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Investigation of Physicochemical and Sensory Properties of Ice Cream Containing Different Concentrations of Sugar and White Mulberry Juice

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ABSTRACT: Ice cream is the most popular dairy products. However, it can endanger people's health due to the high sugar content. Therefore, it is suggested that natural ingredients such as white mulberry juice, which has lower sugar and calories and healthier ingredients, be used in ice cream instead of sugar. In this study, white mulberry juice at 0, 25, 50, 75, and 100% substituted sugar consumption in the formulation of control samples, and physicochemical properties (pH, moisture, carbohydrate, lithium, potassium, brix, calories, and viscosity), total phenolic contents, antioxidant properties, overrun, melting resistance, color, and overall acceptance were evaluated one day after production. The results indicated that by increasing the content of white mulberry juice in the treatments, moisture, lithium, potassium, viscosity, total phenolic content, and antioxidant activity increased while pH, carbohydrate, brix, calories, overrun, melting resistance, and lightness decreased. There was no significant difference between the treatment containing 50% sugar and 50% white mulberry juice and the control sample in terms of overall acceptance score, the calorie content of the treatment was significantly lower than the control sample, and total phenolic content and antioxidant activity of the treatment were significantly higher than the control sample and selected as the optimal treatment.

Keywords: Functional, Ice Cream, Low-Calorie, Sugar, White Mulberry Juice.

Introduction

Ice cream is a frozen dessert made from milk fat, milk solids-non-fat (MSNF), sweeteners, stabilizers, emulsifiers, and flavorings. It is a popular food product that can be one of the most complex foods due to its three phases: solid (ice crystals and fat), liquid (liquid sugar), and gas (air bubbles). The nutritional value of ice cream depends on the content of protein, fat, carbohydrates, antioxidants, and micronutrients used in it. Many efforts have been made to improve the nutritional value of this product in recent years (Naseripour and Fadaei-Noghani, 2019). Considering the role of sugar in people's diet and the need to reduce its amount in the daily food basket, choosing the right formulation and producing a frozen dessert with the right sugar content to maintain health, along with maintaining the sensory

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and textural properties of consumer-accepted products, is a challenge in the food industry (Arbuckle, 1986). The sugar substitute is a food additive that usually has the same effect as sugar on taste, usually with less energy. Many of these products are available as diabetic foods. Manna (sugar leachate) has a special place as a by-product of pastures and forests (Kroger *et al*., 2006). Fruits and vegetables are important sources of fiber, and fiber plays an important role in lowering cholesterol and glucose levels and maintaining a healthy gastrointestinal tract, especially the intestines (Yoğurtçu and Kamişli, 2005). The sugar in berries is a monosaccharide (glucose and fructose) and is rapidly absorbed. Besides, berries are good sources of minerals such as potassium, manganese, and magnesium (Aksu and Nas, 1996). This fruit is rich in B-complex vitamins and vitamin K. It also has good amounts of vitamin B6, niacin, riboflavin, and folic acid. These vitamins act as cofactors and help the body metabolize carbohydrates, proteins, and fats (Bae and Suh, 2007). White mulberries contain minerals such as phosphorus (1987.1 ppm), potassium (14205 ppm), magnesium (950.4 ppm), calcium (3012.3 ppm), sodium (1987.8 ppm), aluminum (44.7 ppm), silicon (338 ppm), sulfur (3327 ppm), chromium (0.80 ppm), iron (34.7 ppm), manganese (17.4 ppm), strontium (8.5 ppm), and zinc (18.1 ppm) (Yigit *et al*., 2010). White mulberry phenolic compounds have a wide range of biochemical activities such as antioxidant, antimutagenic, anti-cancer properties, and the ability to modify gene expression (Karazhiyan and Keyhani, 2019). Fruit juice concentrate is one of the traditional products in Iran and other countries, including Turkey, which is obtained from concentrating fruit juice to Brix (TTS) 70 to 80. This product is mostly obtained from fruits with high sugar content such as grapes, dates, berries, and figs by adding fruit juice without adding sugar or other food additives. As a result, it is considered a product rich in natural sugars such as glucose, galactose, and minerals. The concentration of fruit juice can reduce the water content, pasteurize the fruit juice, and, ultimately, increase the shelf life. The juice obtained in the food industry has various applications, including as a sweetener, additive in cakes, cookies, and sweets, and increases the nutritional properties and shelf life of the product, and creates color and taste in cakes and other baking products (Mahdiyan *et al*., 2013). Excessive consumption of sugars and sweets weakens the body's ability to make insulin and can lead to diabetes or the accumulation of fat in the liver. Excess blood cholesterol builds up in the walls of vessels (Lim, 2012) and causes hardening of the walls, narrowing of the arteries, and, ultimately, heart attack, lower blood cholesterol reduces the risk of cardiovascular disease (Sheiham and James, 2014). Production of ice cream with natural sweeteners and fewer calories seems necessary due to the high-calorie content of ice cream and the use of sugar as a sweetener, which increases the risk of type 2 diabetes (Lee, and White, 1991). The aim of current study was investigation of physicochemical and sensory properties of ice cream containing white mulberry juice.

