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ENHANCING THE PRO-HEALTH AND PHYSICAL PROPERTIES OF ICE CREAM FORTIFIED WITH CONCENTRATED GOLDEN BERRY JUICE

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ABSTRACT

Background. Ice cream is a product rich in calories, due to its high carbohydrate, protein, and fat contents, but poor in antioxidants, fibers, and vitamins. The golden berry is a fruit rich in phenols, fibers, minerals, and vitamins. This study was carried out to improve the functional properties of ice cream by incorporating concentrated golden berry juice (CGBJ) in its formulation.
Materials and methods. The fresh juice of mature golden berries was concentrated (41.01% total solids) and added at the level of 0, 3, 6 and 10% respectively to the ice cream formulations.
Results. The CGBJ contained a high level of total soluble solids (37.69 Brix), total phenolic compounds (21.31 mg TAE/100 g) and ascorbic acid (97.15 mg/100 g). It was also rich in some elements, including K (1522.8 mg/100 g), Fe (9.49 mg/100 g) and Zn (3.05 mg/100 g). The antioxidant activity of CGBJ measured using DPPH and ABTS methods were 440.4 and 420.4 µg TE/g, respectively. The acidity, surface tension, and apparent viscosity of the ice cream mixture increased, but the pH value and freezing point decreased as the level of CGBJ in the formulation increased. The addition of 6% CGBJ improved both the whipping ability and overrun of the ice cream with more acceptability and quality. Inversely, ice cream containing 10% CGBJ had the lowest overrun and melting properties, while also having the highest fat destabilization compared to any other ice cream.
Conclusion. The physical and sensory properties of ice cream can be improved by adding CGBJ up to 6%. In addition, CGBJ can be used to produce a functional ice cream rich in bioactive components including antioxidants, vitamins, and some elements.

Keywords: ice cream, concentrated golden berry juice, antioxidant activity, physical properties

INTRODUCTION

Ice cream is considered to be one of the most popular frozen milk products consumed widely in Egypt and all over the world. It is highly appreciated, not only by adults, but also by children (Robinson, 1994). The production of ice cream and its popularity is also increasing rapidly (Patil et al., 2018). Ice cream is a sweetened frozen food typically eaten as a snack or dessert. It is usually made from milk, cream, sweeteners, emulsifiers and stabilizers, and combined with fruits or other ingredients and flavors (Koxholt et al., 2001). In recent years, several key technological developments have taken place in the way ice cream is

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manufactured. These developments have been largely driven by consumer factors such as the desire for healthy products (low fat and low calorie products as well as products enriched with probiotics, antioxidants, phytosterols and others) and the continuous need for product innovation (packaging, textures, or flavors) to facilitate new interest and differentiation in the marketplace (El-Shenawy et al., 2016; Gasmalla et al., 2017). Ice cream is rich in calories due to the fact that it contains a high level of carbohydrates (sweeteners), protein and milk fat. However, it is poor in natural antioxidants, dietary fibers and some minerals (Erkaya et al., 2012). Functional foods can be defined as foods containing a significant level of bioactive components (antioxidants, dietary fibers, minerals, vitamins, and free of synthetic additives, etc.) which provide specific health benefits (Drozen and Harrison, 1998). Ice cream formulated with fruit rich in bioactive components may improve the nutritive quality.

The golden berry fruit, *Physalis peruviana* L., originated in South America. Today, it is grown in several tropical and semi-tropical countries and is widely available in many international markets (Puente et al., 2011). It is an important source of bioactive compounds including minerals, phenolic compounds, carotenoids, essential fatty acids (linoleic and oleic acids), as well as vitamins A, B, C and K (Bravo and Osorio, 2016; Szefer and Nriagu, 2007). These bioactive compounds have nutritional value and health benefits as well as strong antioxidant properties. Its health benefits include hepatoprotection, anti-hypertension, anti-inflammatory, anti-carcinogenic, anti-diabetic, and a reduced risk of cardiovascular diseases (CVD) and coronary heart disease (Hassan et al., 2017; Zapata et al., 2016). Other health benefits include increasing levels of potassium in the diet, high levels of which may protect against hypertension in people who are sensitive to high levels of sodium (Nguyen et al., 2013), and levels of zinc, which acts as a nonenzymatic antioxidant, thus helping to prevent oxidative damage to the cell (Wu et al., 2005). Although the golden berry is generally used as a fresh product, it is also used in sauces, syrups, and marmalades, or dehydrated for use in bakeries, cocktails, snacks, and breakfast cereals (Puente et al., 2011; Yıldız et al., 2015).

