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Research Article

Impact of Stevia and *Alyssum homolocarpum* Seed Gum on Some Physicochemical, and Sensory Characteristics of Ice Cream

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Abstract: Hydrocolloids and sweeteners play a crucial role in ice cream production. This study aimed to assess the substitution effects of five levels of stevia (0%, 25%, 50%, 75%, 100%) and five levels of *Alyssum homolocarpum* seed gum (AHSG) on the physicochemical and sensory properties of soft ice cream. The ice cream with 0.2% AHSG and 0% stevia had the highest solids content, while the pH remained unaffected by the substitutions. Specific gravity decreased significantly with increasing stevia concentration, whereas the substitution of AHSG had no significant effect on specific gravity. The samples containing 100% stevia had the highest melting resistance (107.18%). Additionally, an increase in gum concentration significantly boosted ice cream overrun, however, with the substitution of stevia, the overrun values remained unchanged. The sensory qualities were notably improved by stevia and AHSG. The study provides valuable insights into using alternative ingredients for enhancing ice cream quality.

Keywords: ice cream, stevia, *Alyssum homolocarpum* seed gum, overrun, sensory properties

1. Introduction

Ice cream, which is one of the most well-known and desirable food desserts, is a frozen foam consisting of interconnected fat particles, air bubbles, ice crystals and an aqueous phase (serum), in which polysaccharides, proteins, lactose and mineral salts are dispersed [1]. The global ice cream market was estimated to be worth USD 113.40 billion in 2023 and is expected to grow at a compound annual growth rate of 3.9% from 2024 to 2030 [2]. The texture of ice cream is determined by a variety of elements, including the accumulation state of fat globules, the number and size of air bubbles, the viscosity of the aqueous phase, and the size and accumulation state of ice crystals. By employing appropriate manufacturing and formulation processes, it is possible to achieve the desired quality in ice cream [3, 4]. Hydrocolloids, commonly referred to as edible gums, polysaccharides along with a small number of proteins. These substances dissolve in water and can become fully hydrated under specific conditions, resulting in thick dispersions and/or gels. Incorporating hydrocolloids into food products can enhance the water retention of gels, increase the mechanical strength of gels, and improve the stability of hybrid dispersion systems [5]. Hydrocolloids play a crucial role in ice cream production, as they are used to maintain the product's thermodynamic stability. Additionally, these additives impact texture, flavor release, creaminess, and melting qualities of the ice cream [6]. Food manufacturers are currently

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creating products with higher fiber contents and lower levels of fat, sugar, and salt. It is a result of a better understanding of how healthy eating may improve one's health and prevent certain diseases like obesity, coronary heart disease, diabetes, and certain types of cancer [7]. Today, there are a variety of artificial sweeteners such as cyclamate, saccharin, and aspartame, as well as alcoholic sugars like sorbitol and mannitol. Additionally, with advancements in processing, a new generation of natural sweeteners like stevia are being used as substitutes for sugar. These sweeteners are added to low sugar meals to provide volume and texture, and they have qualities similar to sucrose [8, 9]. In recent years, new and modified hydrocolloids and gums have been developed by chemical modifications and derivatization of natural gums, resulting in novel polymers with higher hydrophilicity [3]. *Alyssum homolocarpum* is a plant belonging to the Brassicacaea family and originating in Eurasia. The seeds of this plant are known as one of the most important sources of mucilage and gum production. The resultant gum has a wide range of applications, including thickening and emulsion stabilization in the food sector [10]. The sweetness in stevia is related to diterpene glycosidase, which is soluble in water and 300 times sweeter than sucrose. Glycosidases are organic compounds that consist of a glyconic part and a non-glyconic part. Steuzide is the most important and abundant sweetening compound of the plant and it includes 5 to 10% of the dry weight of the plant [11]. The study conducted by Herrera et al. [12] examined the release properties of frozen fructose and sucrose solutions with the substitution of xanthan, guar, and locust bean hydrocolloids. The presence of these hydrocolloids was found to reduce the ease of molecular transport in the solutions containing sucrose and fructose. The results indicated that the stabilizing function of hydrocolloids may be attributed to their ability to regulate diffusion-dependent processes such as crystallization and facilitate molecular mobility [12]. The study evaluated the sensory and textural properties of ice cream containing two flavors of coffee and mixed flavors of strawberry, apple, and vanilla in equal proportions. The product with the highest taste index score was the coffee sample, and the product with the highest color score was the mixed flavor sample. The stevia sample produced fewer calories than the sucrose sample, and it also had lower dry matter than the sucrose sample. As a result of the lower sucrose content in the stevia sample, the total acceptance value decreased as well [13]. The aim of this study is to examine the feasibility of manufacturing ice cream with stevia at five different substitution levels: 0, 25, 50, 75, and 100%. Additionally, the study will examine the impact of AHSG at five different levels: 0, 0.1, 0.2, 0.3, and 0.4%, as well as how it influences the product's physicochemical and sensory characteristics. The study investigated the impact of stevia sweetener and AHSG on some physicochemical (solid content, specific gravity, pH, melting resistance (%), Overrun (%)) and sensory characteristics of ice cream.

