

ORIGINAL RESEARCH PAPER

EVALUATION OF PHYSICAL, CHEMICAL, AND SENSORY CHARACTERISTICS OF ICE CREAM CONTAINING *GRACILARIA CORTICATA* (RED MACROALGAE) DURING STORAGE

Sara Akhoundi, Sepideh Bahrami*, Maryam Moslehishad

Islamic Azad University, ShQ.C., Department of Food Science and Technology, Shahr-e Qods, Iran

*Corresponding author: sepideh.bahrami@iau.ac.ir

Received: June, 19, 2026

Accepted: September, 10, 2026

Abstract: The *Gracilaria corticata* (red macroalgae) is a valuable source of nutrients for producing functional food products. This study aims to investigate how different concentrations of *Gracilaria corticata* affect the physical, chemical, and sensory properties of ice cream during a 60-day storage period. In this study, powders from *Gracilaria corticata* were used at concentrations of 0, 0.5, and 1 % in ice cream preparation. Results showed that adding algae powder significantly increased dry matter, protein, overrun, total phenolic content, and antioxidant activity ($p < 0.05$), while it did not significantly change carbohydrate, fat content, and melting rate ($p \geq 0.05$). Despite their acidity, samples with algae powder had a higher pH than the control, although pH decreased and acidity increased during storage ($p < 0.05$). The powder reduced the melting rate and altered color properties, with L* and a* decreasing and b* increasing ($p < 0.05$), although storage time did not significantly affect color ($p \geq 0.05$). Sensory evaluation indicated that flavor and aroma scores increased, while color scores decreased ($p < 0.05$). Storage time did not significantly impact flavor and aroma ($p \geq 0.05$), but it did reduce other sensory parameters ($p < 0.05$). Overall, the addition of 0.5% macroalgae of the species *Gracilaria corticata* could be acceptable, considering the product's physicochemical properties and consumer acceptance.

Keywords: functional food, *Gracilaria corticata*, ice cream, macroalgae, sensory

INTRODUCTION

One of consumers' most important demands is the development of new products with improved nutritional and quality characteristics [1]. In addition to meeting consumer demands, foodstuffs should also have natural properties and health benefits [2]. In this regard, using food supplements derived from natural sources is an excellent solution to meet these needs [3]. From this point of view, macroalgae, as a complementary additive, can be effectively used in the development of new foodstuffs due to their valuable, interesting components and diverse applications [4 – 6]. Among macroalgae, *Gracilaria corticata* is a good and diverse source of beneficial compounds [7, 8]. On the other hand, dairy products such as ice cream have high nutritional value and play an essential role in the diet. They are widely consumed worldwide, and their beneficial properties can be enhanced by adding algae [1, 3, 9, 10].

Algae, known as "superfoods", are a large group of unicellular or multicellular organisms. They are the most abundant photoautotrophs in diverse habitats such as water, land, and extreme conditions. However, they are mainly aquatic and can be found in freshwater ecosystems or the sea. There are also small microscopic forms (microalgae) and large macroscopic forms (macroalgae) [8, 11 – 13].

Macroalgae, also known as seaweed, are a group of multicellular algae that are divided into three categories: red, brown, and green algae based on their color [10, 14 – 16]. Macroalgae are a premium nutrient base containing higher amounts of macro- and micronutrients and bioactive molecules, including vitamins, proteins, minerals, unsaturated fatty acids, carbohydrates, carotenoids, amino acids, lipids, and dietary fiber. These components are biologically active and commercially valuable. Macroalgae can be used as a low-calorie food, gelling agent, thickener, food additive, thickening agent, stabilizer, and emulsifier [17 – 19].

Gracilaria corticata, belonging to the family *Gracilariaceae* and the order *Gracilariales*, is a large red algae and one of the most dominant seaweeds in the world [7, 20]. Protein, calcium, magnesium, and other nutrients are abundant in these algae, and they include a variety of physiologically active chemical compounds like phytochemicals that have a wide range of applications, particularly in the food industry. They have antioxidant, antimicrobial, antidiabetic, heart protection, stomach, and liver protection activities, among others [7, 13, 18, 21].

Ice cream is a frozen dessert that is widely enjoyed and popular due to its beneficial properties, especially its cooling effect on hot days [22 – 25]. Its composition varies but typically includes milk, sweeteners, hydrocolloids, emulsifiers, flavorings, and coloring agents. Rich in protein, fat, carbohydrates, minerals, and vitamins, it is a nutrient-dense, high-energy food [23, 26, 27]. Ice cream also has the potential to be enhanced and diversified by adding various healthy ingredients [9, 28].

Therefore, it seems that the use of macroalgae as a natural source with nutritional and functional properties can improve the content of their compounds in various foodstuffs such as ice cream, bring health benefits to the consumer, and make them become value-added products, which is a very interesting basis for the development of new food products. However, more studies are needed in this field. The purpose of this research is to prepare ice cream enriched with *Gracilaria corticata* macroalgae and to investigate the physicochemical and sensory characteristics of this product.

MATERIALS AND METHODS

Materials

In this research, milk, and cream from the Mihan company (Iran), skim milk powder from the Pegah company (Iran), the stabilizer-emulsifier compound from the Roberte company (France), sugar from the Golha Company (Iran), vanillin from Qutbi Company (Iran), phenol phthalein, sodium hydroxide, sulfuric acid, boric acid, hydrochloric acid, Folin-Ciocalteu reagent, and DPPH radical from Merck company (Germany), 96 % ethanol and methanol from Pars company (Iran) and standard gallic acid were purchased from Sigma Aldrich Company (USA). *Gracilaria corticata* macroalgae powder was obtained from the Biotechnology Research Institute of Agricultural Jihad in Northwest Iran.

Ice cream production

The ice cream formulation included 10 % fat, 15 % sugar, 11 % skim milk powder, 1 % stabilizer-emulsifier mixture, and 0.1 % vanillin as a flavoring. Ice cream was produced using the method of Ganesan and Shanmugam with some modifications [29]. After weighing, the milk and cream were blended until a 10 % fat content was reached. The fat-milk mixture was then heated to 50 °C and stirred regularly. Next, a blend of dry ingredients (sugar, vanilla, milk powder, emulsifier, and stabilizer mixture) and varying percentages of *Gracilaria corticata* algae powder (0, 0.5, and 1 %) was added and thoroughly mixed with a mixer. The resulting mixture was pasteurized at 80 °C for 25 seconds. After pasteurization, the mixture was rapidly cooled and matured at 4 °C for 24 hours. Ice cream was then frozen in a non-continuous ice cream machine for 35 minutes and filled into 120 g glass containers with a height of 5 cm. Production samples were stored in a freezer at -18 °C until testing.

Physicochemical analysis of the ice cream samples

For dry matter assessment, the method of Erem *et al.* was used with a slight modification. 3- 4 g of ice cream sample was weighed and placed on aluminium foil [30]. The foil, along with the sample, was placed in a vacuum oven at 102 °C for 4 h. The sample was taken out of the oven, and after cooling in the desiccator, it was weighed immediately. The value of dry matter of the sample was calculated using equation (1).

$$\text{Value of dry matter [\%]} = \frac{\text{Weight of dried sample}}{\text{Initial weight of the sample}} \times 100 \quad (1)$$

All samples' proximate analyses were carried out in compliance with official procedures. The amount of protein was ascertained using the Kjeldahl technique. The Soxhlet extraction method was employed to measure the fat value. The Fehling technique was used to determine the total sugar [31].

Using the pH-meter digital model pH 827 (Metrohm, Switzerland), the pH of the samples was determined [24].

The acidity of ice cream samples in the presence of phenolphthalein reagent was measured by titrating with 0.1 N NaOH until a slight pink color developed, and the acidity was calculated according to lactic acid percentage (% LA) based on equation (2) [32].

$$\text{Acidity [\%]} = \frac{0.009 \times \text{volume used of } 0.1\text{N NaOH (mL)}}{\text{Weight of Sample (g)}} \times 100 \quad (2)$$

To measure the overrun, the weight method was used by comparing the weight of a specific volume of ice cream. In this way, samples were taken and weighed from the sample mixture before and after freezing in the ice cream maker (Moulinex- type A85, Italy). Then, using equation (3), the overrun was calculated [33].

$$\text{Overrun} = \frac{\text{Sample weight before freezing} - \text{Sample weight after freezing}}{\text{Sample weight after freezing}} \times 100 \quad (3)$$

To measure the percentage of ice cream melting resistance, Bajestani *et al.*'s method was used with some modifications [3]. A quantity of 30 g of the ice cream sample was poured into the Buchner funnel immediately after the completion of the freezing stage, and the funnel was placed in the mouth of a dry Erlenmeyer flask, which had been previously weighed. Then it was transferred to the incubator at 25 °C, and after 15 min, the amount of melted ice cream in the Erlenmeyer flask was weighed.

