*Review Article*

Utilization of Various Sweeteners as Sugar Substitutes in Ice Cream: A Review

ABSTRACT

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| Ice cream is frozen dessert known for its sweet taste. In response to increasing consumer demand for healthier food options, particularly those with a low glycemic index, there is a growing interest in replacing sucrose with alternative sweeteners in ice cream formulations. This review explores and compares the use of various natural sweeteners and sugar alcohols, highlighting their effects on the physicochemical properties of ice cream, including texture, melting behavior, sweetness profile, and stability. The analysis reveals that while alternative sweeteners offer promising functional and nutritional benefits, their application also presents several formulation challenges, such as off-flavors, textural changes, and altered freezing points. Therefore, sweeteners alternative requires technological innovations, including optimized processing techniques, the use of supporting ingredients, and appropriate combinations of sweeteners. This review provides valuable insights for the development of healthier ice cream products through strategic sweetener substitution. |

*Keywords: innovation, natural sweetener, sucrose, sugar alcohol,*

1. INTRODUCTION

Ice cream is a frozen dessert that is loved by everyone, from children to adults because this food has a sweet taste. The type of sweetener that is often used in ice cream products comes from sucrose sugar. The use of sugar in ice cream is about 12 to 17% of the total volume of ice cream dough (Varelaa et al., 2014). Sugar in ice cream products serves to control the sweetness and ice phase. The use of sugar can reduce the freezing point of ice cream mix so that freezing will be slower. This condition causes more air to be trapped and produces a soft texture. Sugar in ice cream formulations also serves to prevent the formation of large ice crystals during product manufacture, resulting in a soft texture (Mulyani et al., 2017). The use of sugar in food production needs to be considered because it is not only a giver of sweetness and texture but also needs to be considered from a health aspect. People are increasingly interested in reducing sugar consumption. The use of sugar or sucrose has limitations for with diabetes or obesity consumers because these types of sugar has high calories and GI (glucaemic indices). The GI content of sucrose is 65 (Qi et al., 2020). Alternatives to sucrose sugar substitutes in ice cream can be one solution to meet consumers demand that who focus on healthier food. Several studies have been conducted regarding the various uses of sweeteners to provide healthier effects such as lowering calorie content and improving the functional properties of ice cream (Arslaner and Salik 2020).

The use of sweeteners in ice cream products can use natural sweeteners such as syrup, *Stevia*, and honey or sugar alcohols such as sorbitol, maltitol, and xylitol (Popescu et al., 2024). Based on this description, it is necessary to study the use of natural sweeteners and polyols as an alternative to sugar in ice cream. This study aims to compare the effect of various types of natural sweeteners and polyols on the physicochemical characteristics of ice cream based on literature studies so that the application challenges of using these alternative sweeteners in ice cream can be known.

2. TYPES OF NATURAL SWEETENERS

**2.1 *Stevia***

*Stevia (Stevia rebaudiana* Bertoni) is a plant from the *Asteraceae* (Compositae) family that has been used as medicine and sweetener (Samuel et al., 2018). *Stevia* originated in South America, but has now been cultivated in Asia, Europe and North America (Ahmad et al., 2020). *Stevia* has been widely used in food products because it does not have teratogenic, carcinogenic, mutagenic, and toxicity effects (Momtazi-Borojeni et al., 2017). The advantage of *Stevia* compared to other artificial sweeteners is that it is more heat stable and pH resistant so that it does not give the effect of discoloration after cooking (Saharudin et al., 2020).

*Stevia* has a sweetness level 100-300 times higher than sucrose (Ahmad et al., 2020). The sweet content in *Stevia* comes from the steviol glycosides component (Ahmad et al., 2020). *Stevia* extracted with high purity can produce steviol glycosides of 95% or more (Saharudin et al., 2020). Types of steviol glycosides include stevioside, rebaudioside A, Rebaudioside D, and Rebaudioside M. Stevioside is a type of diterpene glycoside that has three glucose molecules and glucose-steviol parts (Peteliuka et al., 2021). The stevioside content in *Stevia* is available as much as 4% to 13% of all glycosides (Marcinek and Krejpcio, 2015). Rebaudioside A is a diterpene steviol glycoside that has a sweetness level 180-400 times sweeter than sugar (Kaplan and Turgut, 2019). Rebaudioside D and rebaudioside M are diterpene glycosides contained in small amounts in dried *Stevia* leaves, namely 0.2% and 0.1% (Peteliuka et al., 2021). diterpene glycosides in the form of rebaudioside D and rebaudioside M have a much less bitter after taste than Rebaudioside A (Muenprasitivej et al., 2022).