Materials and Methods

Ingredients for the production of ice cream samples included milk (Mihan Dairy Co., Iran), sugar (Tavakol Co., Iran), butter (Domino Dairy Co., Iran), skim milk powder (Aria Rama Co., Qom, Iran), carboxymethyl cellulose and xanthan gum (Denisco Chemicals, Iran), glucose syrup (Aryan, Iran), Mulberry juice (Pak Shahd

Sanaw, Iran) were purchased from the mentioned companies. All the chemicals compounds used in this study were purchased from Merck chemical company, Germany.

- ***Preparation of ice cream***

Ingredients include milk with 3% fat (66.5%), sugar (16%), glucose syrup (4%), butter with 82% fat (9%), carboxymethyl cellulose stabilizer (0.25%), xanthan stabilizer (0.25%), and skim milk powder (4%) were weighed to prepare the control ice cream. The weighed ingredients were mixed in a blender (Kika-Labortechnika, Germany) at a temperature of 60-65 °C and then homogenized at a temperature of 73 °C and pressure of 160 bar (APV, Germany). The ingredients were pasteurized for 15 seconds at 85 °C and then cooled to 4 °C. Aging of the mix was performed for 14 hours at 4°C. Overrun was performed at a rate of 50% overrun in the continuous ice cream freezer with a temperature of -6 ˚C. After filling the samples in the desired containers, ice cream was hardened in the freezing tunnel (2 hours at -34 °C) (Maleknejad *et al*., 2018). 25, 50, 75, and 100% of white mulberry juice replaced sugar consumption in the control sample formulation to prepare the test samples. The prepared samples were placed in the refrigerator at -20 °C in order to perform the relevant tests one day after production.

- ***Methods***

- ***Physicochemical properties of ice cream***

Iranian National Standard (ISO) No. 2450 was used to measure the moisture, ash, protein, fat, and carbohydrate of ice cream treatments. The carbohydrate content was obtained by reduction of the percentage of protein, ash, fat, and moisture from 100 (Iranian National Standard 2450, 2008 [a]). Total soluble solids content (Brix) was measured at 4 °C using a DBX-55 digital refractometer (Japan) (Moriano and Alamprese, 2017).

- ***Measuring the content of lithium and potassium***

10 g of the samples were weighed in a crucible and kept in afurnace at 550 ° C for 6 hours until the samples completely turn to ash. The resulting ash was then dissolved in 1 ml of the nitric acid solution, the contents of the crucible were transferred to a 250 ml volumetric flask by washing, and the contents of the flask were brought up to a volume of 250 ml with water. The test solution was diluted using micropipettes in marked volumetric flasks, the lanthanum (III) chloride solution was added to it using a graduated cylinder to the eleventh volume of the balloon, and the solution was brought up to the volume in the volumetric flask with water. Finally, the spectrometer was set at 671 nm for lithium and 767 nm for potassium, and the absorbance was read (Iranian National Standard 10780, 2008 [b]).

- ***Calorie measurement***

The calorie content of the samples were calculated using Equation 1 (Gheybi *et al*., 2017).

$$(9\times\text{fat}) + (4\times\text{protein}) + (4\times\text{carbohydrate}) = \text{caloric content (kCal)} \quad (1)$$

- ***Viscosity measurement***

Ice cream mix viscosity was measured at 25°C after aging for 8 hours using a Höppler falling ball viscometer (BH2, Germany) (Marshall and Arbuckle, 1996).

- ***Measurement of total phenolic content***

Ice cream samples were first extracted. For this purpose, 0.5-1 g of ice cream samples were extracted by vortex shaking with mechanical vortex for 4 hours and finally sonication for 20 minutes with 50 ml of methanol. The methanol extract was filtered through Whatman Grade 1 filter paper, and the supernatant was tested. The content of phenolic compounds in the samples was determined by Folin–Ciocalteu following the method proposed by Kanika *et al*. (2015) by mixing 0.5 ml of ice cream extract and 0.1 ml of Folin–Ciocalteu (0.5 N) reagent and placing at room temperature for 15 minutes. 2.5 ml of saturated sodium carbonate was then added and placed at room temperature for 30 minutes. The absorbance at 760 nm was then measured by a spectrophotometer (Thermo Fisher Scientific, USA).

