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Applications and Challenges of Sweetener in Ice Cream

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Abstract. As the global obesity problem continues to deepen, consumers' pursuit of healthy, low-sugar and low-fat foods is also gradually deepening, so the production of new low-sugar ice cream is also gradually concerned. In the continuous innovation and research of manufacturers and researchers, many low-sugar ice cream have been made and innovated, but many of them have various problems, such as the lack of taste and flavor, safety and so on. This review will focus on different kinds of sweeteners and their characteristics and classification, and analyze the application of sweeteners in ice cream, analyze the advantages and disadvantages of sweeteners in the application process of ice cream. This paper sorted out and classified the application of sweeteners in ice cream by subsequent researchers, and analyzed the existing problems. Further confirmation, research and continuous improvement are needed on the taste, flavor and safety of sweeteners. In future research, further analysis of sweeteners is needed, analysis of different problems, and further innovation, innovation of new sweeteners and different kinds of compounding.

Keywords: Ice cream; sweeteners; low-sugar food.

1. Introduction

Dairy products are popular in consumer food choices, with sales of more than $125 billion annually (IDFA, 2017). This means that the market for dairy products is huge. For dairy products, in addition to being safe, foods that actively support excellent health are sought after by many customers. In the contemporary consumer market, customers frequently cite health as a factor in their food selections. With the promotion of dairy products, many of which contain high levels of sugar, there has been a lot of demand for sugar substitutes in ice cream as awareness of dietary control continues to grow. Some common procedures used to create healthier food items—like reducing fat, sugar, and salt—lead to dairy products having an unsatisfactory flavor [1].

At the same time, many are choosing different sweeteners and combinations of sweeteners to reduce the loss of flavor and texture caused by the reduction in sugar content, like Men long et al choose to create an ice cream with sucralose, stevioside, and erythritol as sugar substitutes [2], they think that the bitterness, astringency, and chemical-like sensations of the sweetener were barely perceptible when Suc, Ste, and Ery were added to ice cream. In addition, many other scholars have used other sweeteners to replace sugar in ice cream. Stevia has been chosen by Pon S.Y. [3] as a sweetener in ice cream because of its excellent performance in diabetic patients and health benefits such as anti-hypertension. For some factories that make ice cream, it is good to use sweeteners such as aspartame for low-calorie ice cream for cost reasons [4]. In addition to these, some scholars have chosen to use date syrup as a sweetener and flavoring agent [5]. In general, there are many sweeteners available for us to use in the production of low-calorie healthy ice cream, but different sweeteners have different properties in terms of safety, efficacy, cost, sweetness, taste, etc. In this review, the function and application of different sweeteners in ice cream will be described from several different aspects. Firstly, the main types of sweeteners and their effects on the human body will be studied, and secondly, the current status of the application of different sweeteners in ice cream will be elaborated, as well as the related controversies.

2. Types of Sweeteners

Sweeteners are food additives that can give a food a sweet taste. Based on where they come from, sweeteners can be categorized as either natural or artificial. For the purpose of this article, sweeteners providing energy will be described as 'nutritive sweeteners' (NS), whereas those that provide no/negligible amounts of energy will be described as 'non-nutritive sweeteners' (NNS) [6].

2.1. NS

Nutritive sweeteners are further divided into bulk sweeteners (like polyols) and sugars (like sweet-tasting mono- and di-saccharides). In this part, the emphasis is on bulk sweeteners.

2.1.1. Sugar alcohol.

The sugar alcohols are those compounds obtained when the aldo or keto group of sugar is reduced to the corresponding hydroxy group. The sugar alcohols are very similar to sugars in terms of chemistry, physics, and biology; in fact, some of them even taste sweet. Most sugar alcohols have anti-caries effects and can cause gastrointestinal upset in high doses, like xylitol, based on the research of Mäkinen, Kauko K [7], it indicates that when xylitol is used in place of sugar, it haves anticaries action. Because the energy of erythritol and steviol in sugar alcohols is negligible, all sugar alcohols except erythritol and steviol are nutritive sweeteners.