*Stevia* also contains vitamins, minerals, essential amino acids, fatty acids, and bioactive compounds such as non-glycosidic labdane diterpenes, flavonoids, phenolic compounds, crude fiber, phytosterols, chlorogenic acid, tri terpenes and hydrocarbons (Ahmad et al., 2020). These bioactive compounds provide benefits as anti-diabetes, anti-obesity, anti-tumor, antihypertension, anti-microbial, anti-caries and antioxidants (Momtazi Borojeni et al., 2017).

**2.2 Maple Syrup**

Maple syrup is a natural sweetener made by evaporating sap from maple, red maple, or black maple trees (Mellado-Mojica et al., 2016). Maple sap has a water content of about 97% and solids of 3% which are mainly sucrose sugar and small amounts of glucose and fructose (Mohammed and Mahmood, 2022). The distinctive flavor of maple syrup comes from the interaction of various compounds such as sucrose, oligosaccharides, amino acids, organic acids, minerals, phenolic and aromatic compounds (Nimalaratne et al., 2020). Maple syrup contains sucrose (96%), organic acids, minerals, vitamins, and phytochemicals (lignans, coumarins, stilbenes, and phenolic derivatives) (Ramadan et al., 2021). The use of maple as a natural sweetener is of interest because it also contains minerals and phenolic compounds that can be antioxidant, antiradical, antimutagenic, and anticancer (Nimalaratne, 2020). The physicochemical composition of maple syrup is influenced by processing methods, microbial contamination, seasonal and geographical differences, minerals and phenolics. The flavor of lighter maple syrup tends to be sweet, while darker maple syrup has a caramel flavor and contains more beneficial bioctive compounds such as phenolics (Saraiva et al., 2022).

**2.3 Honey**

Honey is one of the most widely used natural sweeteners (Kuropatnicki et al., 2018). Honey is a sweet, viscous liquid made by bees from nectar and then collected and stored as bee food. Honey is a complex solution consisting of two main components namely sugar and water (Saranraj and Sokolonski 2018). Honey contains a large amount of carbohydrates which is 95% of the total dry matter (Saha et al., 2015). The carbohydrate content of honey consists of various sugars such as fructose, monosaccharides (levulose), as well as glucose (dextrose), sucrose, maltose, disaccharides, and oligosaccharides with the percentage composition determined based on the botanical source of the flower. The components of honey contain about 80% carbohydrates (35% glucose, 40% fructose, and 5% sucrose), 20% water, and other minor constituents such as organic acids, mineral salts, vitamins, proteins, phenolic compounds (Sharma et al. 2023). Fructose is the main sugar in most honey varieties (Saha et al., 2015). Honey that has a higher fructose content has a lower glycemic index. Honey has a sweetness level 1.5 times higher than white sugar with a calorie content of 3.04 kcal/gram (Wulandari et al.,2017). Honey not only provides sweetness but also has nutritional, biological, and pharmacological effects, such as anticancer, immunosuppressive, antioxidant and antitoxin, antimicrobial, anti-inflammatory, and antimutagenic because it has bioactive substances such as vitamins, organic acids, antioxidants, and enzymes (Cheepa et al., 2022). The amount and type of acids and amino acids can affect the distinctive aroma of honey (Saha et al., 2015). Honey has a low pH of around 3.5 to 5.5 due to the presence of 0.57% organic acids that provide a slightly sour taste and protection against microbes (González-Montemayor et al., 2019). The organic acid is produced during the honey formation process by enzymes secreted by bees (Alqarni et al., 2016). Honey enzymes include invertase, α- and β-glucosidase, catalase, and glucose oxidase (Pita-Calvo and Vázquez, 2017).