- ***Measurement of antioxidant properties***

The antioxidant activity of the samples was determined using the method proposed by Rahman *et al*. (2014) by placing 50 g of ice cream samples with 25 ml of methanol for 12 hours. The mix was then filtered through Whatman Grade 1 filter paper, 3 ml of the mix was added to 1.2 ml of methanol, and then 1.5 ml of DPPH or 0.5 mmol/L was added. The resulting solution was placed at room temperature for 90 minutes, and its absorbance was measured at 517 nm by Equation 2, in which Acontrol was the adsorption of the control solution and Asample was the adsorption of ice cream samples.

$$I\% = (Acontrol – Asample/control) \times 100 \quad (2)$$

- ***Overrun measurement***

The empty container was weighed first. The container was then filled to the mark with ice cream mix and weighed. Next, the ice cream mix was transferred to the freezer. During the making, the container was filled to the mark with ice cream and weighed carefully. This was repeated during freezing (Sharifi *et al*., 2013). The overrun was obtained from Equation 3.

$$\text{Overrun} = \frac{(W2-W1)-(W3-W1)}{(W3-W1)} \times 100 \quad (3)$$

Where W1 was the weight of the empty container, W2 was the weight of the container and the ice cream mix, and W3 was the weight of the container and the ice cream.

- ***Measurement of melting resistance***

30 g of the sample was placed in the Buchner funnel on the opening of a previously weighed 500 ml dry Erlenmeyer flask (W1). The sample and Erlenmeyer were then kept at room temperature (24 ° C) for 15 minutes. Then, Erlenmeyer and its contents were weighed (W2), and the melting resistance was obtained from Equation 4 (Marshall and Arbuckle, 1996).

$$\text{Melting resistance} = 30 - \frac{(W2-W1)}{30} \times 100 \quad (4)$$

- ***Color measurement***

Calorimeter (D25-DP9000, Germany) was used for colorimetric evaluation with standard black and white paper references for experiments. The white sample with a height of 1.5 cm was adjusted to standard papers, 98.03 z = 81.26 x = 83.32 y =, and the CIE system was used. L * (lightness) from black (0) to white (100), a * (green to red), and b * (blue to yellow) were calculated from -120 to 120 (Iranian National Standard 2450, 2008 a).

- ***Sensory evaluation***

Sensory evaluation was performed by a 12-member group of semi-trained sensory evaluators using a 5-point hedonic scale. In the evaluation of the overall acceptance score, a score of 5 was given to a very pleasant sample, and a score of 1 was given to a very unpleasant sample (Crizel *et al*., 2014).

- ***Data analysis method***

The treatments were designed in a completely randomized design with a factorial arrangement. Therefore, 5 treatments were designed, and the tests were performed in three replications. Data were analyzed by one-way ANOVA (Duncan) at a 95% confidence level using Minitab 16 software.

Results and Discussion

- ***Evaluation of changes in pH, moisture, and carbohydrate of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production***

The results of the evaluation of changes in pH, moisture, and carbohydrate of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production are presented in Table 1.

The results indicated that the pH of the treatments was reduced by replacing sugar with mulberry juice in the ice cream formulation. The highest pH was observed in the control sample containing 100% sugar (6.850), and the lowest pH was observed in the sample containing 100% berry juice (5.530), which were significantly ($p \leq 0.05$) different. The reason for the decrease in pH with increasing concentration of white mulberry juice might be attributed to the natural acids in white mulberries and, consequently, in white mulberry juice. Iqbal *et al*., (2010) studied the physicochemical properties of several different mulberry cultivars in Pakistan and found that the acidity of the cultivars varied in the range of 0.13 to 0.3 and that there was a significant difference between the acidity of different varieties. Moreover, Elmac and Altuq (2002) examined the properties of three types of blackberries, arguing that the acidity of the studied blackberry cultivars ranged from 1.51 to 1.79%. In confirming the presence of acid in mulberries, in a study conducted by Elhami Rad and Steiri, (2009), on two varieties of mulberries (seeded and seedless), it was observed that there is a significant difference between the pH and acidity of the two varieties of white mulberries, therefore the acidity of the seeded variety (in terms of acetic acid) was about 3 times that of the seedless variety. Accordingly, the mean pH of the seeded variety was 5.6, and the mean pH of the seedless variety was 6.4.