About sugar alcohols that are mainly used in some foods, like xylitol and sorbitol, are organic compounds. About safety, xylitol is generally considered safe and does not need to be regulated by ADI [8]. However, there are two clinical symptoms associated with xylitol toxicity: hyperinsulinemia and liver necrosis, or a combination of the two. The liver's conversion of xylitol into compounds that disrupt regular pentose phosphate pathways and alter the control of insulin synthesis and release is thought to be the cause of hyperinsulinemia. Additionally, xylitol's relative sweetness is 1, which is the same as sucrose's sweetness. Besides, xylitol's food energy is 2.4 kcal/g.

Sorbitol's relative sweetness is 0.6. Besides, sorbitol's food energy is 2.6 kcal/g. About safety, the adi value of sorbitol is not specified. Sorbitol oral suspension for laxative purposes. Sorbitol induces constipation by drawing water into the large intestine and causing bowel motions. In addition, sorbitol has a weaker anticaries ability than xylitol.

In general, sugar alcohols have some positive effects in terms of reducing the risk of cardiovascular disease and can also provide a good degree of sweetness, but they produce a certain amount of calories.

2.1.2. Sugar.

Syrup is a solution that contains a high concentration of sugar and therefore has a long shelf life. It is very common in the modern food industry and is often used to make drinks and desserts. The typical one in syrup is high-fructose corn syrup (HFCS), a fructose-glucose liquid sweetener substitute for sucrose. Fructose content in the two most significant HFCS products sold in the market is 42% (HFCS-42) and 55% (HFCS-55). Therefore, this article will focus on these two syrups. The sweetness value of HFCS-55 is same like that of sucrose, for the sweetness value of HFCS-42, it has 90 percent the sweetness of sucrose. For the energy, HFCS will contribute 4kcal/g like sucrose. There is a strong similarity between sucrose and HFCS, and it is safe to predict no change in caloric intake, but the cost of HFCS is relatively low. For other syrup like maple syrup. The sap that emerges from Acer stems in the spring is used to make maple syrup. Sap is a diluted mixture mostly of sucrose and water that also contains trace quantities of organic and amino acids, as well as phenolic compounds. Maple syrup has a sugar content of 66%, the primary sugar in maple syrup is sucrose (96%), with trace amounts of hexoses. It is rich in macronutrients (sucrose) and micronutrients as well as phytochemicals. Maple syrup has many health benefits: the ABA substance in maple syrup has been shown to have anti-diabetic properties and may prevent Type-2 diabetes [9]. In other aspects, some antibacterial activity was found in the phenolic rich maple syrup extract. In addition, it has a certain protective effect in various pathological, cardiovascular, tumor and other aspects. Although, as

mentioned above, maple syrup is healthier, maple syrup has a high sugar content, so we need to control the amount while using it.

Besides, there are some other sugars like D-Tagatose, which is approximately 90% sweeter than sucrose. Under some regulations, glucose is now widely accepted as a safe ingredient for use in food and drink products. Its possible application in the management of type 2 diabetes, demonstrates significant potential in promoting weight loss and raising HDL cholesterol and stress-related weight reduction.

In addition, some oligosaccharides are also a good choice as sweeteners, which not only provide low calories but also have different health effects, such as preventing dental caries and promoting the growth of gastrointestinal probiotics.

2.2. NNS

With the increasing incidence of obesity and related health problems, NNS has become increasingly important in food because it provides essentially no extra calories. Among them, NNS can be divided into two types according to its source, one is natural NNS and the other is synthetic NNS (artificial NNS).

2.2.1. Artificial NNS.

Artificial NNS are artificial chemicals that do not occur in nature and are commonly used to replace sugar in food and beverages. It is about 200 to 700 times sweeter than sucrose. Because of their simple and convenient process and low cost, they are often used in the production and processing of food factories. Although artificial NNS has many advantages, it also has shortcomings, such as several common artificial NNS, aspartame, saccharin and acesulfame, which have been specified adi values, and there are many safety controversies, the most serious of which is aspartame, based on the review of Shankar, Padmini, et al [10], aspartame has been reported to cause a number of health problems, such as headaches, seizures and certain nephrotoxicity. But one of them, sucralose, is relatively safe, has no adi regulations, and is relatively stable, being used as a sweetener in many countries.