**3. SWEETENER POLYOLS**

Polyols, also referred to as polyalcohols, sugar alcohols, polyhydric alcohols, alditols, or glycitols, are white solids that are naturally or industrially produced to be water soluble for use as sweeteners and thickeners in food products (Godswill, 2017). Polyols are polyhydric alcohols produced in the process of hydrogenation or fermentation of carbohydrates (Kalicka et al., 2019). Polyols are also referred to as sugar alcohols which are chemically obtained from mono and disaccharides. Polyols are naturally present in some fresh fruits (melons, berries, nectarines), dried fruits (plums, dates), and vegetables (avocados, cauli flowers, celery). The use of sugar alcohols in frozen food products such as ice cream can affect the characteristics of the product due to its ability to lower the freezing point. Sugar alcohols are able to lower the freezing point higher than disaccharides (Kilara et al., 2015).

Erythritol is a poly alcohol that naturally occurs in small amounts in fruits, vegetables, mushrooms, and fermented foods. Erythritol is naturally found in fruits such as melon, watermelon, pear, grapes, and fermented products such as cheese, soy sauce (Mazi and Stanhope, 2023). Industrial-scale erythritol production is made by enzymatic hydrolysis of starch from corn to produce glucose, then the glucose is fermented with yeast or other fungi (Godswill, 2017). Erythritol consists of only four carbon atoms and thus has the smallest molecular weight compared to other sugar alcohols (Regnat et al., 2018). This condition causes slight differences in physical and chemical properties. Erythritol has characteristics in the form of stability against acidic, alkaline, high temperature environments and a sweetness level close to sucrose with lower calories and glycemic index, (Cock et al., 2016). Erythritol has a sweetening power of about 0.7 compared to sucrose. This type of sweetener has a positive effect on health, which is safe for teeth and diabetics. The caloric value of erythritol is also low at 0.3 kcal/g (Long et al., 2023).

Xylitol is a sugar alcohol utilized as a sweetener that can also help dental health by reducing caries (Godswill, 2017). Xylitol has a lower calorie content than sucrose, which is 2.4 kcal/g with a low glycemic index (GI) of 7 (Blecharczyk et al., 2025). The characteristics of xylitol are water soluble, colorless, and thermally stable. Xylitol has hygroscopicity which allows it to absorb air from food (Asasta et al., 2024). Xylitol is naturally present in low concentrations in fruits and vegetables such as extraction in berries, pulms (Sakallioğlu et al., 2014). Industrial scale xylitol production is made by hydrolysis of xylan (hemicellulose) of hardwood or corn cobs (Godswill, 2017). Xylitol can be produced through the chemical process of xylose hydrogenation to convert sugars (aldehydes) into primary alcohols. Xylitol can also be produced through biotechnological processes such as fermentation and enzymatic

**4. CHEMICAL QUALITY OF ICE CREAM WITH THE USE OF DIFFERENT TYPES OF SWEETENERS**

The development of ice cream products with the use of various types of sweeteners as an alternative to sugar can be an important factor that not only controls the level of sweetness but also influences the characteristics of ice cream. Some alternative sweeteners used in ice cream are derived from natural sweeteners or polyols. The chemical quality of ice cream with the use of various types of sweeteners can be seen in Table 1.

Honey is a type of natural sweetener derived from animals. Increasing the concentration of honey substitution causes a decrease in the pH value of ice cream (Asminaya et al., 2022). A lower pH value can inhibit the growth of bacteria in honey, but a pH value that is too low will reduce the quality of ice cream such as producing a too sour taste. The pH parameter is a variable that shows the acidity value of a product, so if the pH is lower, it causes an increase in acidity value. The pH value of ice cream with honey substitution can decrease because honey has organic acids that can create a sour taste (González-Montemayor et al., 2019).

*Stevia* is a sweetener that is used only in small amounts. The use of *Stevia* in ice cream shows a decrease in pH value (Gençdağ et al., 2021). The decrease in pH value is attributed to the lower pH value of *Stevia* leaves. The pH value of dried *Stevia* leaves ranges from 5.95 to 6.24 (Gasmalla et al., 2014). Increased use of *Stevia* in ice cream led to an increase in protein content values but resulted in decreased values in total solids, carbohydrates, pH, and calories (Rajdivana et al., 2023). *Stevia* caused an increase in ash, protein and a decrease in calories of aloevera ice cream as the concentration of *Stevia* use increased (Rajdivana et al., 2023). Basically, dried *Stevia* leaves (per 100 g dry mass) contain 11.2-16.0 g protein, and 6.8-15.2 g dietary fiber (Abou-Arab et al., 2010).