Table 1, indicates that by increasing the concentration of white mulberry juice in the ice cream formulation the moisture content of the ice cream samples are increased as compared to the control sample. The highest moisture content was observed in the sample containing 100% white mulberry juice (44,062%) and the lowest was observed in the control sample containing 100% sugar (39.229%), that were significantly ($p \leq 0.05$) different. The reason for this can be attributed to the difference between the moisture content of sugar (as a solid powder with a very low amount of moisture) and grape juice (as a viscous fluid with some moisture content). Elhami Rad and Steiri, (2009), studied two varieties of white mulberries (seeded and seedless) and concluded that there was a significant difference between the moisture content of the varieties with an average moisture content of 72% in the seedless variety and an average moisture content of 69.5% in the seeded variety. In line with the results, Giri *et al*., (2012) examined the effect of sugar substitution with stevia on the quality of a traditional frozen dairy product called Kulfi and reported that with increasing substitution of sugar with stevia, specific gravity, melting rate, carbohydrate content, and calories decreased significantly, and moisture increased significantly.

The results of evaluating the carbohydrate content of ice cream samples showed that the sugar content of ice cream samples decreased by increasing the concentration of white mulberry juice in the ice cream formulation. Therefore, the highest carbohydrate content was observed in the control sample containing 100% sugar (16.760%), and the lowest was observed in the sample containing 100% white mulberry juice (12.094%), that were significantly ($p \leq 0.05$) different. This is due to the presence of compounds other than sugar in the structure of white mulberry juice (such as moisture, minerals, etc.) compared to sugar. Sugar has two main functions in ice cream, one is to create a sweet taste in ice cream, and the other is to control the amount and growth of ice crystals (Akalin and Erisir, 2008). Sugar reduces the freezing point of solutions, and as a result, reduces the volume of ice. Sugar can have a great effect on improving the texture of ice cream due to its effect on viscosity (Sofjan and Hartel, 2004).

In a study by Ebrahimi *et al*. (2018), the effect of sugar replacement with two sweeteners, liquid date sugar and date juice, on the properties of low-calorie ice cream was investigated. For this purpose, liquid date sugar and date juice at levels (25, 50, 75, and 100%) replaced sucrose in ice cream formulation. The results suggested that the lowest total sugar content was related to the sample containing 25% of liquid date sugar with total sugar of 18.57% and that the highest total sugar content was related to the sample containing 50 to 100% of date juice with total sugar of 20.83-20.20%.

- ***Evaluation of changes in lithium and potassium content of ice creams containing different concentrations of white mulberry juice and sugar on the first day after production***

Humans must always follow a proper diet. Proper diet plays an important role in healthy eating. Healthy eating refers to receiving the necessary and sufficient amount of nutrients needed by the body during the day and night, including minerals. Minerals are vital for improving body function. Minerals are inorganic and are found in soil and water absorbed by plants or consumed by animals (Hooda *et al*., 2004). The human body needs to receive large amounts of minerals every day to ensure the proper functioning of organs, bones, tissues, and the immune system. Providing the body with mineral resources such as food and supplements is vital because of the loss of minerals with age (Machelle, 1999).

Potassium is significantly involved in the muscle structure of the body and the function of cells. It promotes better cardiovascular function and is effective in

Table 1. The results of evaluation of changes in pH, moisture, and carbohydrate of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production

Sample	pH	Moisture (%)	Carbohydrate (%)
Sugar 100%	6.850 ± 0.028[a]	39.294 ± 0.614[c]	16.760 ± 0.438[a]
White mulberry juice 25% + sugar 75%	6.270 ± 0.056[b]	41.614 ± 0.404[b]	15.662 ± 0.311[a]
White mulberry juice 50% + sugar 50%	5.915 ± 0.021[c]	42.775 ± 0.007[ab]	14.290 ± 0.240[b]
White mulberry juice 75% + sugar 25%	5.785 ± 0.035[c]	42.584 ± 0.091[ab]	13.631 ± 0.198[b]
White mulberry juice 100%	5.530 ± 0.056[d]	44.062 ± 0.979[a]	12.094 ± 0.156[c]

Results are shown as mean ± standard deviation.
Different small letters indicate a significant difference in each column.

transmitting nerve messages, converting glucose to glycogen, regulating the aldosterone, and the catalytic activity of enzymes. Potassium plays a well-known role in regulating the blood pH and solutions, regulating blood pressure, and preventing cardiovascular disease (Lindsey *et al*., 2010). The results of evaluating the changes in lithium and potassium content of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production are provided in Table 2. According to the table, the content of lithium and potassium increased significantly by increasing concentration of white mulberry juice in the formulation of ice cream samples.