A few reports appear in the literature about the use of golden berries in ice cream manufacture (Erkaya et al., 2012; Goraya and Bajwa, 2015), but no information is available for the use of concentrated golden berry juice in the production of ice cream as a functional dairy food. Therefore, the aim of this work was to enhance the functional properties and nutritional value of ice cream using concentrated golden berry juice (CGBJ) and to evaluate the physical and sensory properties of the resultant ice cream.

MATERIALS AND METHODS

Materials

Fresh buffalo's milk and sweet cream (~60.0% fat) were obtained from the farm of Fac. Agric., Cairo Univ., Egypt. Fresh mature golden berries (*Physalis peruviana* L.), skim milk powder made in the USA, commercial grade granulated sugar cane produced by Sugar and Integrated Industries Co., Egypt and Vanilla (chem. rein 100%) made by Boehringer Manheim GMB, Germany, were purchased from a local market in Cairo, Egypt. Commercial Lacta 9050, as a stabilizer, was obtained from the Egyptian office for Trading & Agencies (ETA), Cairo, Egypt. The 2,2-diphenyl-1-(2,4,6-trinitrophenyl)-hydrazinyl (DPPH); 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) and Trolox were obtained from Sigma--Aldrich (St. Louis, MO, USA).

Methods

Concentrated golden berry juice preparation (CGBJ)

Fresh mature golden berries were crushed, cleaned (using tap water) and screened using the home mixer (Philips, HR 7740, Hungary). The goldenberry juice was filtered with a single layer of muslin cloth to remove seeds and skins. The fresh juice, ~12.2°Brix, was freeze-dried in a freeze dryer (Christ Freeze Dryer, ALPHA 1–4 LSC, German) under –55°C. The concentration of juice was adjusted to ~37°Brix, similar to the total solids of the ice cream mixture, using distilled water, and then stored at –20°C until analysis and ice cream making.

Chemical analysis. Total solids and total nitrogen (TN) of CGBJ were determined according to AOAC (2007). The protein content was obtained by multiplying the percentage of TN by 6.25. Total soluble solids (TSS) of CGBJ were measured using hand a Refractometer (ATAGO N2, Brix 28–62%, Japan). Total phenolic content of CGBJ was determined using the method of Kim et al. (2006) based on the oxidation of polyphenols to a blue colored complex with a maximum absorbance of 750 nm. Quantification was done with respect to the standard of tannic acid. The total phenolic content was expressed as tannic acid equivalents (TAE) in mg/100 g juice. Ascorbic acid of CGBJ was extracted in 2% oxalic acid and determined using 2,6-dichlorophenolindophenol according to Hughes (1983).

Mineral concentrations. A dry-ashing method was used for the destruction of organic matter as described by Abou-Arab et al. (2015). Briefly, 5 g of the CGBJ was weighed into a crucible and dried in an oven at 105°C for 5 h. Dried CGBJ was ashed in a muffle furnace at 550°C until it became whitish ash (~5 h). The ashed sample was cooled to room temperature and dissolved in 1 mL HCl before being completed to 50 mL with de-ionized water. The mixture was filtered through ashless Whatman filter paper No 42 and stored in a refrigerator until quantitative analysis. The concentration of K, Mg, Ca, Na, Cu, Fe, and Zn were measured using an Atomic Absorption Spectrometer (SensAA Spectrometer, GBC Scientific Equipment, Germany). Phosphorus was measured in digested CGBJ using a Shimadzu spectrophotometer (UV-Vis. 1201, Japan) according to the method described by Jackson (1973).