2. Materials and methods

2.1 *Materials*

Sterilized and homogenized cow milk (1.5% fat) and sterilized and homogenized cream (30% fat) were provided by Kale company, non-fat dry milk from Pegah Khorasan company, stevia from Tekfa company, *Alyssum homolocarpum* seeds, white sugar and vanilla were purchased from a local market.

2.2 *Extraction of Alyssum homolocarpum seed gum (AHSG)*

The *Alyssum homolocarpum* seeds were cleaned carefully to eliminate any extraneous particles. Subsequently, the seeds were subjected to extraction using deionized distilled water under specific conditions: temperature of 36 °C, pH = 4, and a water-to-seed ratio of 1 : 40 for an hour. The pH of the water was regulated using 1 M acetic acid. The solution was then refrigerated overnight, followed by extraction of the gum from the seeds using a laboratory extractor. The resulting gum was then dried in an oven at 40 °C. Subsequently, the dried gums were ground using a CNCM13ST1 grinder from Bosch, Germany, and sieved through a 100 mesh sieve [10].

2.3 *Ice cream preparation*

The ice cream formulation included 16% sugar, 49.82% milk, 28.29% cream, 0.4% stabilizer, 5.38% dry milk and 0.1% vanilla powder. For the stability of the final product, AHSG was used at a concentration of 0, 0.1, 0.2, 0.3 and 0.4%. The sample containing 100% of carboxymethyl cellulose was selected as a control sample and stevia was substituted in the ratio of 0, 25, 50, 75 and 100% in other samples. To make ice cream, milk and cream were combined in a steel container and heated to 50 °C, stirring continuedly. The mixture was then mixed for 5 minutes at 30 rpm with an electric mixer (Tefal, France), to ensure consistency. Next, the solids combination, which included sugar, nonfat dry milk, and stabilizer, was progressively added and carefully mixed before being pasteurized in a bain-marie at 69 °C for 1.5 h. Finally, it was quickly cooled down to 5 °C with the help of a freezing mixture (ice and saltwater) and kept in the refrigerator for 24 hours, and after finishing the process, vanilla powder was added. The final mixture was frozen for 40 minutes in a one-liter non-continuous ice cream maker (Delonghi, Italy). The ice cream samples were placed in containers and frozen at -18 °C until they became solid.

2.4 *Investigating the physicochemical characteristics of ice cream*

The physicochemical characteristics of ice cream were examined by determining the ice cream solids content through the method described by Goraya et al. [14]. Additionally, the pH of the mixture was measured using a pH meter at a temperature of 25 °C.

Specific gravity is determined by comparing the density of a substance to the density of water. The specific gravity of the ice cream mixture was determined using the pycnometric method at a temperature of 25 °C. The procedure involved measuring the weight of the dry and empty pycnometer (G), the weight of the pycnometer with distilled water (G_1), and the weight of the pycnometer with the sample (G_2). The specific gravity was then calculated using the following equation [14].

$$\rho = \frac{G_2 - G}{G_1 - G}$$

To measure the melting resistance of ice cream, 80 grams of the sample was placed on a wire mesh connected to a graduated cylinder at a temperature of 25 °C with a constant relative humidity of 50%. The extracted volume was measured at intervals of 10 minutes and for a total of 45 minutes [15].

$$\text{Resistance to melting (\%)} = \frac{\text{weight of unmelted ice cream}}{\text{weight of melted ice cream}} \times 100$$

The increase in volume by weight method was determined by comparing the specific volume of the ice cream mixture before freezing (M_1) with the volume after freezing (M_2), and then calculating the difference percentage using the following equation [14].

$$OR\% = \frac{M_1 - M_2}{M_2}$$

2.5 *Sensory evaluation*

Sensory evaluation for 50 ice cream samples produced in this research was performed by trained people (5 levels of gum and 5 levels of stevia) based on the nine-point hedonic method (9 excellent, 5 average and 1 weak). Sensory attributes evaluated included taste and flavor and overall acceptability.