The color parameters of the ice cream samples were evaluated using the Hunter Lab device (ColorFlex EZ, Germany) and based on three factors : L^* , a^* , and b^* [30]. Three points were used to quantify each sample's L^* (lightness : 0 = black, 100 = white), a^* (greenness (-), redness (+)), and b^* (blueness (-), yellowness (+)) factors.

For Total phenolic content (TPC), 0.5 to 1 g of ice cream samples were extracted by vortexing with mechanical shaking for 4 hours, and finally sonication for 20 min with 50 mL of methanol. The methanolic extract was filtered, and filtered and the supernatant was tested. TPC was measured by the Folin-Ciocalteu reagent according to the method of [6]. In this way, 0.5 mL of ice cream extract and 0.1 mL of 0.1 mL of 0.5 N Folin-Ciocalteu reagent were mixed and placed at a temperature of 25 °C for 15 min. After adding 2.5 mL of saturated sodium carbonate and letting it sit at a temperature of 25 °C for 0.5 h, a spectrophotometer (Shimadzu UV-1601, Japan) was used to measure the absorbance at a wavelength of 760 nm. The total phenolic content was determined using gallic acid equivalents (mg GAE/kg).

The antioxidant capacity of the samples was measured using DPPH (1,1-diphenyl-2-picrylhydrazyl) according to the procedure described by Szmejd *et al.* [34]. To do this, 3 mL of sample extract was incorporated into 3.9 mL of freshly obtained 0.1 mM DPPH radical solution in 80 % methanol and stirred. After 30 min of dark storage at 20 °C, the absorbance of the samples was determined at 517 nm by a UV-Vis spectrophotometer (Shimadzu UV-1601, Japan).

10 trained evaluators assessed the sensory characteristics of ice cream using the 7-point hedonic method, evaluating flavor, odor, color, melting rate, coldness, and overall acceptance [2, 30, 35, 36]. The samples were rated on a scale of like very much (7), like moderately (6), like slightly (5), neither like nor dislike (4), dislike slightly (3), dislike moderately (2), and dislike very much (1).

All experiments were performed in triplicate. The findings of this study were evaluated with SPSS statistical software version 22. Statistical differences in the experimental groups were analysed using a one-way analysis of variance (ANOVA) followed by Duncan's post hoc test. $p < 0.05$ values were considered statistically significant. Excel 2013 (Microsoft Office) software was used to draw graphs.

RESULTS AND DISCUSSION

The dry matter values of the samples are given in Table 1. The results showed that adding *Gracilaria corticata* macroalgal powder to ice cream significantly increased dry matter content ($p < 0.05$). The ice cream containing 1 % powder had the highest dry matter content, while the control ice cream had the lowest. Due to the presence of protein, fiber, and minerals in large amounts in *Gracilaria corticata* algae, the increase in dry matter due to the rise in *Gracilaria corticata* algae powder concentrations is related to this [7, 37, 38]. Similar results were observed in the research of Agustini *et al.* in the dry matter of ice cream supplemented with *Spirulina platensis* algae powder [37]. Additionally, the results of this research were consistent with the findings of Boyanova *et al.*'s study. They stated that incorporating *Spirulina platensis* algae in all concentrations into ice cream enhanced the dry matter of ice cream [22]. Overall, all of the samples' dry matter met the standards set by the National Standardized Agency. The maximum dry matter value for ice cream is 42 %; if it exceeds this, the weight and humidity of the products may be impacted [37]

The results of the proximate composition analysis for ice cream samples are shown in Table 1. In terms of protein, there was a significant difference between the samples ($p < 0.05$). The highest protein value was assigned to ice cream containing 1 % *Gracilaria corticata* macroalgae powder, and the lowest value was assigned to control ice cream. The reason for the increased protein value of samples containing *Gracilaria corticata* macroalgae powder compared to the control sample is the presence of a notable amount of protein (21 %) in *Gracilaria corticata* macroalgae [7]. The findings of the present study were in agreement with the other results [3, 22, 37, 39]. Regarding fat and sugar, there was no significant difference between the samples ($p \geq 0.05$). The highest fat and sugar values were assigned to ice cream containing 1 % *Gracilaria corticata* macroalgae powder, and the lowest values were assigned to the control ice cream.

Table 1. The effect of “*Gracilaria corticata*” algae powder on the dry matter value and proximate composition values of ice cream

Amount of algae powder [%]	Chemical composition [%]			
	Dry matter	Protein	Fat	Sugar
0	35.56 ± 0.15 ^c	2.82 ± 0.21 ^c	7.55 ± 0.05 ^a	23.50 ± 0.30 ^a
0.5	36.0 ± 0.20 ^b	3.02 ± 0.19 ^b	7.56 ± 0.16 ^a	23.50 ± 0.10 ^a
1	36.47 ± 0.05 ^a	3.40 ± 0.18 ^a	7.58 ± 0.08 ^a	23.52 ± 0.12 ^a

Numbers in each column that do not have the same letters have a significant difference ($p < 0.05$).

Figure 1 shows the effect of different concentrations of *Gracilaria corticata* algae powder on the pH changes of ice cream samples during the 60-day storage period. The comparison of the average data showed that as the percentage of different concentrations of *Gracilaria corticata* algae increased, the pH of the ice cream samples also increased. However, this difference was statistically significant only on the 20th day of storage ($p < 0.05$). The increase in the pH of different ice cream samples can be attributed to the alkaline pH of *Gracilaria corticata* [38]. The results of this study conflicted with the findings of other researchers. They stated that as the levels of *Spirulina* algae increased, the pH level decreased [39, 40]. On the other hand, the significance of the difference on the 20th day of storage and the non-significance on the other days of storage indicate the

gradual and transient effect of algae on pH, which reaches its maximum in a certain interval. These changes are probably related to algal composition, chemical reactions, and the dynamics of storage processes.

According to another part of the results, the pH of different ice cream samples decreased significantly with the increase in storage time ($p < 0.05$). The transformation of sugar or starch molecules into acids may be the cause of the pH drop during storage [32]. In addition, the production of lactic acid by psychrophilic and lactic acid bacteria (LAB) during storage may have contributed to the decline in pH [41]. The findings of the present study were consistent with the results of Mudannayake *et al.*'s study [35]. They reported that with enhanced storage time, the pH of different ice cream samples (samples containing *Kappaphycus alvarezii* algae and samples without *Kappaphycus alvarezii* algae) diminished.

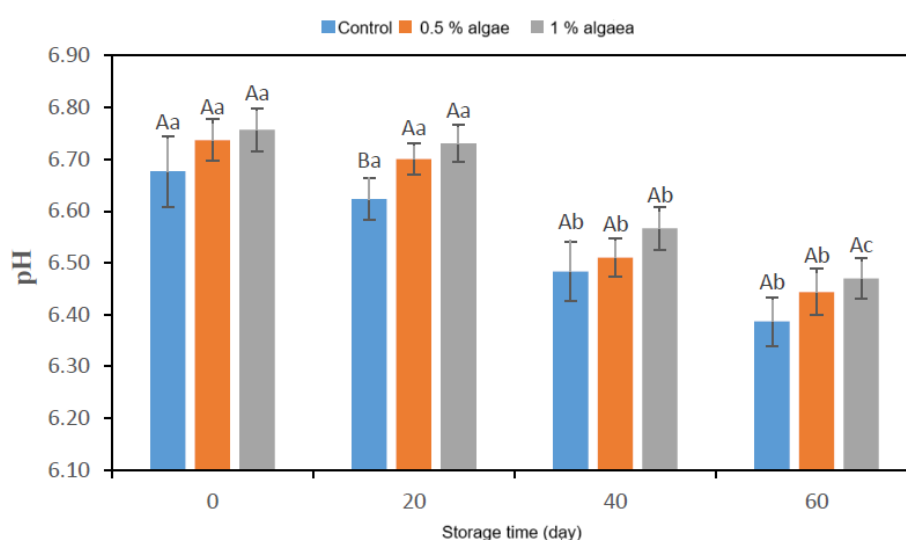


Figure 1. Changes in pH of different ice cream samples during storage

Dissimilar lowercase letters indicate significant changes in the pH of each treatment during the storage period ($p < 0.05$). Dissimilar capital letters indicate significant changes in the pH of different treatments at the same point in the storage period ($p < 0.05$)