Antioxidant activity. The antioxidant activity of the CGBJ was assessed by the use of DPPH radical scavenging activity and ABTS as described by Brand-Williams et al. (1995) and Re et al. (1999), respectively. Trolox was used as a standard with a calibration curve from 20–200 μg/mL.

Ice cream making

Buffalo's milk and sweet cream, skim milk powder, sugar and Lacta 9050, as a stabilizer, were used to prepare a plain ice cream mixture with a composition of 10.0, 12.0, 15.0 and 0.4% for fat, non-fat milk solids, sugar and stabilizer, respectively. After preheating and mixing all the ingredients, the mixture was homogenized using a laboratory homogenizer ((EURO TURRAXT 20b, IKA lobortechnik 27000 min G1) at 65°C for 5 min, pasteurized at 81°C, cooled and aged overnight at 5 ±1°C. Just before freezing in a batch freezer (Staff Ice System, BTM 10, Rimini Italy), the aged ice cream mixture was divided into four equal parts, and the CGBJ was added at rates of 0, 3, 6 and 10% to create a control (plain ice cream), T_1, T_2, and T_3, respectively. Overrun was calculated for all formulated ice cream using the weight-volume method as described by Adapa et al. (2000). The resultant ice milk was poured into plastic cups, covered and hardened in a deep freezer at –20°C for 24 h before analysis. Three replicates were done for each batch.

Ice cream mixture properties. The pH value of both CGBJ and ice cream mixtures were measured using a laboratory pH meter with a glass electrode (HANNA, Instrument, Portugal). The acidity content was determined by adding 0.1N sodium hydroxide to the phenolphthalein endpoint as described by Arbuckle (1986). The surface tension of the ice cream mixtures was measured according to the method of Arbuckle (1986). To explain briefly, a tube of the uniform bore is used and the number of drops of the sample falling per measurement of time is compared with that of water. The surface tension of water is 72–73 dynes. The structural viscosity of the ice cream mixtures was determined using a Brookfield Synchro-Lectric viscometer (Model LVT; Brookfield Engineering Inc. Stoughton, MA). Readings were taken at speeds of 4–60 rpm using a spindle-00 at 5 ±1°C for an upward curve. The viscosity was expressed as mill Pascal (mPa·s). Whipping abilities of the ice cream mixtures were determined using a mixer with 2.6 cm blades (Heidolph No. 50 111, Type RZRI, Germany) according to the method described by Baer et al. (1999). The freezing point of the ice cream mixtures was measured as described by Baer and Keating (1987), using a precision electronic thermometer, Model 15, Kreuzwertheim, Germany.

Ice cream properties. The melting properties of the frozen ice cream was determined according to Goff and Hartel (2013), by carefully cutting the foamed plastic cups from the ice cream samples (~70 g), placing the samples onto wire mesh over a glass funnel fitted to a conical flask, and weighing the amount of ice cream drained into the conical flask at 25 ±2°C every 10 min until the entire sample had melted. The fat destabilization index of ice cream was determined according to Goff and Jordan (1989) by dilution of mixed or melted ice cream (1:500 with water) and measurement of turbidity (absorbance) in a spectrophotometer at 540 nm.

Sensory properties. The samples of frozen ice cream were evaluated for appearance, melting quality, body & texture, and flavor by a regular taste panel of 21 staff members from The Dairy Science Dep., National Research Centre. Frozen ice cream was sensorially evaluated using the nine-point hedonic scale, ranging from like extremely (9 points) through like or dislike (5 points) to dislike extremely (1 points) according to the method of Fiol et al. (2017).

Statistical analysis. Data were expressed as means ±SD. Statistical analysis was performed using the GLM procedure with SAS (2004) software. Analysis of variance (ANOVA) and Duncan's multiple comparison procedure were used to compare the means. A probability of $P \leq 0.05$ was used to establish statistical significance.