2.2.2. Natural NNS.

Natural NNS mainly include erythritol, stevia and monk fruit. They are proven safe. The typical one is erythritol. Erythritol is an odorless white crystalline powder with a relative sweetness of 0.70. Since erythritol is found in nature, erythritol made by microbes is a natural sweetener. The energy value of erythritol is only 1.67Kj/g at most, its energy is usually around 0.21kcal/g, based on this data, its energy value is considered negligible. Along with the artificial sweetener sucralose, erythritol is the only polyol that is non-caloric, providing no energy to the body. Besides, it is easy to crystallize, soluble in water and has high stability to acid and heat. It is insoluble in strong oxidizing agents. In addition to this, erythritol has attracted interest in food preparation because of its remarkable stability at extreme pH and temperature settings. About safety, its safety has been certified, and it has been widely used in beverages, yogurt and other foods. There are other aspects of erythritol: generally speaking, consuming too much sugar alcohol might have unfavorable consequences on the stomach. At equivalent dosages, erythritol is less likely to cause gastrointestinal adverse effects and is better tolerated than sorbitol and xylitol. In the ability to prevent dental caries, a caries study showed a higher rate of plaque reduction in erythritol compared to xylitol, while no plaque reduction was observed in the xylitol or sorbitol groups [11], this indicates that erythritol has better function in preventing caries than sugar alcohol.

Stevia is 300 times sweeter than sucrose. Stevia leaves provide diterpene glycosides, which are non-nutritive, non-toxic, high-potency sweeteners that can replace sucrose and other artificial sweeteners. Apart from sweetness, it has a wide range of therapeutic benefits, including the ability to reduce dental cavities, act as an antihyperglycaemic, anticancerous, and antihypersensitive agent, as well as have contraceptive effects. Moreover, it can stop the growth of germs and fungi. Besides, its taste changes with the dose, which may be accompanied by astringency, bitterness.

To sum up, in terms of safety, sugar, sugar alcohol are relatively safe, and artificial sweeteners in addition to sucralose have a certain safety risk. Function-wise, sugar alcohols and some sugars, such oligosaccharides, have an anti-carcinogenic effect; moreover, sweeteners like stevia can lower the risk of developing cancer.

3. The Application of Sweeteners in Ice Cream

3.1. The Present Situation of Market Use in Ice Cream

With the development of the ice cream market and the increasing pursuit of healthy living diets by consumers, the demand for low-sugar ice cream is also increasing. Furthermore, there is the naturalness effect, whereby customers like meals made with natural components because they believe them to be healthier. In several European nations, the strong relationship between "natural" and "healthy" makes naturalness a "decisive buying incentive" [12]. On the contrary, artificial sweeteners are gradually not accepted by consumers because of different safety controversies. Sucrose and HFCS are important sweeteners in the traditional ice cream market. About the different kinds of syrups, mainly used to make different flavors of ice cream. Low-sugar sweeteners such as sugar alcohols and oligosaccharides are on the rise in the market.

3.2. The Effect of Different Sweeteners on the Characteristics of Ice Cream

Ice cream is a kind of complex colloidal food. In ice cream, there are many factors that affect its taste, and the addition of sweeteners will also affect some of the characteristics of ice cream. Besides, different kinds of sweeteners have different effects on the characteristics of ice cream. Because milk and cream are added to ice cream, protein content is an important part of the flavor composition of ice cream, and the protein content of ice cream does not change significantly when sweetener replaces sucrose. Because of the sweetness of artificial NNS, it is added less in ice cream and has little effect on the characteristics, so it will be less mentioned in the following article. Based on the paper of Asghar, M., et al. [13], when artificial NNS were used in ice cream, there was an increase in solids content and a non-significant decrease in pH.