Figure 2 exhibits the mean values for the acidity of *Gracilaria corticata* algae powder-enriched ice cream. As can be seen, at the same storage time, the acidity of ice cream samples containing *Gracilaria corticata* algae powder was lower than the control sample, although this difference was not statistically significant ($p \geq 0.05$). As mentioned, by adding *Gracilaria corticata* algae powder to ice cream, the pH of the samples increased. Therefore, the reduction of acidity in samples enriched with algae was expected. The results of the current investigation are consistent with the earlier work of Mudannayake *et al.* [35]. They checked the effect of different concentrations of *Kappaphycus alvarezii* seaweed powder on ice cream features. They deduced from their investigations that adding *Kappaphycus alvarezii* seaweed powder to ice cream reduced acidity. On the other hand, the findings of this research conflicted with those of other studies [22, 39, 40]. For instance, Malik *et al.* reported the acidity of ice creams supplemented with *spirulina* powder to be between 0.20 and 0.25 % lactic acid [40]. The reason for the enhancement in the acidity of ice cream containing *Spirulina* was attributed to the presence of high amounts of protein and minerals in this alga. Similar outcomes were observed in the

research of Boyanova *et al.* on the acidity of ice cream enriched with *Spirulina platensis* algae powder [22]. Jadhav and Chawla also observed enhanced acidity in ice creams supplemented with spirulina algae powder [39].

According to another part of the results, the acidity of different ice cream samples significantly increased with the increase in storage time ($p < 0.05$). The decrease in pH during storage may be the cause of the rise in acidity. These results are consistent with the findings of Singh *et al.* [41].

For ice cream, the pH value is crucial for preserving the stability of the mixture [42]. Typically, ice cream has a pH of 6 - 7. The quantity of acids present in any ice cream sample is measured by its acidity. The normal ice cream acidity is 0.198 % [32]. Excessive pH makes the protein soluble, which weakens the emulsion stability. Furthermore, excessive acidity is undesirable since it inhibits development, thickens the ice cream's texture, and produces disagreeable tastes [42]. Since, in the present research, pH and acidity values are within acceptable ranges, *Gracilaria corticata* algae powder has great potential in the dairy industry for fortifying ice cream.

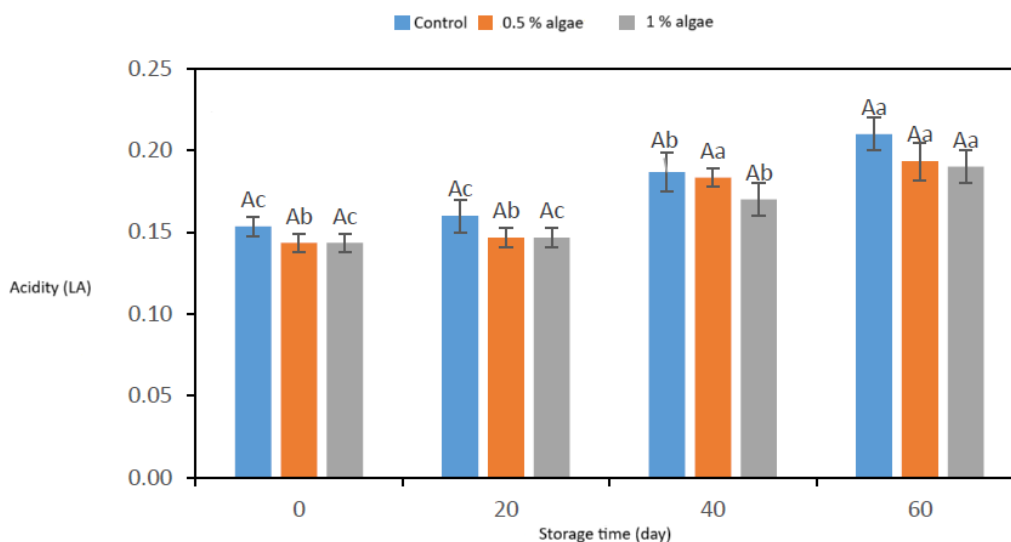


Figure 2. Changes in the acidity of different ice cream samples during storage
Dissimilar lowercase letters indicate significant changes in the acidity of each treatment during the storage period ($p < 0.05$). Dissimilar capital letters indicate significant changes in the acidity of different treatments at the same point in the storage period ($p < 0.05$)

Overrun is one of the parameters that affect the quality of the product [22]. In addition, one of the most crucial factors in the manufacturing of ice cream is overrun, which can impact the financial gain. The amount of earnings increases with the overrun level [42]. This parameter refers to the increased volume of the ice cream mixture resulting from the incorporation of air during the mixing and freezing processes within an ice cream maker [3, 37]. As seen in Figure 3, adding *Gracilaria corticata* powder significantly increased the amount of overrun of ice cream ($p < 0.05$). The highest amount of overrun (45 %) is related to the sample containing 1 % *Gracilaria corticata* powder, and the lowest (24 %) is related to the control sample. Protein can make ice cream softer and more consistent. When *Gracilaria corticata* powder is incorporated during homogenization, the foam volume produced can be higher than when it is not incorporated. Incorporating protein-

rich ingredients into ice cream may result in more air being trapped inside the dough, which would raise the volume of the foam [37]. The presence of compounds such as polysaccharides in *Gracilaria corticata* can increase the viscosity of the mixture. A higher viscosity allows air bubbles to be held more effectively in the ice cream structure, which helps to increase the overrun [4]. On the other hand, polysaccharides (gums) extracted from *Gracilaria corticata* algae have emulsifying and stabilizing attributes, which affect the increase of ice cream overrun [4, 43]. Overrun's changes in the present study were similar to the findings of other researchers [3, 22, 37, 40]. For example, Malik *et al.* reported the overrun of ice creams containing *spirulina* powder between 90.6% and 0.95%. The reason for the increase in the overrun of ice cream supplemented with *spirulina* was attributed to the surface-active features of the protein and fat content in microalgae [40]. Similar results were observed in the study of Bajestani *et al.* in ice cream containing *Spirulina platensis* algae biomass [3]. Agustini *et al.* considered the high protein content of *Spirulina platensis* as the reason for the increase in the amount of overrun in ice cream containing this alga [37]. Boyanova *et al.* enhanced the overrun of ice cream enriched with *Spirulina platensis* because of its high ability to foam and emulsify the lipids and proteins in algae, which aids in creating and maintaining dispersed gas, or integrated air [22]. Therefore, as mentioned in the review of sources, *spirulina* algae contain protein and fat, which may explain the increased overrun content of ice creams containing this alga. In the present study, the presence of protein in *Gracilaria corticata* algae is considered to be one reason for increasing the moisture content of ice cream. In addition, the presence of carbohydrates in this alga increases the moisture content of ice cream.

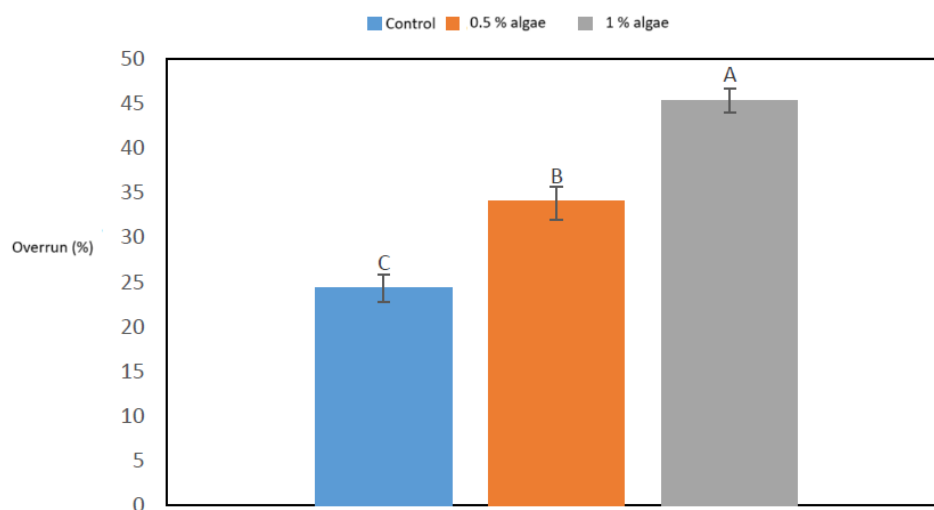


Figure 3. The effect of adding *Gracilaria corticata* algae powder on the amount of overrun in ice cream

Dissimilar letters indicate significant differences ($p < 0.05$)

One of the crucial characteristics of frozen dairy goods is the meltdown [32]. It is influenced by some elements, such as the amount of air added, ice crystals, fat globule networking, amount of product water, ice cream mix composition, and consistency of the ice cream mix [44 – 46]. For consumers, the melting rate is crucial since rapidly melting ice cream might result in an unfavourable experience when consumed [47]. In addition,

fast-melting ice cream is less resilient to heat shock, but high-quality ice cream melts more slowly [32].