2.6 *Statistical analysis*

The experiments were conducted using a completely randomized design, with data averages compared using Duncan’s multi-range test at a 95% confidence level and SAS software version 2.9.

3. Results and discussion

3.1 *Analysis of the effect of stevia and AHSG on physicochemical parameters*

3.1.1 *The solid content of cream*

Results revealed that the substitution of stevia sweetener significantly reduced the solid content of ice cream (Figure 1a). The control samples (without stevia) exhibited a solid content of 39.87%, whereas the treatment containing 100% stevia exhibited a solid content of 32.9%. As stevia content increased, the solid content of the treatments decreased (Figure 1a). In contrast, the solid content of ice cream containing different concentration of AHSG was almost the same. The ice cream containing 0.2% AHSG and 0% stevia had the most solid content (38.92%), whereas the treatment with 100% stevia and 0.4% gum exhibited the least solid content of 32.9 and 38.32%, respectively. Similarly, Ahmed et al. [16] substituted sugar with natural sweetener stevia in ice cream to improve its quality. They reported that ice cream containing stevia exhibited lower total solids content, compared to sucrose-based ice creams, making it a potential option for diabetic patients and individuals of all ages. On the other hand, insufficient total solids in ice cream can lead to a decline in textural quality, resulting in a coarse texture and weak body [17].

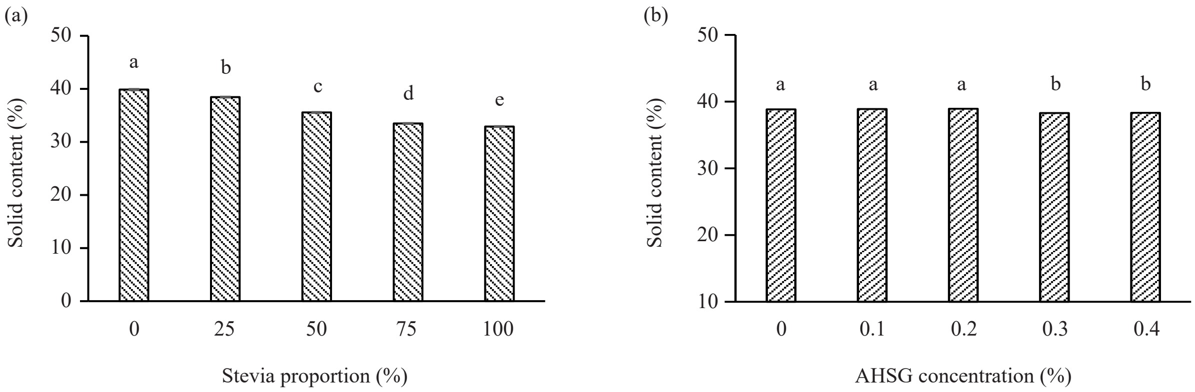

Figure 1. Effect of stevia (a) and AHSG (b) at different ratios on the ice cream solid content. Values with different letters represent significant difference within the columns ($P < 0.05$)

3.1.2 *The specific gravity of ice cream*

Results showed that the substitution of stevia significantly reduced the specific gravity of ice cream from 1.13 to 1.02 (Figure 2a). While the substitution of AHSG in the ice cream recipe did not result in a significant change in specific gravity (Figure 2b). Indeed, this measurement is often affected by the components of the mixture, such as stabilizers [18]. Additionally, the control sample (100% carboxymethyl cellulose) did not display a significant difference compared to the samples containing AHSG (Figure 2b). The substitution of carboxymethyl cellulose with AHSG does not seem to make a difference in the solid content and specific gravity of the ice cream. The specific gravity of a liquid is essential for various operations such as centrifugation, homogenization, and calculating pump power. Ice cream mixtures typically have a specific gravity ranging from 1.12 to 1.05, depending on their components. This range aligns with the results of our study. According to Figure 2a, it is evident that replacing sugar with stevia at all levels resulted in a significant reduction in the specific gravity of the ice cream mixture compared to the control sample. However, Najaf Najafi et al. [8] reported that by increasing the ratio of quince seed mucilage, the specific gravity of ice cream significantly increased.