RESULTS AND DISCUSSION

Chemical properties of concentrated golden berry juice

The chemical properties of concentrated golden berry juice (CGBJ) are presented in Table 1. The CGBJ presented with a low pH value and high total soluble solids (TSS), total phenolics and ascorbic acid contents. The pH value, total solids, TSS, total phenolics and ascorbic acid contents of CGBJ were 3.48, 41.01%, 37.69°Brix, 21.31 mg TAE/100 g and 97.15 mg/100 g, respectively. The pH value was close to that reported by Erkaya et al. (2012) in dried Cape gooseberry (pH, 3.39) but lower than that reported by Ordóñez-Santos et al. (2017) in diluted (1:1) Cape gooseberry juice (pH, 3.98). The ratio of total phenolic to TSS content (0.52 mg TAE/g TSS) was similar to that reported by El-Beltagy et al. (2013) in golden berry fruit (0.48 mg TAE/g TSS). However, the ratio of ascorbic acid of CGBJ to TSS content, 2.65 mg/g TSS, was close to that found by Ordóñez-Santos et al. (2017) in Cape gooseberry juice, 2.52 mg/g TSS. Minerals are essential to stay healthy and play an important role in several bodily functions. As shown in Table 1, the CGBJ was rich in major and trace elements, especially K (1522.8 mg/100 g), Fe (9.49 mg/100 g) and Zn (3.05 mg/100 g). The K and Fe contents were higher than those reported by Erkaya et al. (2012) in a dried Cape gooseberry. However, the P, Ca, Mg, Na and Zn contents were lower than those found by El Sheikha et al. (2010) in fresh golden berry juice but close to those in a report by Erkaya et al. (2012) on dried Cape gooseberry.

Table 1. Chemical properties of concentrated golden berry juice

Items	Values
pH	3.48
Total solids, %	41.01
Total soluble solids, °Brix	37.69
Protein, %	1.79
Ash, %	2.30
Minerals, mg/100 g CGBJ	
P	31.21
K	1 522.8
Ca	43.56
Mg	35.61
Na	25.54
Fe	9.49
Zn	3.05
Cu	0.47
Total phenolic, mg TAE/100 g CGBJ	21.31
Ascorbic acid, mg/100 g CGBJ	97.15
Antioxidant activity, µg TE/g CGBJ	
DPPH assay	440.4
ABTS assay	422.4

CGBJ – concentrated golden berry juice, TAE – tannic acid equivalent, TE – Trolox equivalent, DPPH – 2,2-diphenyl-1-(2,4,6-trinitrophenyl)-hydrazinyl, ABTS – 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid).

The DPPH and ABTS assays were conducted to evaluate the antioxidant activities of CGBJ as Trolox equivalent (TE). The antioxidant activity measured by DPPH and ABTS methods were 440.4 and 422.6 μg TE/g CGBJ, respectively (Table 1). The CGBJ exhibited higher antioxidant activity for DPPH radicals than that reported by Olivares-Tenorio et al. (2017) in fresh Cape gooseberry. The high antioxidant activities of CGBJ could be due to the increase in antioxidant components such as phenols and vitamin C in the concentrated juice. A strong positive correlation was found between total phenols and DPPH radical scavenging activity (Jung et al., 2011).

Ice cream mixture properties

Table 2 shows some physical properties of the formulated ice cream mixtures with different levels of CGBJ. The addition of CGBJ caused a significant decrease ($P < 0.05$) in pH value and a significant increase ($P < 0.05$) in acidity content of the ice cream mixtures; the changes were proportional to the amount added ($P < 0.05$). The pH value decreased from 6.58 ±0.08 in the plain ice cream mixture (control) to 6.02 ±0.06, 5.62 ±0.09 and 5.25 ±0.12, while acidity content increased from 0.22% to 0.33, 0.48 and 0.54% in the formulated ice cream mixtures with 3 (T_1), 6 (T_2) and 10% CGBJ (T_3), respectively. These findings coincide with those found by both Erkaya et al. (2012) in dried Cape gooseberry-fortified ice cream and Goraya and Bajwa (2015) in processed *amla* (Indian gooseberry) ice cream. The decrease in pH value may result from the existence of various acid compounds in CGBJ, such as ascorbic acid, hydroxybenzoic acid derivatives (gallic, p-hydroxybenzoic, vanillic and syringic acids) and hydroxycinnamic acid derivatives (p-coumaric, cinnamic, caffeic and chlorogenic acids) which interacted with milk proteins and reduced the pH value of the ice cream mixture (Colak et al., 2016; Vega-Gálvez et al., 2014). The decrease in pH value may be related to the interaction of phenolic compounds of CGBJ with milk proteins. Sagdic et al. (2011) reported that the addition of citrus fiber and some phenolic compounds caused a decrease in pH value due to the acidic nature of phenolic compounds.

