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Determination of physicochemical and antioxidant properties of icecream produced with the addition of Jerusalem artichoke (*Helianthus tuberosus* L.)

Yer elması (Helianthus tuberosus L.*) ilavesiyle üretilen dondurmanın fizikokimyasal ve antioksidan özelliklerinin belirlenmesi*

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Abstract

The study investigates the effects of incorporating Jerusalem artichoke (*Helianthus tuberosus* L.) into ice cream formulations on their physicochemical and antioxidant properties of icecream. Jerusalem artichoke (JA), known for its high inulin content and beneficial carbohydrates, was added to ice cream in varying concentrations (5%, 10%, and 15%) and evaluated for its impact on dry matter, protein, ash, pH, acidity, sugar content, viscosity, volume increase, initial dripping time, total melting time, color values, total phenolic content, DPPH free radical scavenging activity, and total antioxidant capacity.The results revealed that the addition of JA significantly improved the dry matter and antioxidant properties of the ice cream, with the highest values observed in samples containing 10% and 15% JA. Total phenolic content increased from 363.51 mg GAE/kg in the control to 587.47 mg GAE/kg with 15% JA, while DPPH scavenging activity rose from 12.49% to 18.04%. On the other hand, the control sample has the highest total antioxidant capacity (4517.29 mg AAE/kg), while the JA samples generally exhibit lower values. The protein content decreased slightly with the addition of JA, while ash content increased. The pH and titratable acidity values also showed significant changes, with higher concentrations of JA resulting in higher pH and acidity. Overall, the incorporation of JA into ice cream formulations enhances the nutritional and functional properties. These findings suggest that JA is a valuable ingredient for developing functional ice cream with potential health benefits.

Keywords: Antioxidant activity, Colour, Ice cream, Jerusalem artichoke, Melting time, Sucrose content

Öz

Çalışma, Yer elması (Helianthus tuberosus L.) ilavesinin dondurma formülasyonlarının fizikokimyasal ve antioksidan özellikleri üzerindeki etkilerini araştırmaktadır. Yüksek inulin içeriği ve faydalı karbonhidratlarıyla bilinen yer elması, dondurmaya farklı konsantrasyonlarda (%5, %10 ve %15) eklenmiş ve kuru madde, protein, kül, pH, asitlik, şeker içeriği, viskozite, hacim artışı, ilk damlama süresi, toplam erime süresi, renk değerleri, toplam fenolik içeriği, DPPH serbest radikal giderme aktivitesi ve toplam antioksidan kapasite üzerindeki etkileri değerlendirilmiştir. Sonuçlar, yer elması ilavesinin dondurmanın kuru madde ve antioksidan özelliklerini önemli ölçüde iyileştirdiğini, en yüksek değerlerin %10 ve %15 yer elması içeren örneklerde gözlendiğini ortaya koymuştur. Toplam fenolik madde içeriği control örnekte 363.51 mg GAE/kg iken %15 oranında yer elması içeren örnekte 587.47 mg GAE/kg düzeyine çıkmıştır. Öte yandan toplam antioksidan kapasite en yüksek control örnekte (4517.29 mg AAE/kg) bulunurken yer elması içeren örneklerde daha düşük bulunmuştur. Yer elması ilavesiyle protein içeriği az miktarda azalırken, kül içeriği artış göstermiştir. pH ve titrasyon asitliği değerlerinde de bazı değişiklikler gözlenmiş, yer elmasının daha yüksek konsantrasyonları daha yüksek pH ve asitlik değerleri ile sonuçlanmıştır. Genel olarak, yer elmasının dondurma formülasyonlarına dahil edilmesi, besleyici ve fonksiyonel özellikleri artırmıştır. Bu bulgular, yer elmasının potansiyel sağlık faydaları olan fonksiyonel dondurma geliştirmek için değerli bir bileşen olduğunu göstermektedir.

Anahtar kelimeler: *Antioksidant aktivite, Renk, Dondurma, Yer elması, Erime zamanı, Şeker içeriği*

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1. Introduction

Ice cream is often enhanced with various ingredients to improve its nutritional and sensory properties. Recent trends in food science have emphasized the incorporation of prebiotics, probiotics, and synbiotics into dairy products to confer health benefits alongside their traditional sensory appeal (Rudke et al., 2024). Among these functional ingredients, Jerusalem artichoke (*Helianthus tuberosus* L.) has gained significant attention for its potential to improve gut health and enhance the functional properties of food products (Bekers et al., 2007).

JA tuber is a low-calorie vegetable rich in inulin, vitamins, and minerals (Singthong & Thongkaew, 2020). Its incorporation into various food products has been studied for its ability to enhance nutritional value and improve physical and sensory attributes. For instance, the addition of JA powder to cake formulations has been shown to positively influence the internal structure, aroma, sweetness, and chewiness, suggesting its potential to improve daily dietary fiber intake (Celik et al., 2013).