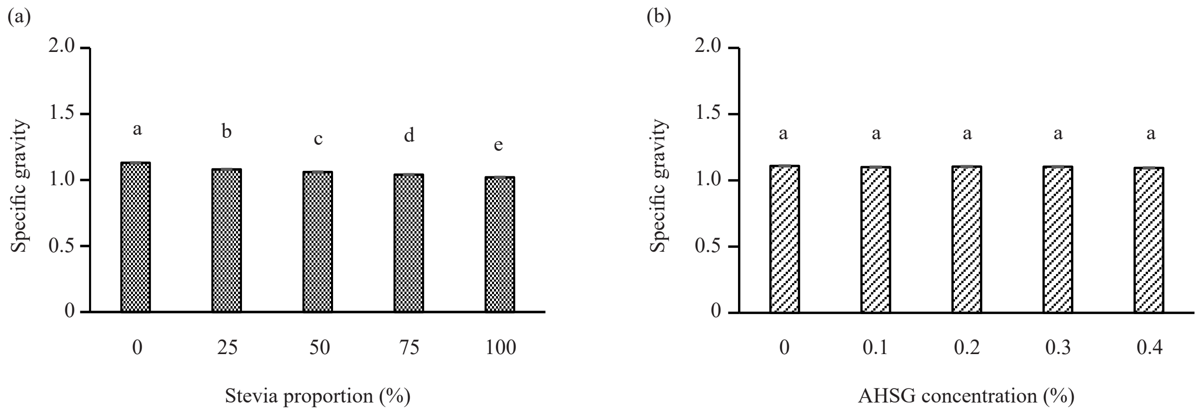

Figure 2. Effect of stevia (a) and AHSG (b) at different ratios on the specific gravity of ice cream. Values with different letters represent significant difference within the columns ($P < 0.05$)

3.1.3 *The pH of ice cream*

The pH of the ice cream did not change much after the substitution of stevia sweetener. Furthermore, different ratios of AHSG did not induce considerable change in the pH value (Table 1). It can be noted that the pH levels of the samples in this study fall within the recommended range for ice cream, which is typically between 6.4 and 6.7.

Similarly, Najaf Najafi et al. [8] reported that the addition of quince seed gum did not change the pH value of ice cream. However, Hashmi et al. [19] evaluated the physicochemical properties of ice cream containing date juice, and their findings revealed that the addition of date juice induced a lower pH value, with the control sample having the highest pH of 5.71 among the other samples.

Table 1. Effect of stevia and AHSG at different ratios on the pH of ice cream

AHSG concentration (%)	pH	Stevia concentration (%)	pH
0	6.480 ± 0.003^{a}	0	6.47 ± 0.003^{ab}
0.1	6.472 ± 0.003^{a}	25	6.46 ± 0.003^{b}
0.2	6.470 ± 0.003^{a}	50	6.48 ± 0.003^{a}
0.3	6.474 ± 0.003^{a}	75	6.47 ± 0.003^{ab}
0.4	6.476 ± 0.003^{a}	100	6.47 ± 0.003^{ab}

Values with different letters represent significant difference ($P < 0.05$)

3.1.4 *The resistance to melting ice cream*

The melting behavior of ice cream can be impacted by various factors such as overrun, emulsifier properties, total solids, ice crystal sizes, and the levels of lipids and proteins. Thermal diffusivity, which refers to the ability of heat to spread within the ice cream, is a key factor influencing its melting characteristics [20]. The results revealed that the melting resistance of ice cream was altered by the substitution of AHSG and stevia sweetener (Figure 3). Figure 3a shows that the samples containing 100% stevia had the highest melting resistance (107.18%), whereas the samples with 0% sweetener exhibited the lowest melting resistance (94.45%). In general, the melting resistance of ice cream increased with increasing stevia ratio. The replacement of carboxymethyl cellulose with AHSG in the ice cream mixture resulted in a notable change in melting resistance. Specifically, the value increased from 94.45 to 102.34% when the gum ratio was 0.4%.

When ice cream melts, it undergoes two simultaneous events: heat transmission and mass transfer. As the environment's heat gradually penetrates the ice cream, it causes the crystals to melt. The water formed from the melted ice crystals mixes with the non-frozen serum phase, creating a diluted combination that flows through the structure of the ice cream before dripping and flowing [20, 21]. Thermal diffusivity, which refers to the ability of heat to spread within the ice cream, is a key factor influencing its melting characteristics [20]. Our results show that the substitution of gum resulted in a higher viscosity, which prevents the water molecules from easily moving among the combined molecules and makes them immobile. Therefore, the substituted gum enhanced the melting resistance of the ice cream at all ratios. Javidi et al. [22] found that the addition of gum increased the melting resistance of ice cream samples by increasing the viscosity of the system which is consistent with the results obtained in this study. The melting behavior of ice cream is influenced by various factors, including overrun, emulsifier properties, total solids, ice crystal sizes, and the levels of lipids and proteins, while formulation components, consistency coefficient, volume of the ice phase, and the volume and type of fat globules also play a crucial role in determining its melting speed [23].