A mixture with a lower freezing point has less water frozen as the ice cream exits the freezer (Baer and Czmowski, 1985). The freezing point of the ice cream mixtures decreased as the CGBJ concentration increased; the difference being significant only at the level of 6% and 10% CGBJ ($P < 0.05$). The reduction in the freezing point could be due to the high content of dissolved substances in the CGBJ (37.69 Brix). In this respect, Marshall et al. (2003) reported that the freezing point of an ice cream mixture depends on the soluble constituents and varies with variations in composition. Inversely, the surface tension (dyne) of CGBJ ice cream mixtures was significantly higher ($P < 0.05$) than that of the control. However, the surface tension slightly decreased when the CGBJ content increased ($P > 0.05$). The surface tension of all formulated ice cream mixtures (49.15 ±0.87 – 51.74 ±0.81 dyne) was within the normal range (48–53 dyne) reported by Marshall et al. (2003).

Table 2. Physical properties of ice cream mixtures formulated with different levels of concentrated golden berry juice

Ice cream mixtures	Properties of ice cream mixtures			
	pH	acidity, %	surface tension, dyne	freezing point, °C
Control	6.58^a ±0.08	0.22^c ±0.02	49.15^b ±0.87	-2.63^c ±0.07
T_1	6.02^b ±0.06	0.33^b ±0.03	51.14^a ±0.47	-2.70^c ±0.00
T_2	5.62^c ±0.09	0.48^a ±0.04	51.30^a ±0.55	-2.80^b ±0.00
T_3	5.25^d ±0.12	0.54^a ±0.03	51.74^a ±0.81	-2.88^a ±0.05

Means ±SD ($n = 3$) with the same letter (in column) are not significantly different ($P \le 0.05$). Control – ice cream mixture without concentrated golden berry juice, T_1 – ice cream mixture with 3% concentrated golden berry juice, T_2 – ice cream mixture with 6% concentrated golden berry juice, T_3 – ice cream mixture with 10% concentrated golden berry juice.

The apparent viscosity is necessary for proper overrun and smoothness of texture. The effect of adding different levels of CGBJ on the structural viscosity of the ice cream mixtures is depicted in Figure 1. In general, viscosity decreased along with an increase in the shear rate reflected in all the ice cream mixtures which exhibited shear thinning behaviors. Such results were observed in ice cream mixtures containing cress seed mucilage, flaxseed mucilage or guar gum (Abd El-Aziz et al., 2015), tiger nut aqueous extract (El-Shenawy et al., 2016) and food binders (Alakali et al., 2009). Bajad et al. (2016) reported that the ice cream mixture is not a Newtonian fluid, pseudo-plastic behavior, where the viscosity decreases as the shear rate increases. However, the addition of CGBJ had a positive effect on the viscosity of the mixture, which increased proportionately with the concentration of CGBJ. The ice cream mixture formulated with 10% CGBJ produced significantly a higher viscosity than any others ($P < 0.0$). However, there was no significant difference ($P > 0.0$) in the viscosity produced in ice cream with 3% or 6% CGBJ compared to the control mixture. An increase in the apparent viscosity of ice cream mixtures formulated with the CGBJ was in agreement with the results reported by Erkaya et al. (2012). The increase in viscosity may be related to the decrease in pH (Table 1), and hence, the reduced protein solubility. Ramadan and Mörsel (2009) explained that the increase in viscosity of Cape gooseberry ice cream mixtures was due to Cape gooseberry's high content of dietary fiber. The golden berry fruit contains ~13.8% carbohydrates, of which ~6.4% is (mainly fructose) sugar (Yıldız et al., 2015). The dietary fiber and simple sugars such as fructose tend to produce highly viscous solutions due to their great hydrophilic tendency and solubility (Amiri et al., 2014).