Table 2 indicates that, the highest lithium content was found in the sample containing 100% white mulberry juice (0.127 mg/g), and the lowest was found in the control sample containing 100% sugar (0.092 mg/g), that were significantly ($p \leq 0.05$) different. The highest potassium content was observed in the sample containing 100% white mulberry juice (1.837 mg/g), and the lowest was observed in the control sample containing 100% sugar (1.525 mg/g), that were significantly ($p \leq 0.05$) different. The reason for this increase can be attributed to the properties of white mulberries, which are a good source of minerals such as potassium, manganese, and magnesium (Basiri, 2017).

- ***Evaluation of changes in Brix, calories, and viscosity of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production***

According to the results of Table 3, the Brix value decreased by increasing the concentration of white mulberry juice in ice cream samples.

The highest Brix value was found in the control sample containing 100% sugar (18.05), and the lowest was found in the sample containing 100% white mulberry juice (15.95), which were significantly ($p \leq 0.05$) different. Because the moisture content of white mulberry juice is higher than sugar, the total soluble solids content (Brix) is less. Therefore, the Brix value decreased by increasing white mulberry juice concentration in the treatments. In line with the results of this study, Moriano and Alamprese (2017) examined the possibility of replacing sugar with honey in ice cream, arguing that the highest Brix value belonged to the control ice cream sample and the lowest belonged to the sample containing 100% honey. They attributed the result to the higher moisture content of honey than sugar. According to Elhami Rad and Steiri, (2009), the variety of berries has a significant effect onBrix so that the Brix of the seedless variety was 27, and that of the seeded variety was 18.5.

Table 2. The results of evaluating the changes in lithium and potassium content of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production

Sample	Lithium (mg/g)	Potassium(mg/g)
Sugar 100%	0.092 ± 0.002^{d}	1.525 ± 0.000^{e}
White mulberry juice 25% + sugar 75%	0.102 ± 0.002^{c}	1.612 ± 0.017^{d}
White mulberry juice 50% + sugar 50%	0.111 ± 0.002^{b}	1.687 ± 0.017^{c}
White mulberry juice 75% + sugar 25%	0.116 ± 0.000^{b}	1.750 ± 0.000^{b}
White mulberry juice 100%	0.127 ± 0.002^{a}	1.837 ± 0.017^{a}

Results are shown as mean ± standard deviation.
Different small letters indicate a significant difference in each column.

Due to the high-calorie production of sugar in ice cream, today there is a great demand for low-calorie ice cream. According to the results of this study, the caloric content of the treatments decreased with increasing the concentration of white mulberry juice instead of sugar in the ice cream formulation. The highest caloric content (106.28 kCal) was related to the control sample containing 100% sugar, while the lowest (87.61 kCal) was related to the sample containing 100% white mulberry juice, which were significantly ($p \leq 0.05$) different.

In this aspect, Deshmukh *et al*., (2014) investigated the replacement of stevia with sugar in ice cream formulation and found that the sample containing stevia had significantly lower calories than the control sample.

Ice cream mix viscosity is generally one of the most important factors that affect the structure and texture of ice cream. This property is usually affected by the content of raw materials used in ice cream (especially fat), the type and quality of these ingredients, the process and transfer of the ice cream mix, the concentration, and the temperature of the ice cream mix. As viscosity increases, the melting strength and hardness of the ice cream texture increases but its overrun rate decreases (Marshall and Arbuckle, 2005). According to Table 3, by increasing the concentration of white mulberry juice in the ice cream formulation, the viscosity increased significantly. The results showed that the highest viscosity was observed in the sample containing 100% white mulberry juice (214 cP), and the lowest was observed in the control sample containing 100% sugar (99 cP), that were significantly ($p \leq 0.05$) different. The reason for this can be attributed to the hydrophilic properties and high solubility of sugars in white mulberry juice. Hydroxyl groups of white mulberry juice can form stronger hydrogen bonds with water molecules than sucrose and increase the viscosity by reducing the mobility of free water (Fennema Owen, 1996).

In a study by Gohari Ardabili *et al*., (2005), the effect of date juice on the viscosity of ice cream was investigated, and it was found that the molecular structure of sugars in date juice (sucrose, fructose, and glucose) created stronger hydrogen bonds than sucrose, which increased the viscosity more than the control sample. The tendency of sweeteners to absorb water depends on their size and molecular weight. The lower the molecular weight of the saccharides, the greater the tendency to absorb water and the higher the viscosity. Koeferli *et al*., (1996) also reported an increase in the viscosity of the ice cream mix when using glucose syrup instead of sugar.

In a study by Faraji Kafshgari *et al*., (2014), grape juice was used instead of sugar in ice cream formulation. The results showed that the viscosity of ice cream increased by replacing grape juice with sugar. According to Milani *et al.* (2011), the viscosity of low fat orange yogurt ice cream increased with an increasing percentage of sugar replacement with honey, date and guar.