According to Figure 4, by adding *Gracilaria corticata* macroalgae powder to the ice cream formulation, the melting rate of the ice cream was significantly reduced ($p < 0.05$). In other words, the melting resistance of ice creams enriched with *Gracilaria corticata* algae powder increased compared to the control ice cream. The reason for the decrease in melting rate with the addition of *Gracilaria corticata* algae powder can be attributed to the presence of compounds that have a high water absorption capacity and cause an increase in viscosity [7, 38]. Increasing the number of carbohydrates and proteins, or in other words, hydrophilic functional groups, converts more free water into water of hydration. This, in turn, increases the viscosity in the unfrozen phase of ice cream and enhances its resistance to melting. Additionally, salts also contribute to the resistance to melting by increasing the stability of the emulsion [47]. Thus, more time is required for the water to diffuse in this phase, as well as its flow from the inside to the outside of the ice cream, and then drip through the holes in the metal mesh used in the experiment [48]. Another reason for the increased resistance to melting ice cream can be attributed to the increase in the overrun of ice cream. The results of this research were aligned with the findings of other studies. Malik *et al.* stated that the inclusion of *Spirulina* algae powder noticeably decreased the melting rate of ice cream samples.

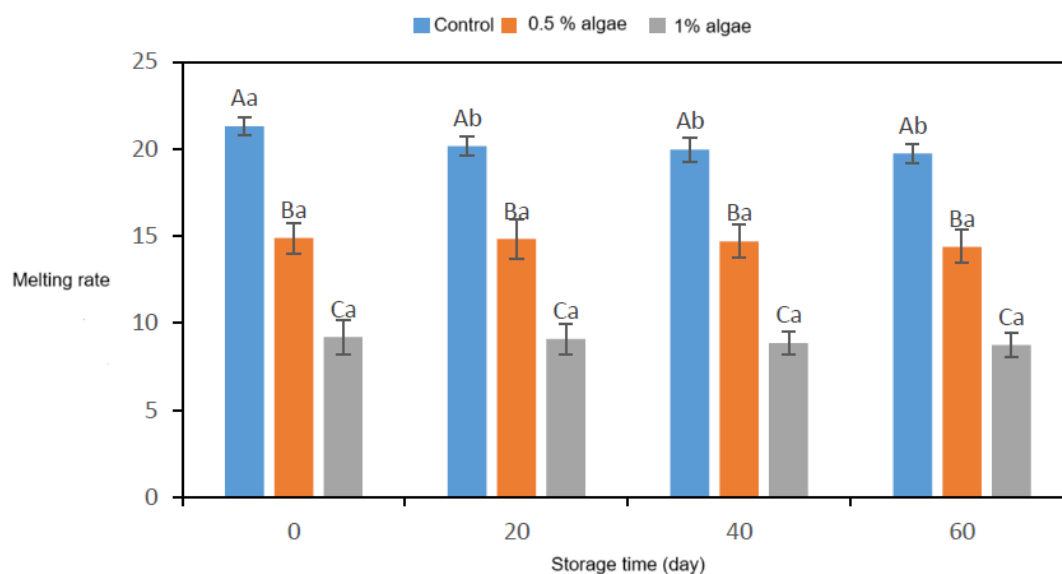


Figure 4. Changes in the melting rate of different ice cream samples during storage

Dissimilar lowercase letters indicate significant changes in the melting rate of each treatment during the storage period ($p < 0.05$). Dissimilar capital letters indicate significant changes in the melting rate of different treatments at the same point in the storage period ($p < 0.05$)

The reason for these results was attributed to the water, protein, and fat absorption capacity of *Spirulina* algae [40]. Additionally, *Spirulina*'s high protein value might help stabilize the air cells and increase their melting resistance. Similar outcomes were found in the study of Boyanova *et al.* in ice cream containing *Spirulina platensis* algae powder [22]. Agustini *et al.* observed that high levels of *Spirulina platensis* algae powder

incorporation raised the melting resistance of ice cream samples [37]. Jadhav and Chawla obtained similar results and stated that the melting resistance of ice cream was enhanced by increasing the amount of *Spirulina* algae powder [39]. Bajestani *et al.* also reported that as the level of *Spirulina platensis* algae biomass increased, the resistance to melting of ice cream was enhanced [3]. During the storage period, the melting rates of ice creams did not significantly decrease ($p \geq 0.05$).

One of the main factors determining whether a product is accepted or rejected by consumers is its color [32]. The L^* parameter represents the amount of blackness and whiteness of the sample. Parameter a^* shows the intensity of the green-to-red color of the sample, and parameter b^* also shows the intensity of the appearance of blue or yellow color in the sample [30]. Data related to the color of ice cream enriched with *Gracilaria corticata* are shown in Figure 5. The results showed that at the same stages of storage, the addition of *Gracilaria corticata* powder significantly reduced the L^* value ($p < 0.05$). In other words, with the increase in the amount of *Gracilaria corticata* powder in the ice cream formulation, the lightness index decreased, which could be due to the dark color of the macroalgae. The findings of the present research are in general agreement with those of Tiepo *et al.*, who found that with the incorporation of *Spirulina platensis* algae in ice cream, the value of L^* decreased [49]. The results of the present study were inconsistent with the findings of Durmaz *et al.*'s study [23]. They reported that increasing the levels of the *Diacronema vlkianum*, *Porphyridium cruentum*, and *Nannochloropsis oculata* microalgae species has no noticeable impact on the L^* value of ice cream. In this research, the a^* values of all the samples were in the range of positive numbers, and their value decreased with the addition of *Gracilaria corticata* powder. This indicates the reduction of the redness of the samples and their tendency toward a green color. The reduction of red color in ice cream containing *Gracilaria corticata* macroalgae with increasing algae concentration is due to its color properties and chemical compounds. This macroalga has phycobiliprotein pigments that include phycoerythrin (red pigment) and phycocyanin (green-blue pigment). At low concentrations, the effect of the red color is dominant. However, with an increase in algae concentration, the impact of phycocyanin pigments becomes more visible, resulting in a tendency toward a green color or a decrease in the intensity of the red color [50]. Similar results were obtained by Tiepo *et al.* because of adding *Spirulina platensis* algae to ice cream on the value of a^* [49]. The findings conflicted with the results of Durmaz *et al.* They stated that with increasing levels of microalgae species *Diacronema vlkianum*, *Porphyridium cruentum*, and *Nannochloropsis oculata* from 0.1 to 0.3 %, the value of a^* decreases. In terms of the b^* value, by adding *Gracilaria corticata* powder, its value increased significantly ($p < 0.05$) [23]. In other words, by adding *Gracilaria corticata* powder to the ice cream formulation, the yellowness of the samples increased. As mentioned, this alga contains the pigment phycoerythrin. It also contains carotenoid pigments [50]. Therefore, increasing the value of yellowness in ice cream color by adding higher concentrations of *Gracilaria corticata* macroalgae can be related to the presence of these natural pigments in this alga. The results of this study were consistent with the outcomes of Durmaz *et al.*'s study and contradicted the findings of Tiepo *et al.*'s study [23]. In addition, the color of the ice cream was not significantly impacted by the storage period ($p \geq 0.05$) [49].