Incorporating *Helianthus tuberosus* L. fermented with lactic acid bacteria into milk products led to more acceptable outcomes, owing to greater taste satisfaction, reduced smoothness, and diminished external taste. This demonstrates its potential to improve both the nutritional value and sensory quality of fermented milk products. (Slapkauskaite et al., 2016). In the other study, substituting 5% of wheat flour with JA flour in bread improved its sensory and physicochemical properties, yielding a product rich in micro and macronutrients with enhanced organoleptic qualities and extended shelf life (Chirsanova et al., 2021).

Optimizing glass noodle production with JA powder revealed that the optimal formulation included 2% alginate, 3% calcium, and 3% JA powder, producing noodles with increased fiber and sugar content, and improved hardness, cohesiveness, springiness, and gumminess. The study underscores the nutritional and functional advantages of incorporating JA powder into food products (Singthong & Thongkaew, 2020). In the other study, yogurt was produced using fresh cow's milk enriched with JA extract at concentrations of 3%, 5%, and 7%, and subsequently stored for 15 days at 5±1°C. The results indicated that the moisture content increased with higher levels of JA extract, reaching its peak at 7%. However, there were no significant differences in protein, fat, and ash content between the control and the treated samples (Bakr et al., 2020).

The use of JA in ice cream production may be particularly promising due to its high inulin content, which can serve as a fat replacer and improve the texture and stability of ice cream. Previous studies have demonstrated that inulin addition can enhance the viscosity, hardness, and melting properties of ice cream, making it a valuable ingredient for developing low-fat and high-fiber ice cream varieties (Ertem & Çakmakçı, 2018).

Moreover, JA is rich in phenolic compounds and exhibits significant antioxidant activity, which can further enhance the health benefits of ice cream (Bach et al., 2012). The incorporation of JA into ice cream not only aims to improve its nutritional profile but also seeks to maintain or enhance its sensory properties, such as taste, texture, and overall acceptability.

This study aims to investigate the effects of incorporating different concentrations of JA into ice cream formulations on their physicochemical and antioxidant properties. This research contributes to the current body of knowledge by examining the ideal quantities of JA addition that optimize health benefits while ensuring consumer satisfaction**.** The findings are expected to contribute to the development of functional ice cream products that meet the growing consumer demand for healthier and more nutritious food options.

2. Material and method

2.1. Materials

For ice cream production, ultra high temperature (UHT) cow's milk, non fat skim milk powder (Pınar Dairy Products Inc., İzmir), Cream (fat, 35%) (Mis Dairy Industry Inc., İstanbul), powdered sugar (Konya Sugar Industry and Trade Inc., Konya), salep (stabilizer) and monoglyceride (emulsifier) were obtained from a local market. The JA were purchased from a local market in Gümüşhane. The ice cream mixtures were prepared in the laboratories of the Food Engineering Department of Gümüşhane University, and the ice cream production was carried out in a pastry shop operating in Gümüşhane.

2.2. Ice cream production

Initially, mixtures were produced. Ice cream mixtures were prepared with 5% fat, 11% non-fat milk solids, 0.6% stabilizer, and 2% emulsifier. The most suitable sugar and JA concentrations were determined to the preliminary sensory analyses. Based on the sensory analysis results, seven type of ice cream were produced: The first type was the control sample (without JA) produced with 15% sugar content. For the other mixtures, two different sugar levels (10% and 15%) and three different concentrations of JAs (5%, 10%, and 15%) were used. JAs were washed, blended with a hand blender, and added during the pasteurization phase of the mixture. Each recipe was prepared separately, and the mixture was pasteurized at 85 °C for 10 minutes with the addition of JAs. After pasteurization, the mixture was quickly cooled to room temperature using iced water, then aged at 4±1 ºC in a refrigerator for 24 hours. Following the aging process, ice cream was produced using an ice cream machine (Uğur Refrigeration Machines Inc., Nazilli, Turkey), and hardened at -22 ºC for 24 hour before the specified analyses were conducted.

2.3. Physicochemical analyses

The pH of the ice cream was measured using a HANNA HI2202-02 pH meter (Kurt et al., 2015). To determine acidity, 10 grams of sample was mixed with 10 mL of distilled water, followed by the addition of 2-3 drops of phenolphthalein. The mixture was then titrated with 0.1 N NaOH until a pink color appeared. For dry matter content, 2-3 grams of ice cream were dried at 105 ºC until a constant weight was achieved, and the percentage was calculated using the initial and final weights. Ash content was measured by ashing 2-3 grams of ice cream at 350 °C and 550 °C, and calculating the percentage based on the weights of the crucible and ash. Protein content was determined using the Kjeldahl method, digesting 1 gram of ice cream with sulfuric acid, distilling into boric acid, and titrating with 0.1 N HCl, with calculations based on volumes of HCl used for the sample and blank, and a factor of 6.38 (Kurt et al., 2015). Overrun in ice cream, resulting from the incorporation of air during mixing, was quantified by comparing the weight of a specific volume of ice cream to that of an equivalent volume of the original mix The volume increase was calculated using the following formula (Erdoğan, 2013).