According to Muse and Hartel, (2004), the apparent viscosity of the ice cream mix was 0.018-0.149 pa.s and 0.584-0.935 pa.s, respectively. Hagiwara and Hartel, (1996) reported that the apparent viscosity of the ice cream mix (at a shear rate of 115/s and a temperature of 5 °C) was 0.023-0.08 pa.s for the non-stabilized mix and 0.579-0.687 pa.s for the stabilized mix.

Table 3. Evaluation of changes in Brix, calories, and viscosity of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production

Sample	Brix	Calories (kcal)	Viscosity (Centipoise)
Sugar 100%	8.050 ± 0.070[a]	106.28 ± 4.24[a]	99.00 ± 4.24[e]
White mulberry juice 25% + sugar 75%	7.450 ± 0.070[b]	101.89 ± 5.83[ab]	133.00 ± 2.83[d]
White mulberry juice 50% + sugar 50%	7.050 ± 0.070[c]	96.40 ± 3.54[ab]	159.00 ± 4.24[c]
White mulberry juice 75% + sugar 25%	6.550 ± 0.070[d]	93.76 ± 3.96[ab]	181.00 ± 2.83[b]
White mulberry juice 100%	5.950 ± 0.070[e]	87.61 ± 4.53[b]	214.00 ± 2.83[a]

Results are shown as mean ± standard deviation.
Different small letters indicate a significant difference in each column.

- ***Evaluation of changes in total phenolic content and antioxidants in ice cream containing different concentrations of white mulberry juice and sugar on the first day after production***

According to the results of some studies, phenolic compounds (such as flavonoids, anthocyanins, and phenolic acids) exert antioxidant properties in edible and non-edible plant products. These natural compounds often protect the body against harmful free radicals and are known to reduce the risk of a variety of disorders such as cancer, cardiovascular disease, stroke, and diseases exacerbated by oxidative agents (Erasto *et al.*, 2007). Due to their secondary compounds, including polyphenols, medicinal plants are a rich source of natural antioxidants. Phenolic compounds act as antioxidants by donating hydrogen to free radicals, inactivating them (Wannes *et al*., 2010), forming complexes with metal ions, and their regenerative properties (Zhang *et al.,* 2010).

Table 4, has indicated that the total phenolic content in the treatments is increased significantly by increasing the concentration of white mulberry juice in the ice cream formulation. The highest phenolic content was observed in the sample containing 100% white mulberry juice (0.915 mg/g), and the lowest was observed in the control sample containing 100% sugar (0.700 mg/g), that were significantly ($p \leq 0.05$) different. The reason for this might be attributed to the phenolic compounds in white mulberries. Ripe white mulberries contain large amounts of resveratrol. This compound is a phytoalexin with a polyphenolic structure that has antifungal properties in plants has been shown to have anti-cancer, anti-viral, anti-inflammatory, anti-aging, nervous system protection, and life expectancy effects in animal species such as mice (Karazhiyan and Keyhani, 2019). Phenolic compounds in white mulberries have a wide range of biochemical activities such as antioxidant, antimutagenic activities, and anti- cancer properties (Bae and Suh, 2007; Ercisli and Orhan, 2007; Imran *et al*., 2010). Antioxidants inhibit the activity of free radicals and neutralize them (Scheibmeir *et al*., 2005; Arab *et al*., 2011).

According to Table 4, the antioxidant properties of ice cream increased significantly with increasing concentration of white mulberry juice. The highest IC50 value and the lowest antioxidant activity were reported in the control sample containing 100% sugar (38.386mg/ml), and the lowest IC50 value and the highest antioxidant activity were observed in the sample containing 100% white mulberry juice (20.956 mg/ml), which were significantly ($p \leq 0.05$) different. The reason for this can be attributed to the richness of white berries and, in general, fruits from antioxidants so that some foods such as fruits and vegetables are rich sources of antioxidants (Arab *et al*., 2011).

In this regard, Alipour *et al*., (2015) studied the effects of white mulberry leaf extract on the antioxidant and sensory properties of yogurt and concluded that the addition of white mulberry leaf extract affects antioxidant properties and increases yogurt shelf life.

- ***Evaluation of changes in the overrun and melting resistance of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production***

Ice cream overrun is due to the entry of air into the mix. fat, MSNF, sweeteners, and stabilizers are some of the factors that affect overrun (Marshall and Arbuckle, 1996). Overrun affects the stability of the foam, the hardness of the texture, and the sensory properties of the ice cream. It also reduces the growth of ice crystals during freezing, reduces the amount of melting, and increases the stability of the foam during storage (Muse and Hartel, 2004).