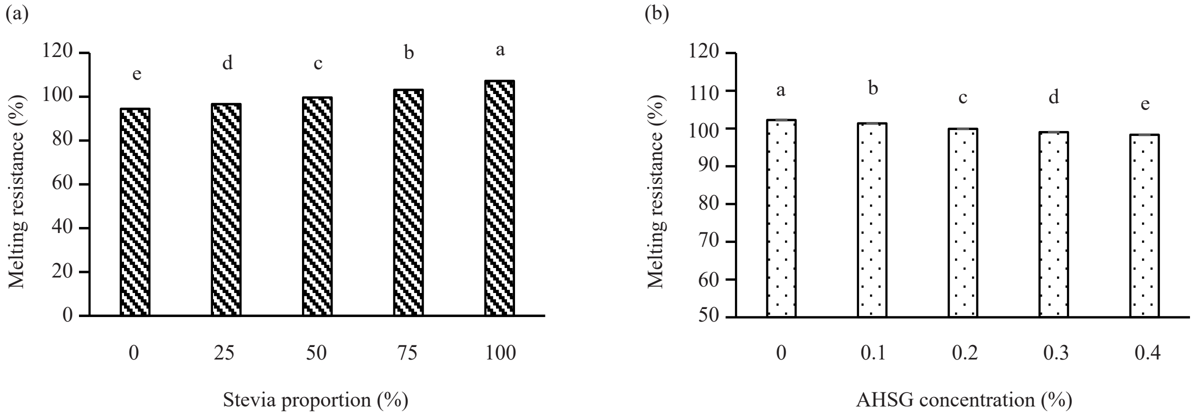

Figure 3. Effect of stevia (a) and AHSG (b) at different ratios on the melting resistance of ice cream. Values with different letters represent significant difference within the columns ($P < 0.05$)

3.1.5 *The overrun of ice cream*

The results revealed that the substitution of AHSG increased the overrun of ice cream and the highest overrun (54.28%) was observed at 0.4% gum concentration. The smallest value of overrun was observed for control treatment (51.80%) (Figure 4b). Javidi et al. [22] showed that the viscosity of the liquid plays a crucial role in achieving the desired overrun. It is essential to have a specific viscosity value in order to properly incorporate air into the liquid. If the liquid is too viscous, it becomes difficult to beat and incorporate air. On the other hand, if the liquid is not viscous enough, the film between the air bubbles drains too quickly, leading to coalescence of the bubbles. This may explain why gum-containing mixes often result in more overrun compared to control mixes [22]. Similarly, Campos et al. [7] also reported that the overrun of ice cream was increased for the formulation with a higher amount of Chia mucilage. Increasing the overrun of ice cream is critical because it affects the textural characteristics of the ice cream. The ideal increase in overrun should be carefully considered to avoid the appearance of cold and wet bodies in the ice cream or the formation of a foam-like texture. It is important to take into account customer acceptability and economic constraints when determining the most suitable volume increase [24]. Results showed that the substitution of stevia had no significant influence on the ice cream overrun (Figure 4a). Hashim et al. [19] also found that increasing the amount of date juice increased the overrun, however, this difference was not statistically significant. Contrary to our results, Alizadeh et al. [25] evaluated the influence of stevia on the physicochemical and sensory features of soft ice cream and found that with increasing stevia concentration, the overrun also increased. Kurt et al. [26] reported that the overrun values of samples did not change considerably when the concentration of gum tragacanth in ice cream increased. The overrun value plays a crucial role in determining the color, structure, sensory perception, texture, and melting characteristics of ice cream [27].