Overrun%= Veight of mix (g)-Veight of ice-cream (g)/Veigh of icecream (g)x100

The first dripping and total melting times were measured using the method described by Güven and Karaca (2002). Equal surface areas and the same amount of 25 g ice cream samples were placed on a sieve with a pore size of 0.2 cm and allowed to melt at room temperature (20 °C). The time to the first drip and the total melting time were recorded in seconds (s).

2.4. Viscosity measurement

The viscosity of ice cream samples was measured using a J.P. Selecta ST 2020 R (Spain) viscometer at 20 and 50 rpm. The average of the readings was taken and the results were reported in c.P (Kurt et al., 2015).

2.5. Color determination

The color of the ice cream samples was measured with a Konica Minolta colorimeter (Chroma Meter CR-400, Japan), and the $L*$, $a*$, and $b*$ values were recorded at four distinct points on each sample (Zor &Sengul, 2022).

2.6. Sugar analysis

Ice cream sample (2.5 g) was mixed with 20 mL of distilled water, homogenized, transferred to a volumetric flask, and diluted to 50 mL. The mixture was incubated in a water bath for 15 minutes, then filtered first through filter paper and then through a 0.45 µm filter. The sugar content was determined using HPLC-RID (Thermo Scientific Products Finnigan Spectra System after calibrating the column and injecting the sugar solutions. Glucose, fructose, and sucrose concentrations were determined using external standard methods and dilution factors (Anonim, 2001).

2.7. Determination of antioxidant properties

2.7.1. Extract preparation

For this purpose, 5 g of JA and experimentel ice creams was homogenized in 25 mL of distilled water and subjected to extraction in an ultrasonic water bath at 30 °C for 20 minutes. The mixture was then filtered first through filter paper and then through a 0.45 µm filter. The filtrate was used for the analysis of total phenolic content, DPPH free radical scavenging activity, and total antioxidant content (Kasangana et al., 2015).

2.7.2. Total phenolic content

A volume of 300 µL of the extract was placed in test tubes, followed by the addition of 3.4 mL of deionized water, 0.5 mL of methanol, and 200 µL of Folin-Ciocalteu reagent. The mixture was vortexed and incubated at room temperature in the dark for 10 min. Subsequently, 600 µL of 10% Na_2CO_3 solution was added, and the mixture was vortexed again. After a 2 hours incubation at room temperature in the dark, the absorbance was measured at 760 nm. The blank solution was prepared using 3.7 mL of distilled water, 500 µL of methanol, 100 µL of Folin-Ciocalteu reagent, and 600 µL of Na_2CO_3. The total phenolic content was expressed as mg Gallic Acid Equivalent (GAE) per kg of JA, using the calibration curve obtained from gallic acid solutions at concentrations of 20, 40, 60, 80, 120, and 160 µg/mL (Kasangana et al., 2015).

2.7.3. DPPH free radical scavenging activity

A volume of 100 µL of the extract mixed with 3000 µL of DPPH working solution. The mixture was vortexed and allowed to stand for 30 min. Absorbance was then measured at 517 nm using a UV-spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) (marka model). The blank solution was prepared with 100 µL of methanol. Standard solutions of ascorbic acid and Trolox were prepared in the same manner (Ahmed et al., 2015). The DPPH free radical scavenging activity was calculated as % inhibition using the formula:

$$IC\% = (Ac - As/Ac) x100 \quad (2)$$

% IC: Percent inhibition capacity, Ac: control absorbance and As: sample absorbance

2.7.4. Total antioxidant content

A volume of 500 µL of the extract was combined with 2500 µL of deionized water and 1000 µL of molybdate reagent. After vortexing of mix, it was incubated at 95 °C in a water bath for 1.5 hour. Following incubation, the mixture was cooled to room temperature for 20-30 minutes. A blank was prepared using 500 µL of distilled water in place of the sample. Absorbance of the reaction mixtures was measured at 695 nm using a spectrophotometer. The total antioxidant content was expressed as mg Ascorbic Acid Equivalent (AAE)/kg, based on the calibration curve obtained from ascorbic acid solutions at concentrations of 25, 50, 100, 150, 250, 500, and 900 µg/mL (Kasangana et al., 2015).

2.8. Statistical analyses

The experimental design consisted of 7 ice cream types: control ice cream (C), 10% sugar + 5% JA (Y1), 10% sugar + 10% JA (Y2), 10% sugar + 15% JA (Y3), 15% sugar + 5% JA (Y4), 15% sugar + 10% JA (Y5), and 15% sugar + 15% JA (Y6). Ice cream production replicated twice. Variance analysis was performed using SPSS for Windows Release 22.0 (2013), and Duncan's Multiple Range Test was applied to statistically significant samples.