A high whipping rate describes the ability to whip rapidly to obtain a high overrun. As shown in Figure 2, the ice cream mixture formulated with 6% CGBJ had significantly higher whipping abilities than the others ($P < 0.05$), followed by that formulated with 3% CGBJ at 5 min. The mixtures formulated with 3 and

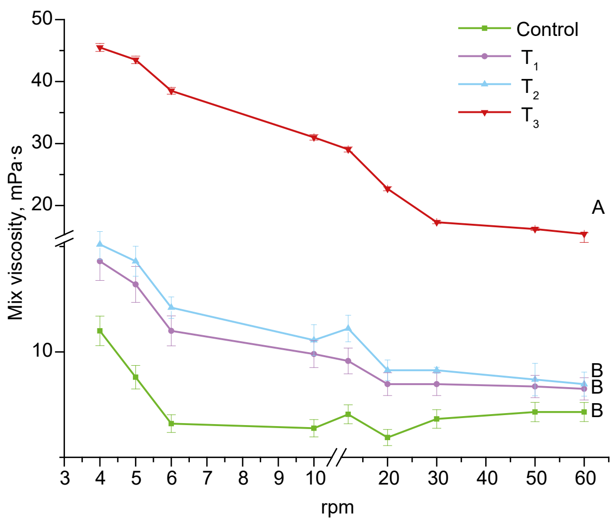

Fig. 1. Structural viscosity of ice cream mixtures formulated with different levels of concentrated golden berry juice. Means ±SD (n = 3) with the same letter are not significantly different ($P \leq 0.05$). Control – ice cream mixture without concentrated golden berry juice, T_1 – ice cream mixture with 3% concentrated golden berry juice, T_2 – ice cream mixture with 6% concentrated golden berry juice, T_3 – ice cream mixture with 10% concentrated golden berry juice

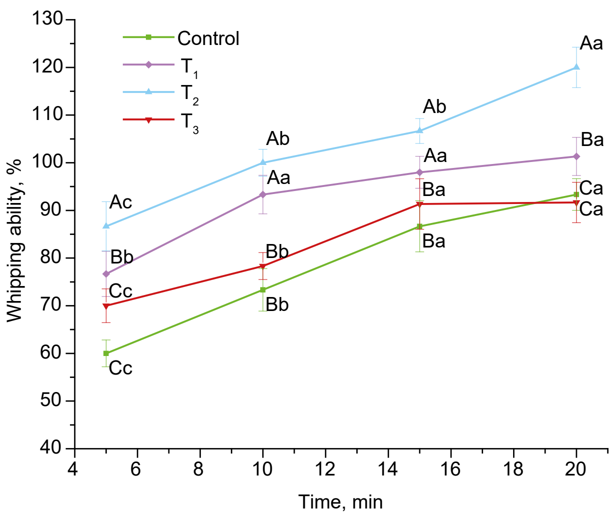

Fig. 2. Whipping ability of ice cream mixtures formulated with different levels of concentrated golden berry juice. Means ±SD (n = 3) with the same capital letter (between treatments) and small letter (between time) are not significantly different ($P \leq 0.05$). Control – ice cream mixture without concentrated golden berry juice, T_1 – ice cream mixture with 3% concentrated golden berry juice, T_2 – ice cream mixture with 6% concentrated golden berry juice, T_3 – ice cream mixture with 10% concentrated golden berry juice

6% CGBJ followed the same pattern at 10, 15 and 20 min; the difference between them was not significant at 10 and 15 min. The control mixture had the lowest whipping ability, while there was no significant difference between the control mixture and 10% CGBJ ($P > 0.05$). The whipping ability of the control mixture and mixtures formulated with 3 and 6% CGBJ, gradually increased as the time of whipping increased from 0 to 20 min, but the increase was not significant after 15 min ($P > 0.05$). The ice cream mixture formulated with 10% CGBJ peaked in 15 min and then leveled off. That means that the higher concentration of 10% CGBJ had the opposite effect on the whipping ability when compared to the lower concentrations (3 and 6% CGBJ). The decrease in the whipping ability of ice cream mixtures formulated with 10% could be related to the increase in structural viscosity (Fig. 1) and acidity content (Table 1). The increase in viscosity could have been the primary reason for the decrease in whipping abilities, as higher viscosity prevents air incorporation (Adapa et al., 2000; Marshall et al., 2003).