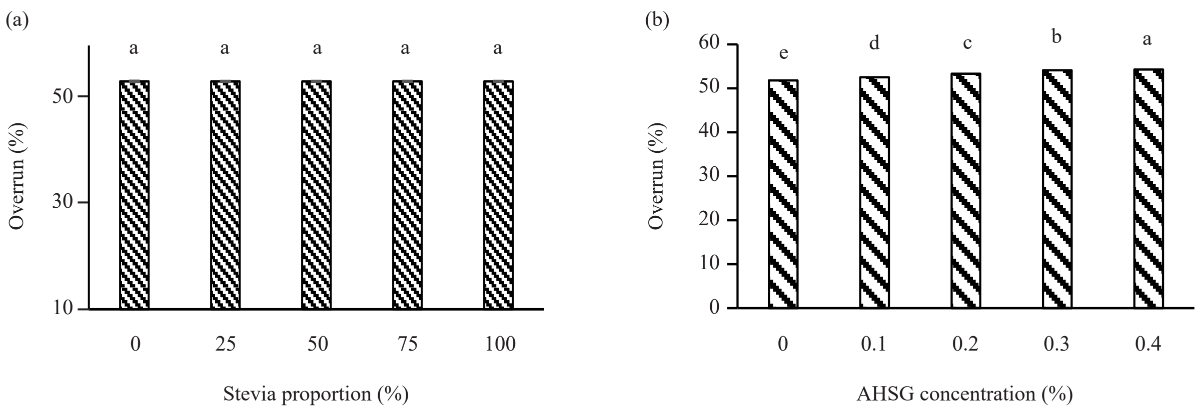

Figure 4. Effect of stevia (a) and AHSG (b) at different ratios on the overrun of ice cream. Values with different letters represent significant difference within the columns ($P < 0.05$)

3.2 *Analysis of the effect of stevia and AHSG on the sensory properties of ice cream*

Table 2 shows the average scores of sensory properties such as aroma, taste, and overall acceptability with different concentrations of stevia and AHSG. The substitution of stevia considerably changed the flavor and taste of ice cream samples. As previously stated, the control sample without stevia received the highest sensory assessment score among the stevia-containing samples, with an average of 8.86. In other words, increasing the concentration of stevia sweetener from 25% to 100% caused a considerable decline in the flavor of ice cream, so the sample containing 100% stevia had an average of 6.06 compared to the control treatment. Results also indicated that the substituting of gum did not significantly affect the organoleptic characteristics of ice cream and it can be used in the formulation of ice cream. Definitely, the texture and taste of ice cream are the most important acceptance factors from the consumer's point of view. Substitution of stevia at a 100% concentration did not enhance the taste or flavor of the ice cream. However, when stevia was used at a 25% concentration, it improved the quality of the ice cream and made it more comparable to the control sample in terms of flavor, aroma scores, and overall acceptability.

Table 2. Effect of stevia (a) and AHSG (b) at different ratios on the sensory properties of ice cream

Stevia concentration (%)	Taste and flavor	Overall acceptability	AHSG concentration (%)	Taste and flavor	Overall acceptability
0	8.86 ± 0.02^{a}	8.34 ± 0.02^{a}	0	8.86 ± 0.02^{a}	8.34 ± 0.02^{a}
25	8.40 ± 0.02^{b}	7.69 ± 0.02^{b}	0.1	8.77 ± 0.02^{ab}	8.16 ± 0.02^{c}
50	8.04 ± 0.02^{c}	7.34 ± 0.02^{c}	0.2	8.73 ± 0.02^{b}	8.21 ± 0.02^{b}
75	7.44 ± 0.02^{d}	7.11 ± 0.02^{d}	0.3	8.78 ± 0.02^{ab}	8.35 ± 0.02^{a}
100	6.06 ± 0.02^{e}	5.60 ± 0.02^{e}	0.4	8.81 ± 0.02^{ab}	8.29 ± 0.02^{ab}

Values with different letters represent significant difference ($P < 0.05$)

4. Conclusion

The use of stevia sweetener resulted in a significant decrease in the solid content and specific gravity of the ice cream. However, substituting carboxymethyl cellulose with AHSG did not significantly affect these properties. The substitution of AHSG and stevia sweetener altered the melting resistance of the ice cream, and the highest ratio of stevia led to the highest melting resistance, while samples without stevia exhibited the lowest melting resistance. The substitution of AHSG improved the overrun of the ice cream as a consequence of viscosity enhancement. The viscosity of the liquid plays a crucial role in achieving the desired overrun. No significant difference was observed between overrun levels with and without stevia. Despite being a natural sweetener, stevia at higher concentrations can deteriorate the flavor and taste as well as the overall acceptability of the ice cream samples. However, the substitution of AHSG as a natural hydrocolloid did not significantly impact the sensory characteristics of the ice cream. With the increasing demand for healthier foods and advancements in technology, a dairy product with an optimal texture and sensory attributes can be produced. The ice cream market is shifting to sugar-free options with superior texture and taste, while natural sweeteners like stevia may help reduce disease risk.

Conflict of interest

The authors declare they have no conflict of interest.

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