As can be observed in Table 5, the overrun of ice cream samples decreased by increasing the concentration of white mulberry juice in the ice cream formulation. The highest overrun (41%) was observed in the control sample containing 100% sugar, and the lowest (17%) was observed in the sample containing 100% white mulberry juice, which were significantly ($p \leq 0.05$) different. The reason for the overrun of ice cream samples with increasing concentration of white mulberry juice can be attributed to the high viscosity of ice cream samples containing white mulberry juice. This is because the viscosity decreases if the sucrose content increases. As viscosity decreases, stirring is accelerated, and the gel structure and clusters of fat cells rupture, eventually mixing air with the mix and causing more overrun (Marshall and Arbuckle, 1996).

According to Gohari Ardabili *et al.*, (2005), air cannot properly enter the tissue of high-viscosity ice cream samples, thus reducing overrun. The amount of melting ice cream is affected by factors such as the amount of air entering the ice cream, the formation of fat cells during freezing, ice crystals shape and growth, fat instability, and the hardness of the ice cream texture (Muse and Hartel, 2004). Ambient heat melts ice crystals. Water from melting ice crystals is dispersed in the non-frozen serum phase. The diluted liquid then passes through the foam-like structure of the ice cream and, finally, flows (Amiri Aghdaei *et al.*, 2012).

According to Table 5, the melting resistance decreased significantly by increasing the concentration of white mulberry juice in the ice cream formulation. The highest rate of melting resistance (81.648%) was reported in the control sample containing 100% sugar, and the lowest (71.636%) was reported in the sample containing 100% white mulberry juice, which were significantly ($p \leq 0.05$) different. The two phenomena of heat transfer and mass transfer cause the melting of ice cream in such a way that the ambient heat gradually penetrates to the ice cream from the outside and causes the melting of ice crystals (Amiri Aghdaei *et al.*, 2012). In the control sample, heat transfer decreased due to an increase in overrun compared to ice cream replaced with white mulberry juice, thus reducing the amount melting in ice cream and, consequently, increasing the melting resistance (Pon *et al*., 2015).

Giri *et al.*, (2012) investigated the effect of stevia at concentrations of 50, 60, and 70% in Kulfi local ice cream formulation and concluded that ice cream containing stevia had lower melting resistance than the control sample due to its lower dry matter and higher moisture.

Table 4. Evaluation of changes in total phenolic content and antioxidants of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production

Sample	Total phenolic content (mg/g)	IC50 (mg/ml)
Sugar 100%	0.700 ± 0.030[d]	38.386 ± 0.552[a]
White mulberry juice 25% + sugar 75%	0.772 ± 0.022[cd]	33.026 ± 1.485[b]
White mulberry juice 50% + sugar 50%	0.830 ± 0.020[bc]	28.473 ± 1.244[c]
White mulberry juice 75% + sugar 25%	0.877 ± 0.027[ab]	24.482 ± 0.679[cd]
White mulberry juice 100%	0.915 ± 0.035[a]	20.956 ± 0.948[d]

Results are shown as mean ± standard deviation.
Different small letters indicate a significant difference in each column.

Table 5. Evaluation of changes in the overrun and melting resistance of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production

Sample	Overrun (%)	Melting resistance (%)
Sugar 100%	41.000 ± 1.414[a]	81.648 ± 0.520[a]
White mulberry juice 25% + sugar 75%	35.000 ± 1.414[b]	79.278 ± 0.766[a]
White mulberry juice 50% + sugar 50%	29.000 ± 1.414[c]	78.747 ± 0.816[ab]
White mulberry juice 75% + sugar 25%	23.000 ± 1.414[d]	74.867 ± 1.207[bc]
White mulberry juice 100%	17.000 ± 1.414[e]	71.636 ± 1.435[c]

Results are shown as mean ± standard deviation.
Different small letters indicate a significant difference in each column.

- ***Evaluation of changes in the color of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production***

The red color of the ice cream samples increased by increasing the concentration of white mulberry juice in the treatments (Table 6). The control sample containing 100% sugar showed value of (-0.06), for a* while the sample containing 100% white mulberry juice showed value of (-7.85), that were significantly ($p \le 0.05$) different.

According to the results, the yellow color of the treatments decreased and the blue color increased with increasing the concentration of white berry juice in ice cream samples. The highest value of b* (33.58) was found in the control sample containing 100% sugar and the lowest value of b * (14.27) was found in the sample containing 100% white mulberry juice, which were significantly ($p \le 0.05$) different.

The results indicated that the lightness (L*) of the samples decreased with increasing the concentration of white mulberry juice in ice cream. The highest value of L* (67) was observed in the control sample containing 100% sugar, and the lowest value of L* (28.31) was observed in the sample containing 100% white mulberry juice, which were significantly ($p \le 0.05$) different.