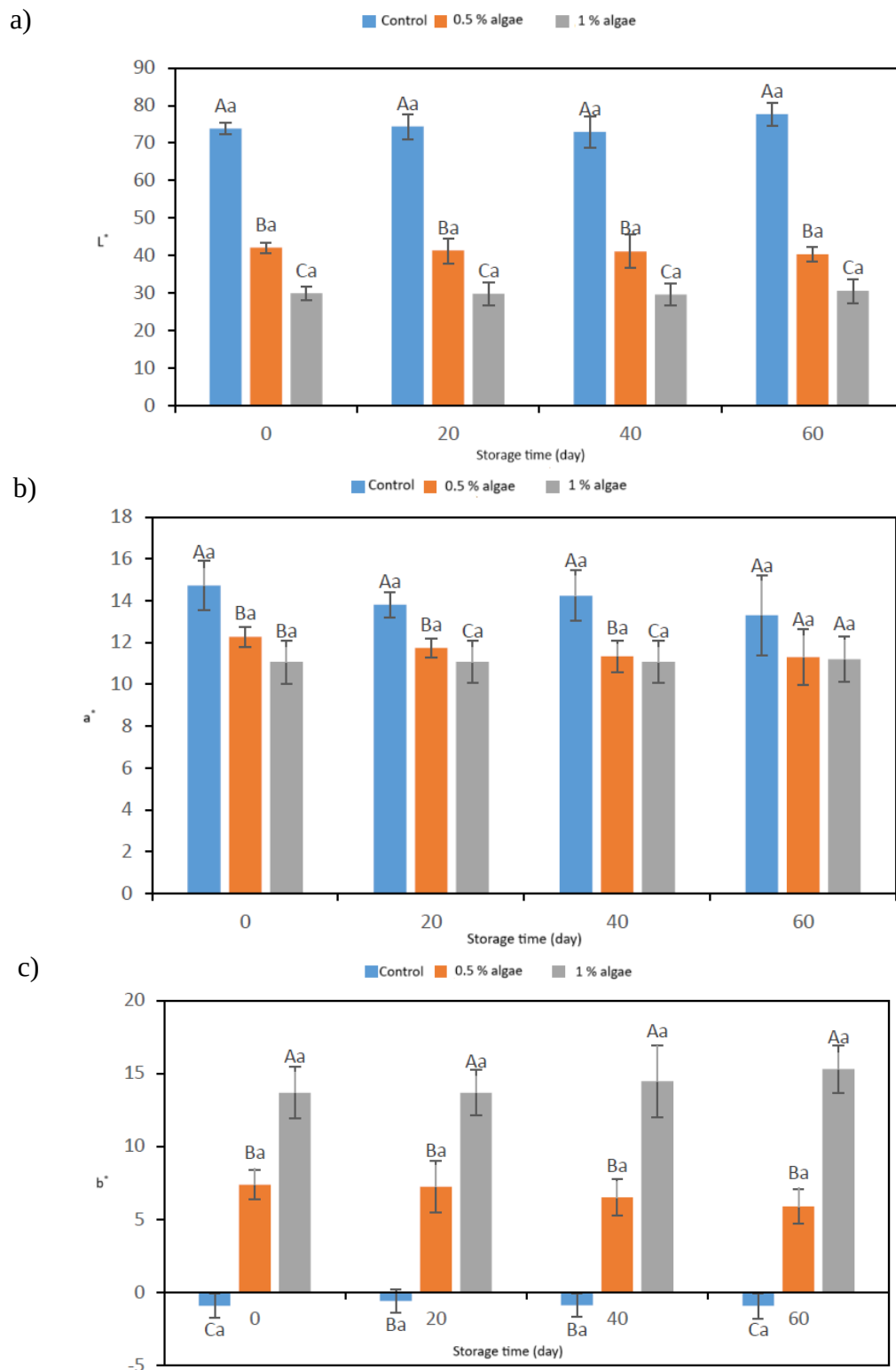


Figure 5. Changes in color values: (a) L^* value, (b) a^* value, (c) b^* value of different ice cream samples during storage

Dissimilar lowercase letters indicate significant changes in the color value of each treatment during the storage period ($p < 0.05$). Dissimilar capital letters indicate substantial changes in the color value of different treatments at the same point in the storage period ($p < 0.05$)

The results of adding different concentrations of *Gracilaria corticata* algae powder to the total phenol content of ice cream samples during storage are shown in Table 2. The results showed that the total phenol content of ice cream samples increased significantly with an increasing percentage of *Gracilaria corticata* algae powder compared to the control sample ($p < 0.05$). The reason for the increase in total phenolic content in ice cream samples containing different percentages of *Gracilaria corticata* algae powder can be attributed to the high amount of phytochemicals and biologically active substances such as catechin, coumaric acid, luteolin, sinapic acid, fucoxanthin, gallic acid, and other phenolic compounds [7]. The results of the present study are in line with those of Durmaz *et al.*, who reported a significant enhancement in the total phenolic content of ice cream enriched with *Nannochloropsis oculata*, *Porphyridium cruentum*, and *Diacronema vlkianum* microalgae species [23]. The findings of the current research are also in agreement with the earlier conclusions of Boyanova *et al.*, who studied the effect of levels of *Spirulina platensis* powder on the TPC of ice cream and concluded a significant increase (24.4 – 43.7 %) in total phenolics [22].

As for storage, the table makes it clear that storage had varying effects on the ice cream's total phenolic content. A notable rise was observed on day 20 of storage. Nevertheless, on the 60th day of storage, a slow drop in TPC was observed. The reduction in phenolic compounds in ice cream during storage may be attributed to oxidation and chemical degradation [51]. Additionally, phenolic compounds may react with other components in ice cream, such as proteins and carbohydrates, reducing their bioavailability. These reactions can lead to a decrease in the concentration of phenolic compounds during storage [52]. The findings of the current research align with the observations made by Shamshad *et al.*, who noted a substantial reduction in the TPC of ice cream supplemented with microencapsulated anthocyanins from black carrots over a storage period of 60 days [32].

Table 2. Total phenol content of different ice cream samples

Total phenol content [mg GAE/100 g]	Storage time [day]			
	0	20	40	60
Control	3.63 ± 0.15 ^{Cb}	4.00 ± 0.10 ^{Ba}	4.00 ± 0.20 ^{Ba}	3.76 ± 0.11 ^{Bab}
0.5 % algae powder	4.23 ± 0.11 ^{Ba}	4.50 ± 0.10 ^{Aa}	4.40 ± 0.17 ^{Aa}	4.26 ± 0.20 ^{Aa}
1 % algae powder	4.60 ± 0.10 ^{Aa}	4.50 ± 0.10 ^{Aab}	4.40 ± 0.10 ^{Abc}	4.30 ± 0.10 ^{Ac}

Dissimilar lowercase letters in each row indicate significant differences ($p < 0.05$).

Dissimilar capital letters in each column indicate significant differences ($p < 0.05$).

The effects of adding different concentrations of *Gracilaria corticata* algae powder on the antioxidant activity of ice cream samples during storage are shown in Table 3. The results showed that adding *Gracilaria corticata* algae powder to ice cream samples significantly increased antioxidant activity ($p < 0.05$). The strong antioxidant potential in ice cream with the addition of *Gracilaria corticata* algae powder is attributed to the presence of compounds with high antioxidant activity, such as catechin, coumaric acid, and phloroglucinol, in this macroalgae [7]. The results of the present study are in line with those of Szmajda *et al.*, who reported a significant increase in the antioxidant activity of ice cream enriched with *Spirulina (Arthrospira platensis)* extract [34]. These researchers stated that the main reason for the antioxidant activity of ice creams containing *Spirulina* algae extract is the presence of phycocyanin in the algae's biomass. The findings of the present study also align with the earlier conclusions of Bajestani *et al.*, who studied the

impact of *Spirulina platensis* microalgae extract on the antioxidant activity of ice cream and reported a noteworthy increase in antioxidant activity [3]. On the other hand, our results were consistent with the findings of Mudannayake *et al.* [35]. These researchers examined the effect of different levels (0, 0.5, and 1 %) of *Kappaphycus alvarezii* macroalgae powder on the DPPH of ice cream. They found that as the level of macroalgae increased, the DPPH value increased noticeably from 10.75 ± 1.91 to 16.54 ± 3.61 %. Regarding the storage period, no significant change was observed in the antioxidant activity of the samples ($p \geq 0.05$). Seaweeds are abundant in antioxidants, which serve to continually eliminate free radicals and diminish oxidative stress, diabetes, cardiovascular disease, aging, and cell damage [7]. Therefore, fortifying ice cream with antioxidant compounds provides health benefits.

Table 3. Antioxidant activity of different ice cream samples

DPPH [% of free radical scavenging]	Storage time [day]			
	0	20	40	60
Control	21.10 ± 0.26 ^{Ba}	22.60 ± 1.15 ^{Aa}	22.46 ± 1.17 ^{Aa}	21.66 ± 0.11 ^{Aa}
0.5 % algae powder	22.73 ± 1.20 ^{Ab}	23.33 ± 1.06 ^{Aa}	23.33 ± 1.06 ^{Aa}	23.33 ± 1.06 ^{Aa}
1 % algae powder	23.14 ± 1.1 ^{Aa}	23.33 ± 1.15 ^{Aa}	23.20 ± 1.03 ^{Aa}	23.10 ± 1.03 ^{Aa}

Dissimilar lowercase letters in each row indicate significant differences ($p < 0.05$).

Dissimilar capital letters in each column indicate significant differences ($p < 0.05$).