3. Results and discussion

Table 1 provides valuable insights into the physicochemical parameters of the raw materials for ice cream production, specifically milk, cream, and JA, which are crucial for assessing food quality and nutritional value. Milk, with a dry matter content of 11% and cream at 39.5%, contributes significantly to the body and texture of ice cream, while JA at 16.20 ± 0.08%, adds to the consistency and nutritional density. The fat content in milk (3.30%) and cream (35%) enhances the creaminess and richness of the ice cream, whereas JA typically has low-fat levels, beneficial for lower-fat ice cream alternatives.

Table 1. Certain physicochemical properties of milk, cream and Jerusalem artichoke

Properties	Milk	Cream	Jerusalem artichoke
Dry matter (%)	11.00	39.50	16.20 ± 0.08
Fat (%)	3.30	35.0	na
Protein (%)	3.00	1.50	na
Ash (%)	na*	na	1.22 ± 0.01
Acidity (L.A%)	na	na	na
pH	na	na	na
TPC (mg GAE/kg)	na	na	301.70 ± 10.78
DPPH (inhibition %)	na	na	28.56 ± 1.14
TAC (mg AAE/kg)	na	na	6128.69 ± 206.54
Fructose (%)	na	na	1.18±0.01
Glucose (%)	na	na	1.00±0.01
Sucrose (%)	na	na	2.14±0.29

na*: not analyzed

Protein content, essential for nutritional quality, was higher in milk (3.00%) compared to cream (1.50%), contributing essential amino acids. Ash content of JA (1.22 ± 0.01%) indicated a good source of minerals, enhancing the ice cream's nutritional profile. Additionally, high total phenolic compounds (301.70 ± 10.78 mg/kg) and significant antioxidant activity of JA (DPPH: 28.56 ± 1.14 mg/kg; total antioxidant: 6128.69 ± 206.54 mg/kg) suggested that it can offer health benefits.

Furthermore, the presence of fructose (1.18%± 0.01), glucose (1.00% ± 0.01), and sucrose (2.14% ± 0.29) in JA may be contributed to the sweetness and potential prebiotic effects due to inulin. Overall, incorporating of JA in ice cream can enhance its nutritional quality by adding minerals, antioxidants, and natural sugars, while milk and cream provide essential proteins and fats for texture and richness, creating a nutritionally balanced and appealing product.

Table 2 underscores the statistically significant variations in the chemical composition of the ice cream samples. For dry matter, sample Y2 (35.08%) was significantly higher than all other samples, with Y6 (26.98%) being the lowest. Similarly, Şimşek (2016) reported dry matter contents were 29.66% and 32.54% for ice creams with 10% sugar + 5% gobdin and 10% sugar + 10% gobdin, respectively, attributing the increase to the high dry matter content of gobdin. This aligns with the high dry matter content observed in sample Y2, indicating a similar effect with JA. However, Çakmakçı et al. (2016) reported that higher kumquat contents in ice cream resulted in lower dry matter, likely because of the low dry matter of the fruit (14.83%), which contrasts with the results seen with JA.

In terms of protein, the control (C) had the highest content (4.07%), significantly different from the lowest, Y4 (3.55%). The addition of JA generally led to a reduction in protein content. Erkaya et al. (2012) reported that increasing gooseberry content in ice cream reduced protein content, and Öztürk et al. (2018) found that adding black and white myrtle fruit pulps decreased the protein content of probiotic ice creams

For ash content, Y2 (0.95%) was higher than most samples, though it was not significantly different from Y3 and Y1 (0.95% and 0.92%, respectively), but it was significantly different from Y4 (0.86%). Regarding ash content, Çakmakçı et al. (2015) reported that the addition of oleaster flour and peel increased the ash content of ice cream, which supports the higher ash content found in sampleY2 and Y3 produced with JA. Conversely, Şanlıdere Aloğlu et al. (2018) found that increasing the concentration of strawberry tree fruit puree in ice cream decreased the ash content, highlighting the variable impact of different functional ingredients.

The pH value was highest in Y6 (6.94%), significantly different from the lowest, Y1 (6.29%). Lastly, the acidity of sample Y2 (0.27%) was significantly higher than C and Y1 (both 0.22%), indicating variability in acidity among the samples. Çınar (2015) found that adding melissa extract at various concentrations increased the pH of ice cream, with the highest pH (6.58) in samples with 9% melissa extract. This result was similar to the high pH observed in sample Y6 (6.94). These differences underscored the impact of varying sugar and JA content on the ice cream's chemical properties.