The results confirm that the color of the treatments tended to red and blue and their lightness decreased with increasing the concentration of white mulberry juice in ice cream samples due to the presence of natural pigments in white mulberries which reduced the lightness of the treatments as compared to the control sample. It is worth noting that white mulberries contain monosaccharide sugars (glucose and fructose) (Yigit *et al*., 2010), therefore when white mulberry juice is produced, processes of non-enzymatic browning and caramelization occur, that causes the color in the product (Basiri, 2017). Basiri (2017) examined the physicochemical properties of juice of different varieties of berries and reported that yellow, red, and lightness of berry juice of seedless variety is higher than seeded variety, due to the type and amount of pigments in berries.

In their study, Basiri and Shahidi (2017) investigated the production of pastilles with white mulberry juice and stated that the possibility of Maillard reactions in pastilles containing white mulberry juice is very high due to the presence of reducing sugars and gelatin. Therefore, brown pigments and dark colors are observed in the mentioned product.

- ***Evaluation of overall acceptance of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production***

Overall acceptance expresses the general feeling of the judges towards the sample under study, that is affected by the characteristics of the sample such as texture, taste, and oral sensation (Nazari *et al.*, 2015). Some of the problems caused by sugar substitution with other sweeteners include adverse effects on taste, physicochemical properties of the product, consumer acceptance, and legal restrictions (Gohari Ardabili *et al.*, 2005).

The results of Table 6, showed that there was no significant difference between the overall acceptance score of the control sample and ice cream samples in which 25% and 50% sugar was replaced with white mulberry juice. The overall acceptance score of ice cream samples in which sugar was replaced with 75% and 100% white mulberry juice decreased significantly with the lowest overall acceptance score (3.75) for ice cream samples containing 100% white mulberry juice. According to Minhas *et al.*, (2002), the viscosity of ice cream affects its texture and structure. Therefore, changes in viscosity, overrun, and melting resistance of ice cream samples containing white mulberry juice compared to the control sample can also affect the overall acceptance score of the product. The presence of fat and sucrose in ice cream reduces the feeling of cold in the mouth (Aime *et al.,* 2001). Thus, the severity of the cold intensifies and the overall acceptance score decreases with decreasing sucrose content and increasing the concentration of white mulberry juice above 50%.

Table 6. Evaluation of changes in color and sensory properties of ice cream containing different concentrations of white mulberry juice and sugar on the first day after production

Sample	**Color**			**Sensory properties**
	a*	**b***	**L***	**Overall acceptance score**
Sugar 100%	-20.06 ± 1.69^{c}	33.58 ± 0.72^{a}	67.00 ± 2.15^{a}	4.75 ± 0.153^{a}
White mulberry juice 25% + sugar 75%	-15.28 ± 1.19^{bc}	28.05 ± 0.96^{b}	51.52 ± 2.31^{b}	4.75 ± 0.212^{a}
White mulberry juice 50% + sugar 50%	-11.49 ± 1.93^{ab}	23.97 ± 0.31^{c}	39.66 ± 0.66^{c}	4.70 ± 0.253^{a}
White mulberry juice 75% + sugar 25%	-9.14 ± 0.59^{a}	18.985 ± 0.37^{d}	35.56 ± 0.49^{c}	4.15 ± 0.212^{ab}
White mulberry juice 100%	-7.85 ± 0.13^{a}	14.27 ± 0.88^{e}	28.31 ± 0.38^{d}	3.75 ± 0.212^{b}

Results are shown as mean ± standard deviation.
Different small letters indicate a significant difference in each column.

Conclusion

This study was conducted to evaluate the effect of adding white mulberry juice to ice cream and to investigate the physicochemical and sensory properties of ice cream. The results showed that by increasing concentration of white mulberry juice in the treatments, moisture, lithium, potassium, viscosity, total phenolic content, and antioxidant activity increased but pH, sugar, °Brix, calories, overrun and melting resistance decreased. As the concentration of white mulberry juice increased, the color of the treatments intensified and the lightness decreased. There was no significant difference between the overall acceptance score of the treatments and the control sample up to 50% sugar and 50% white mulberry juice but it then decreased. Since there was no significant difference between the treatment containing 50% sugar and 50% white mulberry juice and the control sample in terms of overall acceptance score, the calorie content of the treatment was significantly lower than the control sample, and total phenolic content and antioxidant activity of the treatment were significantly higher than the control sample, the mentioned treatment was selected as the optimal treatment. The results indicated that it was possible to produce healthier products, with better quality properties and fewer calories by replacing 50% of sugar with white mulberry juice in ice cream formulation.

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