The overall acceptability of foodstuffs by people and the commercialization of goods are significantly influenced by sensory characteristics [3, 53]. The scores related to the hedonic sensory characteristics of the ice cream during storage, in terms of flavor and aroma, odor, color, melting rate, coldness, and overall acceptance, are presented in Table 4. The results showed that adding *Gracilaria corticata* algae powder to the ice cream formulation significantly increased the aroma and flavor scores ($p < 0.05$). Because *Gracilaria corticata* algae powder contains natural aromatic compounds and bioactive substances like antioxidants and polysaccharides, and interacts with other ingredients in the formulation, it may improve the flavor and aroma scores of ice cream. The findings of this study are consistent with those of Jadhav and Chawla, who found that adding powdered *Spirulina* algae to vanilla ice cream increased its flavor score [39]. The results of another research also showed that increasing the amount of *Spirulina platensis* algae biomass added to ice cream increased the flavor of the ice cream [3]. In contrast, the findings did not agree with those of Malik *et al.* They found that as the concentration of *Spirulina* algae powder increased, the ice cream flavor score declined [40]. These researchers concluded that a bland, oily flavor was the cause of the decline in flavor scores as the concentration of *Spirulina* algae powder increased. The findings of the current research also contradict those of Agustini *et al.*, who investigated the impact of *Spirulina platensis* algae powder levels on the scent score of ice cream and found a reduction [37]. Regarding color, the results showed that adding *Gracilaria corticata* algae powder to the ice cream formulation significantly decreased the color score ($p < 0.05$). This finding implied that panelists favored a paler shade of red (the ice cream containing *Gracilaria corticata* algae powder was dark red). Because *Gracilaria corticata* algae powder contains red pigment (phycoerythrin), incorporating more of it resulted in a darker red ice cream [50]. The results of the current study are in line with those of Agustini *et al.*, who found that adding powdered *Spirulina platensis* algae to ice cream reduced its color score

[37]. Also, similar outcomes were obtained by Durmaz *et al.* These researchers reported that as the amount of microalgae *Diacronema vlkianum* and *Porphyridium cruentum* increased, the color score of the ice cream samples decreased [23]. However, they observed a decline in the color score of ice cream samples as *Nannochloropsis oculata* algal levels increased, which is inconsistent with our study's findings. The reason for this discrepancy in the results of these researchers is the type of algae species used. In terms of color, melting rate, coldness, and overall acceptance, no significant difference ($p \geq 0.05$) was observed among all samples of ice cream. In other words, it can be concluded that the addition of *Gracilaria corticata* algae powder to ice cream samples did not impact these sensory parameters.

According to another part of the findings, increasing the storage time did not have a significant effect on the aroma and flavor parameters ($p \geq 0.05$), while other sensory properties examined (odor, color, melting rate, coldness, and overall acceptance) decreased significantly ($p < 0.05$). The increased susceptibility of ice cream's odor, color, melting rate, coldness, and general acceptability to environmental factors such as oxidation, recrystallization, and structural alterations during storage results in notable variations in these characteristics. However, because volatile chemicals and flavorings are more stable at low temperatures, flavor and aroma did not exhibit any notable alterations. During storage, Murtaza *et al.* observed a progressive decline in scores for every sensory attribute of ice cream samples. Also, Singh *et al.* observed a decrease in scores for all the sensory features of ice cream samples during storage [41, 54].

Table 4. Sensory evaluation results of different ice cream samples during storage

Days	The algae [%]	Flavor and aroma	Odor	Color	Coldness	Overall acceptance
0	0	5.7 ± 0.67 ^{Ba}	5.7 ± 0.67 ^{Ba}	7.0 ± 0.81 ^{Aa}	6.6 ± 0.96 ^{Aa}	6.1 ± 0.56 ^{Aa}
	0.5	6.3 ± 0.67 ^{Aba}	6.3 ± 0.67 ^{Aba}	6.2 ± 0.63 ^{Aba}	6.5 ± 1.43 ^{Aa}	6.8 ± 1.13 ^{Aa}
	1	6.7 ± 1.05 ^{Aa}	6.7 ± 1.05 ^{Aa}	5.8 ± 1.22 ^{Ba}	6.2 ± 1.03 ^{Aa}	7.00 ± 1.05 ^{Aa}
20	0	5.7 ± 0.67 ^{Ba}	5.7 ± 0.67 ^{Ba}	6.4 ± 0.51 ^{Aab}	6.3 ± 0.67 ^{Aa}	5.6 ± 1.17 ^{Aab}
	0.5	6.9 ± 1.1 ^{Aa}	6.9 ± 1.1 ^{Aa}	5.9 ± 0.56 ^{ABab}	5.9 ± 1.19 ^{Aab}	6.3 ± 0.94 ^{Aab}
	1	6.7 ± 1.05 ^{Aa}	6.7 ± 1.05 ^{Aa}	5.4 ± 1.017 ^{Ba}	5.8 ± 0.63 ^{Aab}	6.6 ± 1.07 ^{Aa}
40	0	6.0 ± 0.94 ^{Aa}	6.0 ± 0.94 ^{Aa}	5.9 ± 0.73 ^{Ab}	5.8 ± 0.91 ^{Ab}	5.3 ± 0.94 ^{Aab}
	0.5	6.3 ± 1.17 ^{Aa}	6.3 ± 1.17 ^{Aa}	5.3 ± 1.05 ^{Abb}	5.4 ± 1.07 ^{Aab}	5.7 ± 0.82 ^{Aab}
	1	6.5 ± 1.08 ^{Aa}	6.5 ± 1.08 ^{Aa}	4.9 ± 0.87 ^{Ba}	5.4 ± 0.84 ^{Aab}	6.0 ± 1.15 ^{Aab}
60	0	5.2 ± 1.15 ^{Aa}	5.2 ± 1.15 ^{Aa}	5.1 ± 1.10 ^{Ac}	5.3 ± 1.07 ^{Ab}	4.8 ± 1.07 ^{Ab}
	0.5	6.1 ± 1.52 ^{Aa}	6.1 ± 1.52 ^{Aa}	5.2 ± 1.13 ^{Ab}	4.9 ± 0.87 ^{Ab}	5.5 ± 1.6 ^{Ab}
	1	5.8 ± 1.61 ^{Aa}	5.8 ± 1.61 ^{Aa}	4.8 ± 0.91 ^{Aa}	5.1 ± 1.66 ^{Ab}	5.0 ± 0.94 ^{Ab}

Dissimilar lowercase letters in each row indicate significant differences ($p < 0.05$).

Dissimilar capital letters in each column indicate significant differences ($p < 0.05$).

CONCLUSIONS

The study demonstrated that the inclusion of *Gracilaria corticata* algae powder significantly increased the values of dry matter, protein content, overrun, total phenolic content, and antioxidant activity. The algae powder enhanced the melting resistance of ice cream by reducing the melting rate. While the pH of treatments with *Gracilaria corticata* was higher than that of the control, storage time led to a reduction in pH and an increase in acidity. *Gracilaria corticata* algae powder impacted the color of ice cream,

reducing L^* and a^* values while increasing b^* . Also, storage time had no significant effect on color properties. Flavor and aroma scores improved by incorporating *Gracilaria corticata* algae powder, indicating enhanced sensory appeal. However, adding algae powder reduced color scores and had no significant impact on odor, melting rate, coldness, and overall acceptance. While flavour and aroma scores were stable during storage, other sensory attributes declined. Overall, the results of the present study showed that adding 0.5 % of *Gracilaria corticata* algae to ice cream improved some physicochemical properties and some sensory characteristics. Further studies could be effective in better understanding the role of macroalgae and their application in the preparation of functional products.

ACKNOWLEDGEMENT

We are grateful for the cooperation of the Islamic Azad University Safadasht Branch Algae Research Center in implementing this project.