Table 2. Physicochemical properties od ice cream samples

Sample	Dry Matter (%)	Protein (%)	Ash (%)	pH	Titratable acidity (LA%)
C	33.69 ± 0.03b	4.07 ± 0.03a	0.90 ± 0.02ab	6.47 ± 0.01e	0.22±0.01c
Y1	32.64 ± 0.08c	3.91 ± 0.11bc	0.92 ± 0.03ab	6.29 ± 0.05f	0.23 ± 0.02bc
Y2	35.08 ± 0.18a	3.88 ± 0.01bc	0.95 ± 0.04a	6.72 ± 0.02c	0.27 ± 0.02a
Y3	31.84 ± 0.06d	3.97 ± 0.20b	0.95 ± 0.06ab	6.87 ± 0.02b	0.25 ± 0.02ab
Y4	27.90 ± 0.33e	3.55 ± 0.12c	0.86 ± 0.05b	6.71 ± 0.01c	0.22 ± 0.02c
Y5	28.13 ± 0.20e	3.78 ± 0.02cd	0.89 ± 0.05ab	6.65 ± 0.01d	0.24±0.02abc
Y6	26.98 ± 0.16f	3.67 ± 0.04dc	0.88 ± 0.08ab	6.94 ± 0.02a	0.24 ± 0.02bc

C: Ice cream sample containing 15% sugar without JA, Y1: Ice cream sample containing 15% sugar and 5% JA, Y2: Ice cream sample containing 15% sugar and 10% JA, Y3: Ice cream sample containing 15% sugar and 15% JA, Y4: Ice cream sample containing 10% sugar and 5% JA, Y5: Ice cream sample containing 10% sugar and 10% JA, Y6: Ice cream sample containing 10% sugar and 15% JA. ** Significant at p<0.01 level,*Significant at p<0.05 level

In summary, the observed variations in dry matter, protein, acidity, pH, and ash content in ice cream samples with varying amounts of sugar and Jerusalem artichoke align with trends seen in the literature for other functional ingredients. This suggests that Jerusalem artichoke can be aviable addition to ice cream, enhancing its nutritional profile while impacting its chemical properties in predictable ways based on existing studies.

Figure 1 illustrates the initial dripping times of different ice cream samples. The control sample (C) without JA showed the shortest initial dripping time. In contrast, as the amount of JA increased in the samples, the initial dripping times also increased. Specifically, sample Y1 (15% sugar and 5% JA) had a significantly longer initial dripping time than the control, and this duration continued to rise with higher concentrations of JA, reaching its peak in sample Y5 (10% sugar and 10% JA). This statistical variation indicated that the presence of JA significantly impact the melting behaviour of the ice cream, likely due to its influence on the structural properties and water-binding capacity of the mixture. Hezer (2019) found that the addition of purslane to ice cream delayed the first dripping time compared to the control, with the delay increasing with higher concentrations.

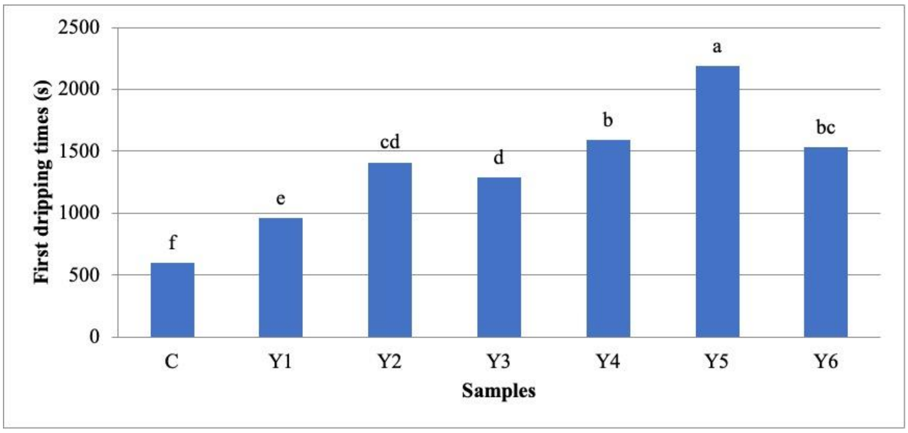

Figure 1. First dripping times of ice cream samples

Figure 2, the results for the complete melting times of various ice cream samples reveal significant differences influenced by the composition of sugar and JA. The sample C had the shortest melting time, whereas samples containing varying percentages of JA and sugar exhibited longer melting durations. Specifically, the sample Y4, containing 10% sugar and 5% JA, demonstrated the longest melting time, suggesting that the inclusion of JA substantially impacts the thermal properties of ice cream, enhancing its resistance to melting. These findings indicated that JA can effectively be used to modify the melting characteristics of ice cream, potentially offering a functional ingredient to improve product stability under varying temperature conditions. Hezer (2019) found that adding purslane increased the total melting time of ice cream compared to the control.

