and development, it is also a memory carrier of childhood and beautiful moments. Food is a reason for people to get together, and memories of the past exist in the taste of food. Sick people eat to survive, and the rational use of sugar substitutes can bring taste and life.

In this experiment, a large number of experiments were not conducted, and the analysis of test data was not comprehensive enough. Insufficient research has been conducted on the utilization of various sugar replacements across diverse groups. The precise quantification of sugar replacement consumption in daily life remains inadequately assessed, despite the various methods by which individuals incorporate these substitutes into their dietary habits. In further investigations, it is possible to examine the consumption of latent non-nutritive sweeteners, including the collective quantity of such sweeteners present in various sources such as drinking water, cleaning agents, vegetables, meat, and other relevant sources. Additionally, it is vital to assess whether the cumulative latent intake, when combined with explicit intake, surpasses the recommended daily permissible intake. At present, the effects of non-nutritive sweeteners on human body are mainly based on animal experiments and speculation. Further design of reasonable experiments requires the collaboration of genomics, anthropology and other disciplines. To clarify the influence mechanism of sugar substitute on human gut microbiota, endocrine system, liver, bone, blood, brain, etc. Further research will be conducted on the specific effects of sugar substitutes on human metabolism and the measurement of the total amount of sugar substitutes consumed by people in various ways of life.

References

[1] SCHIANO C, GRIMALDI V, SCOGNAMIGLiO M, et al. Soft drinks and sweeteners intake: possible contribution to the development of metabolic syn.drome and cardiovascular diseases. Beneficial or detrimental action of al-ternative sweeteners?[J]. Food Res Int, 2021, 142: 110220.

[2] Zhu Yuting Hu Zhihe. Research progress of sugar-free food[J]. Beverage industry,2021,24(3): 75-79.ZHU YT, HU ZH. Research progress of sugar-free foods [i]. Beverage Ind,2021,24(3): 75-79.

[3] HONG SJ, AHN M H, SANGSHETTI J, et al. Sugar alcohol-based polymericgene carriers: synthesis, properties and gene therapy applications [J]. ActaBiomater,2019,97: 105-115.

[4] Zhang Chen, Tan Jun, Julie, et al. Effect of sugar alcohols on the texture of Gellan gum [J] Food Science,2014,35(9): 48-52.[ZHANG C,TAN JZHU L,et al.Effects of alditols on gellan gel texture[J]. Food Science, 2014.35(9): 48-52.]
[5] PERICHE AHEREDIA A, ESCRICHE I,et al. Optical.mechanical and sensory properties of based-isomaltulose gummyconfections[J]. Food Bioscience, 2014(7): 37-44.
[6] DENG Z L.Application of polyglucose to replace sucrose in low-calorie cake and orange juice beverage [J]. Jiangxi Food Industry,2009(04):38-40.
[7] MORA M R, DANDO R. The sensory properties and1]metabolic impact of natural and synthetic sweeteners[J]Compr Rev Food Sci Food Saf, 2021, 20(2): 1554-1583.
[8] Jotham Suez, Yotam Cohen, Rafael Valdes-Mas, Christoph K.Stein-Thoeringer, Eran Segal, Eran Elinav. Personalized microbiome-driven effects of nonnutritive sweeteners on human glucose tolerance[J] Cell 185, 3307–3328, September 1, 2022.
[9] BUSO ME C, BROUWER-BROLSMA EM,NAOMI N D, et al. Dose-Responseand substitution analyzes of sweet beverage consumption and bodyweight in Dutch adults: the lifelines cohort study[J]. Front Nutr, 2022, 9889042.
[10] DE COCK P. Erythritol functional roles in oral-systemic health [J]. Adv DentRes,2018, 29(1):104-109.
[11] Liu Z; Li S Peng. J .Exploring the relationship between sugar and sugar substitutes – analysis of income level and beverage consumption market pattern based on the perspective of healthy china[J] Nutrients,2022,14,4474.