REFERENCES

- Hernández, H., Nunes, M.C., Prista, C., Raymundo, A.: Innovative and healthier dairy products through the addition of microalgae: A review, *Foods*, **2022**, 11 (5), 755, <https://doi.org/10.3390/foods11050755>;
- Bürck, M., Fratelli, C., Assis, M., Braga, A.R.C.: Naturally colored ice creams enriched with C-phycoerythrin and Spirulina residual biomass: Development of a fermented, antioxidant, tasty and stable food product, *Fermentation*, **2024**, 10 (6), 304, <https://doi.org/10.3390/fermentation10060304>
- Bajestani, M.S., Anvar, S.A.A., Nowruzi, B., Golestan, L.: Production of cheese and ice cream enriched with biomass and supernatant of *Spirulina platensis* with emphasis on organoleptic and nutritional properties, *Iranian Journal of Veterinary Medicine*, **2024**, 18 (2), 263-278, <https://doi.org/10.32598/ijvm.18.2.1005364>;
- Deepika, R.C.: phytochemical characterization of *Sargassum wightii*, *Kappaphycus alvarezii* and *Gracilaria corticata* after phycocolloid extraction, *International Journal of Pharmaceutical, Chemical & Biological Sciences*, **2017**, 7(3), 230-239;
- Healy, L.E., Zhu, X., Pojić, M., Sullivan, C., Tiwari, U., Curtin, J., Tiwari, B.K.: Biomolecules from macroalgae-nutritional profile and bioactives for novel food product development, *Biomolecules*, **2023**, 13 (2), 386, <https://doi.org/10.3390/biom13020386>;
- Ullah, M.R., Akhter, M., Khan, A.B.S., Yasmin, F., Hasan, M.M., Bosu, A., Mahmud, Y.: Nutritional composition and phenolic contents of *Gracilariopsis longissima*, *Padina tetrastrum* and *Ulva intestinalis* from the Bay of Bengal, Bangladesh coast, *Heliyon*, **2024**, 10 e31128, <https://doi.org/10.1016/j.heliyon.2024.e31128>;
- Ahmad, S., Jan, K., Sahu, J.K., Jan, S., Chauhan, K., Bashir, K.: Physicochemical, thermal, and functional properties of edible red algae (*Gracilaria corticata*), *Journal of Food Science*, **2024**, 89 (9), 5425-5433, <https://doi.org/10.1111/1750-3841.17283>;
- Fleurence, J., Levine, I.: *Seaweed in Health and Disease Prevention*, 1st edition, Academic Press, **2016**, <https://doi.org/10.1016/C2014-0-02206-X>;
- Al-Younisa, Z.K., Al-Hatim, R.R., Fadhal Abbas, S., Altemimi, A.B., Hesarinejad, M.A., Younis, M.I., Abdelmaksoud, T.G.: The use of transglutaminase and gallic acid as stabilizers and thickeners in the production of ice cream, *Research and Innovation in Food Science and Technology*, **2024**, 13 (3), 163-170, <https://doi.org/10.22101/JRIFST.2024.418256.1520>;
- Bhatnagar, P., Gururani, P., Parveen, A., Gautam, P., Joshi, N.C., Tomar, M.S., Kumar, V.: Algae: A promising and sustainable protein-rich food ingredient for bakery and dairy products, *Food Chemistry*, **2024**, 138322, <https://doi.org/10.1016/j.foodchem.2023.138322>;

11. Boukid, F., Castellari, M.: Food and beverages containing algae and derived ingredients launched in the market from 2015 to 2019: a front-of-pack labeling perspective with a special focus on Spain, *Foods*, **2021**, 10 (1), 173, <https://doi.org/10.3390/foods10010173>;
12. Devaprakash, M., Thirumalaivasan, R., Sivakumar, N., Shyam Kumar, R., Ponmurugan, K.: Nutraceuticals and functional foods from algae: Formulation and health benefits in *Value Added Products From Bioalgae Based Biorefineries: Opportunities and Challenges*, **2024**, 289-341, Springer, https://doi.org/10.1007/978-981-97-1662-3_13;
13. Sangeetha, R.: Independent and synergistic activity of the flavonoids of *Gracilaria corticata* as promising antidiabetic agents, *Brazilian Journal of Pharmaceutical Sciences*, **2020**, 56, e18766, <https://doi.org/10.1590/s2175-97902019000418766>;
14. Mengisteab, M., Tekle, R., Gebreyohannes, D., Gebrezigabheir, Z., Tesfamariam, E.H., Tareke, E.: Proximate and mineral content of seaweeds as an alternative to vegetables in Eritrea, *Food and Humanity*, **2023**, 1, 514-518, <https://doi.org/10.1016/j.fooohum.2023.06.023>;
15. Sharma, U., Jadaun, S., Khapudaang, R., Siddiqui, S: Seaweed-A Sustainable Food Source in the Food Industry in: *Sustainable Food Systems (Volume II)*, (Editor: Thankur, M.), Springer Cham Publishers, **2024**, 187-203, https://doi.org/10.1007/978-3-031-46046-3_10;
16. Warnasooriya, V., Gunawardena, S., Weththasinghe, P., Jayawardana, B., Qader, M., Liyanage, R.: Nutritional properties, antioxidant activity, and heavy metal accumulation in selected marine macroalgae species of Sri Lanka, *Nutraceuticals*, **2024**, 4 (1), 50-64, <https://doi.org/10.3390/nutraceuticals4010004>;
17. Guo, J., Qi, M., Chen, H., Zhou, C., Ruan, R., Yan, X., Cheng, P.: Macroalgae-derived multifunctional bioactive substances: The potential applications for food and pharmaceuticals, *Foods*, **2022**, 11 (21), 3455, <https://doi.org/10.3390/foods11213455>;
18. Hoang, T.-V., Alfarraj, S., Alharbi, S.A.: An investigation on antimicrobial and anticancer competence of macro red algae under in-vitro condition, *Environmental Research*, **2024**, 252, 119026, <https://doi.org/10.1016/j.envres.2024.119026>;
19. Raja, R., Hemaiswarya, S., Sridhar, S., Alagarsamy, A., Ganesan, V., Elumalai, S., Carvalho, I.S.: Evaluation of proximate composition, antioxidant properties, and phylogenetic analysis of two edible seaweeds, *Smart Science*, **2020**, 8 (3), 95-100, <https://doi.org/10.1080/23080477.2020.1795338>;
20. Yumashev, A.V., Doewes, R.I., Shichiyakh, R.A., Suksatan, W., Abdelbasset, W.K., Najm, M., Narimanzadeh, F.: The effects of dietary *Gracilaria corticata* (marine macroalgae, rhodophyta) extraction on growth performance, antioxidant defence, plasma and mucosal immune components and immune-related gene expressions in goldfish, *Agricultural and Food Sciences, Environmental Sciences*, **2022**, <https://doi.org/10.21203/rs.3.rs-1234382%2Fv1>;
21. Chanchpara, A., Sahoo, T.P., Madhava, A.K., Saravaia, H.T.: Non-isothermal kinetic decomposition characteristic of *Gracilaria corticata* biomass and its biochar utilization for efficient heavy metals remediation, *BioEnergy Research*, **2024**, 17 (2), 1055-1064, <https://doi.org/10.1007/s12155-023-10644-0>;
22. Boyanova, P., Gradinarska, D., Dobрева, V., Panayotov, P., Momchilova, M., Zsivanovits, G.: *Effect of Spirulina platensis on the quality and antioxidants characteristics of ice cream*, Paper presented at the BIO Web of Conferences, **2022**, <https://doi.org/10.1051/bioconf/20224501009>;
23. Durmaz, Y., Kilicli, M., Toker, O.S., Konar, N., Palabiyik, I., Tamtürk, F.: Using spray-dried microalgae in ice cream formulation as a natural colorant: Effect on physicochemical and functional properties, *Algal Research*, **2020**, 47, 101811, <https://doi.org/10.1016/j.algal.2020.101811>;
24. Markowska, J., Tyfa, A., Drabent, A., Stępnia, A.: The physicochemical properties and melting behavior of ice cream fortified with multiminer preparation from red algae, *Foods*, **2023**, 12 (24), 4481, <https://doi.org/10.3390/foods12244481>;
25. Tolve, R., Zanoni, M., Ferrentino, G., Gonzalez-Ortega, R., Sportiello, L., Scampicchio, M., Favati, F.: Dietary fibers effects on physical, thermal, and sensory properties of low-fat ice cream, *LWT*, **2024**, 199, 116094, <https://doi.org/10.1016/j.lwt.2024.116094>;
26. Sanjeeva, P., Mylvaganam, P., Liyinthan, V., Janaranjana, T.N.: Evaluation of physicochemical and sensory properties of ice cream incorporating processed amla, *European Journal of Agriculture and Food Sciences*, **2023**, 5 (1), 40-45, <https://doi.org/10.24018/ejfood.2023.5.1.600>;
27. Ürkek, B., Aktaş, H., Öztuğ, M.Ö., Yeniçeri, E., Öztuğ, P.: Physicochemical, sensory and antimicrobial properties of the ice cream containing lavender (*Lavandula angustifolia*) essential oil, *Ovidius University Annals of Chemistry*, **2024**, 35 (2), 91-97;