Polyols are sugar alcohols with a low glycemic index that are used as food sweeteners. The use of sugar alcohols in ice cream in the form of erythritol and xylitol produces a lower total sugar and glycemic index than the use of sucrose in ice cream (Fuangpaiboon and Kijroongrojana, 2013). The glycemic index of ice cream with sucrose was 51.358 while the glycemic index of ice cream with erythritol and xylitol was 12.852 and 20.954, respectively. The use of a combination of alternative sweeteners to sucrose in ice cream, namely erythritol + inulin + fructose, xylitol + inulin and inulin + fructose can also reduce the glycemic index of ice cream 64% lower than sucrose ice cream (Fuangpaiboon and Kijroongrojana, 2015). The classification of glycemic index in foods consists of three groups, namely low (70) (Fuangpaiboon and Kijroongrojana, 2013).

**Table 1.** **The chemical quality of ice cream with the use of various types of sweeteners**

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| **Type pemanis** | **Formulation of pemanis** | **Physical Properties of Ice Cream** | **Additional Effect** | **References** |
| *Stevia* | *Stevia* substitution 0%, 20%, 40%, 60%, 80%, and 100% of sugar | Ash: 0.53-0.74%  Protein: 2.60-3.60%  Fat: 2.16-2.33%  Calorie: 55.14-109.13% | The concentration of sugar substitution with *Stevia* causes an increase in ash, protein and a decrease in calories in aloe vera ice cream. | Rajdivana et al., 2023 |
| *Stevia* | *Stevia* Usage 0%, 1%, 4%, 7%, 10% | pH: 6.20-6.56 | Increasing concentrations of *Stevia* use cause a decrease in the pH value. | Gençdağ et al., 2021 |
| Maple syrup | Substitution sweeteners with maple syrup 0%, 20%, 40%, 60%, 80% | Total solid: 31.26-35.14%  Carbohydrate: 20.73-24.37%  Ash: 0.91-1.49%  pH: 4.92-6.41 | Increasing the concentration of maple syrup substitution causes an increase in total solids, carbohydrate, pH, and a decrease in ash. | Saadi et al., 2022 |
| Honey | Substitution sweeteners with honey 0%, 5%, 7.5%, 10% | pH: 6.1-6.5 | The higher concentration of honey substitute causes a decrease in the pH value. | Asminaya et al., 2022 |
| Sucrose, Erythritol, inulin, fructose, xylitol | Blend sweeteners including  Sucrose  Erythritol+inulin+ fructose  Xylitol+inulin  Inulin+fructose | Total solid: 40.21-39.71%  Reducing sugar: 3.95-5.54%  Total sugar: 10.49-18.95  Glycemix index: 51.569-18.474 | The combination of sugar substitute in the form of Erythritol, inulin, fructose produces the lowest glycemic index and total solids. | Fuangpaiboon and Kijroongrojana, 2015 |

5. EFFECT OF SWEETENER TYPE ON THE PHYSICAL QUALITY OF ICE CREAM

The physical characteristics of ice cream are influenced by the ingredients that make up the ice cream formulation, one of which is sweetener. Sweeteners in ice cream can control sweetness, freezing point, and influence physical characteristics such as ice cream hardness (Syed et al., 2018). The decrease in freezing point in ice cream mix is caused by the interaction between solutes (sugar and milk salt) with water molecules to form crystals (Aukkanit et al., 2019). Sugar can prevent the formation of large ice crystals during the ice cream making process, resulting in a soft texture (Mulyani et al., 2017). The effect of various types of sweeteners on the physical quality of ice cream can be seen in Table 2.