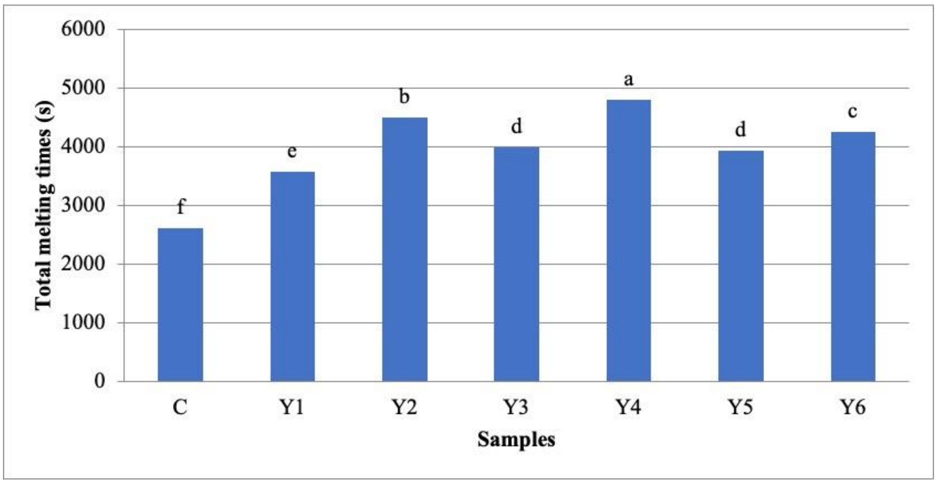

Figure 2. Total melting times of ice cream samples

The analysis of volume increase in ice cream samples were given in Figure 3. Figure 3 showed that the lowest increase (26.60%) occurred in the Y4 sample containing 15% sugar and 5% JA, while the highest increase (38.08%) was in the control sample. As shown in Figure 3.6, adding JA reduced the volume increase compared to the control, with a notable decrease in samples containing 10% sugar when 10% and 15% JA were added, compared to 5% JA. In contrast, samples with 15% sugar showed an increase. While sugar is known to significantly impact volume increase, this study found that JA had a more substantial effect, likely due to its chemical composition. Similar findings were reported by Hacıbektaşoğlu (2019) for sugar beet and by Hezer (2019) for purslane, both of which resulted in lower volume increases due to the additives' chemical interactions. Conversely, Şanlıdere Aloğlu et al. (2018) found that increasing fruit concentration in ice cream with wild strawberries led to higher volume increases, contrary to our results. These findings suggest that volume increase is influenced not only by dry matter content but also by the type, composition, and amount of additives, as well as the chemical interactions between milk proteins and these additives. Edmonds et al. (2013) noted that changes in the emulsifying capacity of milk proteins can alter the interaction of air cells with other components in the ice cream matrix, leading to differences in overrun values. Moreover, Salık and Arslaner (2020) highlighted that the variability in volume increase in ice creams produced with soursop and grape seed was significant at the $p<0.01$ level, possibly due to differences in ice cream formulations, the high dry matter content of the fruits used, the fat and non-fat milk solids content, the absence of homogenization in the ice cream mixes, insufficient air retention during freezing, and technical characteristics of the ice cream machine

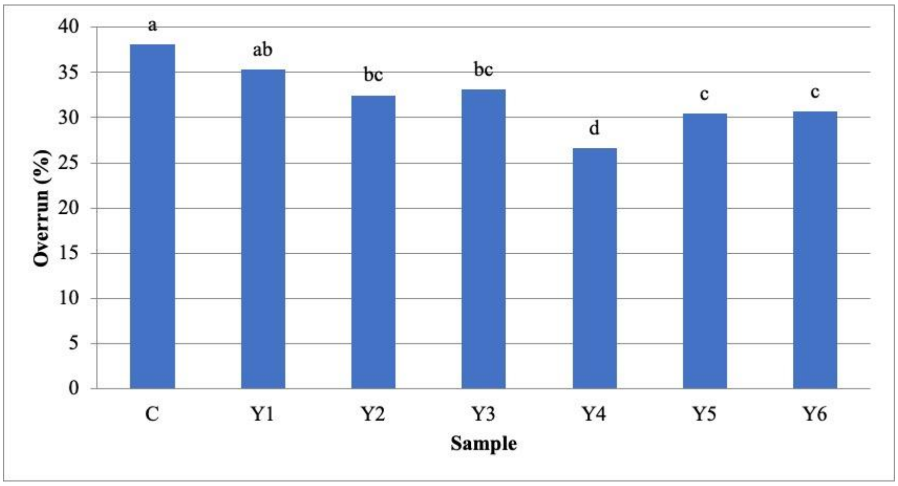

Figure 3. Overrun of ice cream samples used in the current study

In Figure 4, the viscosity measurements for the ice cream samples at 20 rpm and 50 rpm indicated significant variations based on the different formulations. Notably, sample Y2 (with 15% sugar and 10% JA) had the highest viscosity among samples at both 20 and 50 rpm, suggesting that this combination provided a balance between stability and flowability. Conversely, sample Y4 (with 10% sugar and 5% JA) exhibited the lowest viscosity, indicating a more fluid consistency. These results illustrated that the inclusion of JA affected the rheological properties of ice cream. Salık and Arslaner (2020) found that the addition of grape seed increased the viscosity of ice cream, attributing this to the high dry matter content and stabilizing components of the additives.