28. Öztürk-Yalçın, F., Ürkek, B., Şengül, M.: Evaluation of microbiological, antioxidant, thermal, rheological and sensory properties of ice cream fermented with kefir culture and flavored with mint (*Menthaspicata* L.), *Food Science & Nutrition*, **2024**, 12 (10), 7358-7369, <https://doi.org/10.1002/fsn3.4355>;
29. Ganesan, A.R., Shanmugam, M.: Isolation of phycoerythrin from *Kappaphycus alvarezii*: a potential natural colourant in ice cream, *Journal of Applied Phycology*, **2020**, 32, 4221-4233, <https://doi.org/10.1007/s10811-020-02214-0>;
30. Erem, E., Akdeniz, E., Cayır, M., Icyer, N.C., Toker, O.S.: Fruit-based vegan ice cream-type frozen dessert with aquafaba: Effect of fruit types on quality parameters, *Journal of Food Science and Technology*, **2024**, 61 (5), 907-917, <https://doi.org/10.1007/s13197-023-05885-y>;
31. Deepika, C., Ravishankar, G.A., Rao, A.R.: Potential Products from Macroalgae: A Review in: *Sustainable Global Resources of Seaweed Volume 1* (Editors: Rao, A.R., Ravishankar, G.A.), Springer Cham Publishers, **2022**, 17-44;
32. Shamshad, A., Butt, M.S., Nayik, G.A., Al Obaid, S., Ansari, M.J., Karabagias, I.K., Ramniwas, S.: Effect of storage on physicochemical attributes of ice cream enriched with microencapsulated anthocyanins from black carrot, *Food Science & Nutrition*, **2023**, 11 (7), 3976-3988, <https://doi.org/10.1002/fsn3.3384>;
33. Marimon-Valverde, S., Lainez-Ramirez, S., Sepúlveda-Valencia, J.-U., Mejia-Villota, A., Rodriguez-Sandoval, E.: Quality characteristics of low-fat ice cream mixtures as affected by modified cassava starch and hydrocolloids, *International Journal of Food Properties*, **2024**, 27 (1), 123-132, <https://doi.org/10.1080/10942912.2023.2293462>;
34. Szmajda, K., Duliński, R., Byczyński, Ł., Karbowski, A., Florczak, T., Żyła, K.: Analysis of the selected antioxidant compounds in ice cream supplemented with *Spirulina* (*Arthrospira platensis*) extract, *Biotechnology and Food Science*, **2018**, 82 (1), 41-48;
35. Mudannayake, D., Ananda, T.A., Balasooriya, K., Bambaranda, B.: *Kappaphycus alvarezii* seaweed powder incorporated dairy ice cream as a potential functional food: *Kappaphycus alvarezii* seaweed powder incorporated dairy product, *Sri Lankan Journal of Applied Sciences*, **2024**, 3 (01), 14-20;
36. Sangsuriyawong, A., Suwanmongkol, P., Peasura, N., Kornsakaya, N., Disnil, S., Sinchaipanit, P., Nirmal, N.: Preparation of fat-free mulberry ice cream by using inulin and whey protein isolate as a fat substitute, *eFood*, **2024**, 5 (5), e70006, <https://doi.org/10.1002/efd2.70006>;
37. Agustini, T.W., Maâ, W.F., Widayat, W., Suzery, M., Hadiyanto, H., Benjakul, S.: Application of *Spirulina platensis* on ice cream and soft cheese with respect to their nutritional and sensory perspectives, *Jurnal Teknologi*, **2016**, 78 (4-2), 245-251, <https://doi.org/10.11113/jt.v78.8216>;
38. Rosemary, T., Arulkumar, A., Paramasivam, S., Mondragon-Portocarrero, A., Miranda, J.M.: Biochemical, micronutrient and physicochemical properties of the dried red seaweeds *Gracilaria edulis* and *Gracilaria corticata*, *Molecules*, **2019**, 24 (12), 2225, <https://doi.org/10.3390/molecules24122225>;
39. Jadhav, R.R., Chawla, V.: Enrichment of Vanilla Ice-cream with *Spirulina* Powder, *International Journal of Research in Engineering, Science and Management*, **2022**, 5 (3), 1-4;
40. Malik, P., Kempanna, C., Paul, A.: Quality characteristics of ice cream enriched with *Spirulina* powder, *International Journal of Food and Nutrition Science*, **2013**, 2 (1), 44-50;
41. Singh, A., Bajwa, U., Goraya, R.K.: Effect of storage period on the physicochemical, sensory, and microbiological quality of bakery flavoured ice cream, *International Journal of Engineering Research and Applications*, **2014**, 4, 80-90;
42. Irawan, I.: *Ice cream properties affected by carrageenan form seaweed deference type drying methods*, Paper presented at the IOP Conference Series: Earth and Environmental Science, **2021**, <https://doi.org/10.1088/1755-1315/679/1/012022>;
43. Torres, P., Santos, J.P., Chow, F., Santos, D.Y.A.C.: A comprehensive review of traditional uses, bioactivity potential, and chemical diversity of the genus *Gracilaria* (Gracilariales, Rhodophyta), *Algal Research*, **2019**, 37, 288-306, <https://doi.org/10.1016/j.algal.2018.12.009>;
44. Farhah, A.N., Ekantari, N.: *Combination of Sodium Alginate and Kappa-Carrageenan Increases Texture Stability of Spirulina platensis Ice Cream*, Paper presented at the E3S Web of Conferences, **2020**, <https://doi.org/10.1051/e3sconf/202014703006>;
45. Hanafi, F., Kamarudin, N., Shaharuddin, S.: Influence of coconut residue dietary fiber on physicochemical, probiotic (*Lactobacillus plantarum* ATCC 8014) survivability and sensory

- attributes of probiotic ice cream, *LWT*, **2022**, **154**, 112725, <https://doi.org/10.1016/j.lwt.2021.112725>;
46. Tarakçı, Z., Durak, M.: Investigation of the chemical, textural and sensory properties of some fruit puree added ice cream, *Journal of Nutrition, Fasting & Health*, **2020**, **8** (4), 294-301, <https://doi.org/10.22038/jnfh.2020.52696.1302>;
 47. Çam, G., Akin, N., Konak Göktepe, Ç., Demirci, T.: Pea (*Pisum sativum* L.) pod powder as a potential enhancer of probiotic *Enterococcus faecium* M74 in ice cream and its physicochemical, structural, and sensory effects, *Journal of the Science of Food and Agriculture*, **2023**, **103** (6), 3184-3193, <https://doi.org/10.1002/jsfa.12276>;
 48. Smitha, S., Rajiv, J., Begum, K., Indrani, D.: Effect of hydrocolloids on rheological, microstructural and quality characteristics of parotta-an unleavened indian flat bread, *Journal of Texture Studies*, **2008**, **39** (3), 267-283, <https://doi.org/10.1111/j.1745-4603.2008.00142.x>;
 49. Tiepo, C.B.V., Gottardo, F.M., Mortari, L.M., Bertol, C.D., Reinehr, C.O., Colla, L.M.: Addition of *Spirulina platensis* in handmade ice cream: Physicochemical and sensory effects/Adição de *Spirulina platensis* em sorvete caseiro: Efeitos físico-químicos e sensoriais, *Brazilian Journal of Development*, **2021**, **7**, 88106-88123, <https://doi.org/10.34117/bjdv7n9-121>;
 50. Abidizadegan, M., Khalesi, M.K., Ajdari, D.: Depth-dependent pigment fluctuations in the agarophyte *Gracilaria corticata* at intertidal waters, *Thalassas: An International Journal of Marine Sciences*, **2018**, **34**, 247-253, <https://doi.org/10.1007/s41208-017-0058-6>;
 51. Akca, S., Akpinar, A.: The effects of grape, pomegranate, sesame seed powder and their oils on probiotic ice cream: Total phenolic contents, antioxidant activity and probiotic viability, *Food Bioscience*, **2021**, **42**, 101203, <https://doi.org/10.1016/j.fbio.2021.101203>;
 52. Yagmur, N., Sahin, S., Yilmaz Ersan, L.: Bio-yoghurt enriched with *Spirulina*-encapsulated pomegranate peel: Impact on some metabolomics, antioxidative, textural and colour properties, *International Journal of Dairy Technology*, **2024**, **77** (3), 724-734, <https://doi.org/10.1111/1471-0307.13105>;
 53. Ozdemir, Y., Ozbek, C., Ilhan, S.: Ice cream cone enriched with carob molasses pulp, *Journal of Food Measurement and Characterization*, **2022**, **16** (5), 3782-3791, <https://doi.org/10.1007/s11694-022-01489-w>;
 54. Murtaza, M.A., Mueenuddin, G., Huma, N., Shabbir, M.A., Mahmood, S.: Quality evaluation of ice cream prepared with different stabilizers/emulsifier blends, *Agriculture and Biology*, **2004**, **6**, 65-67.