The hardness of ice cream is one of the factors determining the texture of ice cream. Based on research, it can be seen that the use of sucrose alternatives with several types of sweeteners can increase the hardness value of ice cream. The hardness of ice cream with the use of inulin and erythritol has a higher hardness than ice cream with sucrose sweetener (Fuangpaiboon and Kijroongrojana, 2013). The hardness of ice cream also increased with the use of a combination of inulin and fructose (Fuangpaiboon and Kijroongrojana, 2015). Higher hardness may occur because erythritol, inulin, and fructose sweeteners have higher total solids than sucrose. Texture depends on binding force and viscosity (Ghaderi et al., 2020).

Viscosity or viscosity is an obstacle to hold a substance due to movement from one layer to another (Astuti and Rustanti, 2014). Increasing the concentration of *Stevia* showed an increase in viscosity but sucrose ice cream and 7% Stevia formulation showed the same viscosity value (Gençdağ et al., 2021). The increase in viscosity of *Stevia* ice cream may occur due to amphiphilic diterpene glycosides, a property of *Stevia* extracts containing stevioside and rebaudioside A, which can aggregate into micelles in the aqueous phase (Ahmad et al., 2020). Higher viscosity of ice cream can reduce air incorporation resulting in lower overrun (Tolve et al., 2024).

Overrun is the amount of air trapped in the ice cream. The lower overrun value is formed because the more viscous ice cream mix makes it difficult for air to enter (Tamauka et al., 2022). Increasing the viscosity of ice cream causes the air cel to be smaller due to increased shear force so that the air trapped in the cell is also less and results in lower overrun (Syed et al., 2018). The overrun value of ice cream with the use of *Stevia* decreases as the *Stevia* concentration increases (Gençdağ et al., 2021). Ice cream containing *Stevia* has a higher viscosity so that air is more difficult to penetrate the ice cream mix during production. This condition results in a lower overrun value. A decrease in overrun value also occurs when using honey as a sugar substitute in ice cream. The decrease in overrun value with honey substitution can occur because honey can bind water so that the viscosity increases and narrows the air space in the ice cream mix (Asminaya et al., 2022). The narrower air space can make it difficult for air to enter and be trapped. Lower overrun value compared to sucrose-sweetened ice cream was also seen in ice cream with the use of inulin, erythritol, and xylitol (Fuangpaiboon and Kijroongrojana, 2013). The use of a combination of several alternative types of sweeteners showed a decrease in overrun value compared to ice cream sweetened with sucrose and the combination of xylitol and inulin sweeteners showed the lowest decrease in ice cream overrun value (Fuangpaiboon and Kijroongrojana, 2015). The decrease in overrun value also correlates with melting power.

Overrun or the amount of air trapped in ice cream affects melting speed (Umela, 2016). A decrease in overrun value results in a melting point time that tends to be longer (Dewi et al., 2015). Increasing the concentration of honey substitution in ice cream produces longer melting power along with a decrease in the overrun value of ice cream (Asminaya et al., 2022). Melting resistance is also seen in ice cream using a combination of inulin and fructose, while ice cream with a combination of xylitol and inulin and ice cream with sucrose has the highest melting rate (Fuangpaiboon and Kijroongrojana, 2015). This condition may occur due to the higher concentration of inulin in the inulin+fructose ice cream formulation. Inulin in ice cream can form cryogels by binding water so that water molecules cannot move freely and inhibit product melting

**Table 2.** **The effect of various types of sweeteners on the physical quality of ice cream**

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| **Type pemanis** | **Formulation of pemanis** | **Physical Properties of Ice Cream** | **Additional Effect** | **References** |
| Honey | Substitution sweeteners with honey 0%, 5%, 7.5%, 10% | Overrun: 145.75-221.47%  Melting time: 60.15-60.35 | Higher concentrations of honey substitutes cause a decrease in the overrun value and result in longer melting power. | Asminaya et al., 2022 |
| *Stevia* | *Stevia* Usage 0%, 1%, 4%, 7%, 10% | Overrun: 20.63-26.74%%  Viscosity: 451.5-1.040 cp | Increasing concentrations of *Stevia* use cause a decrease in overrun values ​​and an increase in viscosity values. | Gençdağ et al., 2021 |
| Maple syrup | Substitution sweeteners with maple syrup 0%, 20%, 40%, 60%, 80% | Viscosity: 8.84-11.46 Pas  Overrun: 62.35-69.82% |  | Saadi et al., 2022 |
| Sucrose, Erythritol, inulin, fructose, xylitol | Blend sweeteners including  Sucrose  Erythritol+inulin+ fructose  Xylitol+inulin  Inulin+fructose | Hardness: 847.86-1086.28 g  Melting time: 1.40-1.51 g/min  Overrun: 26.11-30.59 | The combination of sweeteners replacing sucrose can reduce the overrun and melting time values ​​but increase the hardness of ice cream. | Fuangpaiboon and Kijroongrojana, 2015 |