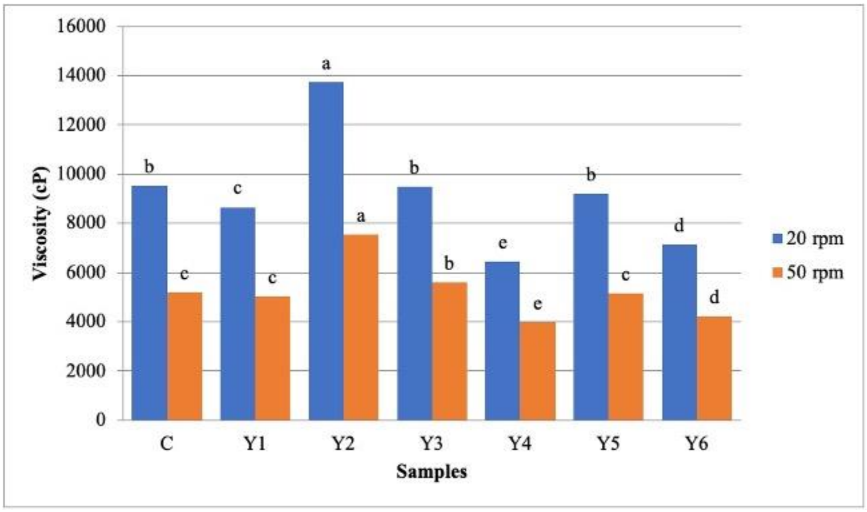

Figure 4. Viscosity parameters of ice cream samples used in the current study

Table 3 provides the average color analysis values for various ice cream samples, including parameters *L** (lightness), *a** (red-green), and *b** (yellow-blue). The control sample (C) had the highest lightness value (87.74), indicating a lighter color, and a significant negative *a** value (-2.41), which suggests a greener hue compared to other samples. Sample Y3 (15% sugar and 15% JA) showed the lowest lightness (81.30) and the highest *b** value (9.35), indicating a darker and more yellowish color. The inclusion of JA generally decreased the lightness and increased the yellowness (*b** values), while the *a** values varied, indicating slight changes in the red-green spectrum. These results demonstrated that adding JA affected the ice cream's color, potentially making it darker and more yellow, which can be a critical factor for consumer preference and product appeal.

Table 3. Colour values of ice cream samples

Samples	*L**	*a**	*b**
C	87.74 ± 0.35a	-2.41 ± 0.10e	7.92 ± 0.20b
Y1	87.06 ± 0.40a	-1.90 ± 0.07cd	7.97 ± 0.17b
Y2	82.90 ± 0.37c	-1.60 ± 0.05ab	8.25 ± 0.28b
Y3	81.30 ± 0.81d	-1.54 ± 0.29a	9.35 ± 0.15a
Y4	84.51 ± 0.51b	-2.06 ± 0.08d	8.28 ± 0.07b
Y5	83.55 ± 0.83c	-1.85 ± 0.08c	9.18 ± 0.44a
Y6	81.60 ± 0.74d	-1.78 ± 0.05bc	9.36 ± 0.35a

C: Ice cream sample containing 15% sugar without JA Y1: Ice cream sample containing 15% sugar and 5% JA, Y2: Ice cream sample containing 15% sugar and 10% JA, Y3: Ice cream sample containing 15% sugar and 15% JA, Y4: Ice cream sample containing 10% sugar and 5% JA, Y5: Ice cream sample containing 10% sugar and 10% JA, Y6: Ice cream sample containing 10% sugar and 15% JA. ** Significant at $p<0.01$ level,*Significant at $p<0.05$ level

Çelik et al. (2009) found that the addition of saffron to plain ice cream significantly affected the *L**, *a**, and *b** values, with saffron samples having higher *b** values due to the color pigments in saffron. Hezer (2019) reported that increasing concentrations of purslane in ice cream decreased the *L** value and increased the *b** value, while the *a** value showed a decreasing trend.

The sugar analysis results for various ice cream samples are presented in Table 4, showing the levels of glucose, fructose, and sucrose. The control sample has the lowest glucose (0.42 g/100) and fructose (0.32 g/100) levels, but the highest sucrose content (14.94 g/100g). In contrast, the samples with JA (Y1 to Y6) generally exhibited higher glucose and fructose levels. Specifically, sample Y6 (10% sugar and 15% JA) had the highest fructose level (0.89 g/100g), and sample Y3 (15% sugar and 15% JA) showed the highest glucose content (0.75 g/100g). Despite these variations, sucrose levels in samples Y1 to Y3 remained close to the control, while samples Y4 to Y6 showed significantly lower sucrose levels, indicating that the addition of JA influenced the sugar composition, particularly increasing fructose and glucose while decreasing sucrose content. Previous studies have reported similar findings. For instance, Celik et al. (2013) found that the addition of JA increased the fructose and glucose contents in cake formulations. Similarly, Harmankaya et al. (2012) reported that JA was rich in fructose and glucose, which could explain the increase in sugar content in the ice cream samples with added JA.