Since viscosity usually goes hand in hand with a suitable body and texture in ice creams, it is one of the most significant characteristics of an ice cream mix. From some experiments [14], the rheological characteristics of ice cream mixes containing maltitol and xylitol showed the strongest viscosity-enhancing activity when sugar alcohol was included. In addition, the addition of some additional added sugars and syrups will also increase the viscosity to some extent.

The freezing point also affects the taste of ice cream to some extent. When the freezing point is low, the texture of the ice cream will be softer, and when the freezing point is higher, it will be harder, which is caused by the difference in the ice cream crystals. Most sugars and syrups, as well as some sugar alcohols such as xylitol, lower the freezing point and give a silky taste, while some sugar alcohols such as erythritol and sorbitol raise the freezing point.

Melting points is also an important characteristic that affects the taste of ice cream. It will bring different experiences in the mouth, fast melting for a smooth and refreshing taste, while slow melting for a thick taste. Sugar and syrups, as well as some sugar alcohols such as xylitol, reduce the melting points. Some sugar alcohols, such as erythritol, increase the melting points.

3.3. Controversy over Sweeteners in Ice Cream Applications

The first controversy over sweeteners is safety. For some NNS, like aspartame, saccharin, may cause certain symptoms when ingested in excess. For some other NNS and NS, although no explicit adi values are specified, there are still certain symptoms that can occur when ingested in excess or in certain groups of people. For example, for a certain group of people who absorb sugar alcohols poorly, overindulgence in sugar alcohols is generally linked to unfavorable gastrointestinal side effects, such

as diarrhea, bloating in the abdomen, and nausea. They cause an osmotic impact and intestinal water retention, which is the cause of these negative effects [15].

In terms of flavor, some sweeteners are also controversial. Although sweeteners can achieve the sweetness of sucrose by controlling the amount added, many sweeteners also have other flavors while having sweetness, which may lead to a flavor different from traditional ice cream after the final addition into the ice cream food, which may be relatively difficult for some consumers to accept. For example, stevia glycosides may have "odors", such as bitter and metallic tastes, slow onset and lingering sweetness [16]. When applying the corresponding sweetener to replace sucrose, this is undoubtedly a challenge for consumers who are used to the taste of sucrose.

4. Conclusion

This review is mainly divided into two parts, the first part mainly introduces different kinds of sweeteners and their corresponding characteristics, and the second part discusses the application of sweeteners in ice cream. By analyzing the characteristics of different sweeteners and their application in ice cream, it is helpful for consumers to understand sweeteners to some extent, and have some rough understanding of the role of sweeteners in ice cream and the change of ice cream characteristics, which is helpful to choose the right sweetener in the food market that constantly emphasizes health to make new ice cream. Through the in-depth understanding of the characteristics of different sweeteners, appropriate changes in the composition of ice cream, help to prevent no loss of flavor and low sugar ice cream. At the same time, through the in-depth study of ADI and disease of different sweeteners, comparing safety can help us make safer food. This review can help researchers or manufacturers to have a rough understanding of the classification of sweeteners and the corresponding typical sweeteners, but the chemical structure of each sweetener, its different characteristics and safety are not comprehensive and detailed enough. The structure of ice cream is relatively complex, and different substances have different reactions. In this paper, the analysis of the changes in taste and flavor caused by the addition of sweeteners in ice cream is not comprehensive enough, and the reaction of different substances to the addition of sweeteners has not been taken into account. In addition, the combination of sweeteners has not been mentioned, and the combination of sweeteners has certain positive effects on the final production of good flavor and taste of ice cream. In the subsequent research, new sweeteners are still waiting for a progress of exploration and innovation; The differences between sweeteners such as aspartame that have been found need to be further studied and tested; In the application of ice cream and other foods, it is still necessary to explore the combination and combination of different sweeteners to achieve the best taste and flavor; Finally, the changes in taste and flavor brought about by the addition of different sweeteners need to explore different effective methods to improve and adjust, such as adjusting the proportion of fat.

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