**6. THE CHALLENGE OF USING DIFFERENT TYPES OF SWEETENERS AS AN ALTERNATIVE TO SUGAR**

The use of alternative sweeteners as a substitute for sucrose sugar is often done to meet the needs of consumers who want low glycemic index food products. Ice cream is one of the desserts that tends to have a sweet taste so it requires alternative sweeteners to meet consumer needs. The alternative sweetener is able to reduce the glycemic index in ice cream products but the use of alternative sweeteners gives different characteristics. The use of alternative sweeteners in ice cream has challenges that need to be faced to maximize its use in ice cream products.

The production aspect is an important aspect to ensure availability if the type of sweetener will be used on a large scale. Some types of sweeteners have limited production because the availability of these types of sweeteners is influenced by the season and the results obtained from the production process are only small. Maple syrup is one type of sweetener whose production process requires time and energy because to produce one liter of maple syrup requires forty liters (Mohammed and Mahmood, 2022).

Sensory challenges are the most important aspect of food products. The use of alternative Stevia sweeteners at high concentrations creates a bitter aftertaste with a liquorice (Saharudin et al., 2020). The level of sweetness and bitterness in *Stevia* is determined by glycoside molecules. These conditions can be affected taste perception and consumer appeal. Innovation is needed to reduce the bitter aftertaste of *Stevia*. The innovation of using a combination of steviol glycosides with high purity has a higher taste advantage compared to the use of single steviol glycosides (Samuel et al., 2018). Other innovations to reduce *Stevia* aftertaste can be microencapsulation in spray drying, the use of flavor enhancers to mask bitter aftertaste, and limiting the use of Stevia containing steviol glycosides with bitter aftertaste such as stevioside (Ahmad et al., 2020).

The challenge of product characteristics is an aspect that needs to be considered because it can affect product quality. One of the factors that affect the characteristics of ice cream products is the freezing point. A low freezing point can reduce the number of large ice crystals (Kalicka et al. 2019). A freezing point that is too low can result in ice cream that is too soft and a freezing point that is too high can result in ice cream that is too hard (Kalicka et al. 2019). The use of sugar alcohols in frozen desserts such as ice cream needs to be considered. Based on sweetness level, sugar alcohols show the strongest cooling effect resulting in a stronger aftertaste during testing (Kalicka et al., 2019). Sugar alcohols are also capable of lowering the freezing point more (Kilara et al., 2015). The use of sugar alcohols can be produced ice cream that is too soft because sugar alcohols such as xylitol and erythritol have a lower molar weight than sucrose so that they can suppress the freezing point. This condition causes ice cream with the use of xylitol to have a too soft texture so it is not recommended as a single sweetener, while the use of erythritol in ice cream can be reduced the freezing point more strongly than xylitol and produce ice cream that is very hard (Burgos et al. 2016). Alternative combinations of sweeteners are recommended to maximize the use of sugar alcohols in ice cream products. The use of an alternative sweetener combination of 4% erythritol, 7% inulin and 2.15% fructose is the potential formulation to replace 12% sucrose in coconut milk ice cream production (Fuangpaiboon and Kijroongrojana, 2015).

**7. CONCLUSIONS**

Alternative sweeteners in ice cream have the potential to meet the needs of consumers who focus on healthier food products with a low glycemic index, but the use of alternative sweeteners provides characteristics to the ice cream that can determine the success of ice cream reformulation. The use of alternative sweeteners in ice cream provides different characteristics and challenges, from the production, sensory, and physical aspects of the product. Innovations are needed to maximize the use of alternative sweeteners such as production techniques, use of supporting ingredients, and sweetener combinations.

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