Table 4. Sugar contents of ice cream samples

Samples	Glucose (%)	Fructose (%)	Sucrose (%)
C	0,42+0,01 e	0,32+0,01 f	14,94+0,57a
Y1	0,50+0,03 d	0,44+0,02 e	14,73+0,2 a
Y2	0,56+0,02 c	0,53+0,02 d	14,49+0,02 a
Y3	0,75+0,01 a	0,77+0,01 b	14,85+0,43 a
Y4	0,66+0,01 b	0,64+0,05 c	10,56+0,23 b
Y5	0,76+0,09 a	0,82+0,04 b	10,21+0,05 ab
Y6	0,65+0,07 b	0,89+0,06 a	9,91+0,1 b

C: Ice cream sample containing 15% sugar without JA, Y1: Ice cream sample containing 15% sugar and 5% JA, Y2: Ice cream sample containing 15% sugar and 10% JA, Y3: Ice cream sample containing 15% sugar and 15% JA, Y4: Ice cream sample containing 10% sugar and 5% JA, Y5: Ice cream sample containing 10% sugar and 10% JA, Y6: Ice cream sample containing 10% sugar and 15% JA. ** Significant at p<0.01 level,*Significant at p<0.05 level

The antioxidant analysis results for various ice cream samples are given in Table 5, showing levels of phenolic compounds, DPPH, and total antioxidants. The control sample had the lowest phenolic content (363.51 mg GAE/kg) but the highest total antioxidant capacity (4517.29 mg AAE/kg). Samples with JA (Y1 to Y6) exhibited significantly higher phenolic content, with sample Y6 (10% sugar and 15% JA) having the highest levels (587.47 mg GAE/kg). This sample also had the highest DPPH value (18.04 mg AAE/kg), indicating the strongest antioxidant activity. The addition of JA consistently increased both phenolic content and antioxidant capacity across the samples, with variations depending on the specific proportions used.

This increase in total phenolic content can be attributed to the high phenolic content (301.70 ± 10.78 mg GAE/kg) of JA, as reported by previous studies (Bach et al. 2012). Phenolic compounds from JA contributes to its antioxidant properties, which are beneficial for enhancing the nutritional value of ice cream. Similar findings have been reported by Sagdic et al. (2012), who found that ice cream samples with added plant extracts, such as grape seed extract, exhibited higher DPPH activity compared to control samples. Previous studies, such as those by El-Nagar et al. (2002), have shown that the addition of inulin, a component found in JA, improves the antioxidant properties of ice cream. This suggests that JA can enhance the functional properties of ice cream by increasing its antioxidant content.

Table 5. Antioxidant properties of ice cream samples

Samples	TPC (mg GAE/kg)	DPPH (İnhibition %)	TAC (mg AAE/kg)
C	363.51 ± 0.06g	13.63 ± 0.04bc	4517.29 ± 0.00a
Y1	448.26 ± 0.06f	12.76 ± 0.36cde	4081.58 ± 14.05b
Y2	536. 52 ± 0.10d	12.49 ± 0.26e	4227.64 ± 300.74b
Y3	573. 86 ± 0.10b	12.67 ± 0.05de	4020.72 ± 44.97b
Y4	499.25 ± 0.08e	13.56 ± 1.19bcd	3071.41 ± 44.97c
Y5	548.34 ± 0.05c	14.37 ± 0.77b	3280.74 ± 342.91c
Y6	587.47 ± 0.09a	18.04 ± 0.46a	3178.51 ± 168.64c

C: Ice cream sample containing 15% sugar without JA, Y1: Ice cream sample containing 15% sugar and 5% JA, Y2: Ice cream sample containing 15% sugar and 10% JA, Y3: Ice cream sample containing 15% sugar and 15% JA, Y4: Ice cream sample containing 10% sugar and 5% JA Y5: Ice cream sample containing 10% sugar and 10% JA, Y6: Ice cream sample containing 10% sugar and 15% JA. ** Significant at p<0.01 level,*Significant at p<0.05 level

4. Conclusion

In conclusion, the incorporation of JA to ice cream formulations significantly affected their physical, and chemical properties. While higher concentrations of JA can increase the antioxidant properties and nutritional value of ice cream, they may also negatively impact its sensory properties. Therefore, it is important to balance the concentration of JA to achieve the desired functional benefits without compromising the sensory quality of ice cream. Future studies should focus on optimizing the concentration of JA in ice cream formulations and exploring the potential health benefits of consuming ice cream enriched with JA. Additionally, further research is needed to understand the mechanisms underlying the changes in physical and chemical properties observed with the addition of JA.

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Author Contribution
The author contributed to all sections. The author read and approved the last version of the manuscript.

Declaration of ethical code
The author of this article declares that the material and the methods used in this study do not require ethical committee approval and/or a special legal permission.

Conflicts of interest
The author declares that she has no conflict of interest.

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