Frozen ice cream properties

The overrun of the CGBJ fortified ice cream formulations compared to plain ice cream is presented in Table 3. The overrun percentage of the ice cream varied depending on the concentrations of CGBJ. The overrun percentage was higher in T_1 (45.32 ±3.97%) and T_2 (49.26 ±3.02%) than that in plain ice cream (41.39 ±3.50%); the difference was significant only between T_2 and plain ice cream ($P < 0.05$). These results are in agreement with those found by Erkaya et al. (2012) in Cape gooseberry ice cream but differ from those found in shreds, pulp, preserve and candy ice cream (Goraya and Bajwa, 2015). The increase in the overrun percentage could be due to the addition of CGBJ up to 6% slightly improving the viscosity of the mixture (Fig. 1), which created a stable foam. However, T_2 exhibited a lower overrun percentage (35.82 ±3.54%) than other ice cream formulations. These results reveal that a high concentration of CGBJ negatively affects the overrun percentage, and agree with the ice cream containing 20% fig paste (Murtaza et al., 2004). The decrease in overrun at a high level of CGBJ (10%) may be related to the high viscosity and acidity content of the mixture. Marshall et al. (2003) observed that, as the viscosity increases, the rate of whipping decreases due to the weakening air incorporation. Bajad et al. (2016) reported that if the liquid is too viscous, it is difficult to integrate the air. Also, a high acidity content induced fat destabilization that was better characterized as coalescence, leading to a decrease in overrun percentage. Peng et al. (2018) have reported that fat coalescence can lead to the formation of thin lamellae between bubbles, which may ultimately destabilize the film and break the air bubble.

Fat destabilization is mechanical damage of fat globules in the ice cream freezer by shear forces and the ice crystallization process, which lead to agglomeration and partial coalescence of the fat globules (Goff and Jordan, 1989; Koxholt et al., 2001). The addition of CGBJ caused a significant increase in fat destabilization ($P < 0.05$); the increase was proportional to the additional level. Fat destabilizations of plain ice cream, T_1, T_2 and T_3 were 6.08 ±1.56, 10.56 ±1.69, 12.25 ±1.91 and 29.31 ±4.22%, respectively. However, the increase in fat destabilization of T_3 was more dominant than T_1, and T_2. A high positive correlation was found between the fat destabilization and acidity content of the ice cream mixture ($r^2 = 0.83$). Also, high levels of soluble constituents decrease freezing temperature and increase whipping times which increase the levels of destabilized fat (Muse and Hartel, 2004). However, there was no significant difference ($P > 0.05$) induced in fat destabilization between addition levels of 3 and 6% CGBJ.

Table 3. Overrun and fat destabilization of ice cream formulated with different levels of concentrated golden berry juice

Ice cream treatments	Overrun, %	Fat destabilization, %
Control	41.39^{bc} ±3.50	6.08^{c} ±1.56
T_1	45.32^{ab} ±3.97	10.56^{b} ±1.69
T_2	49.26^{a} ±3.02	12.25^{b} ±1.91
T_3	35.82^{c} ±3.54	29.31^{a} ±4.22

Means ±SD ($n = 3$) with the same letter (in column) are not significantly different ($P \leq 0.05$). Control – ice cream mixture without concentrated golden berry juice, T_1 – ice cream mixture with 3% concentrated golden berry juice, T_2 – ice cream mixture with 6% concentrated golden berry juice, T_3 – ice cream mixture with 10% concentrated golden berry juice.

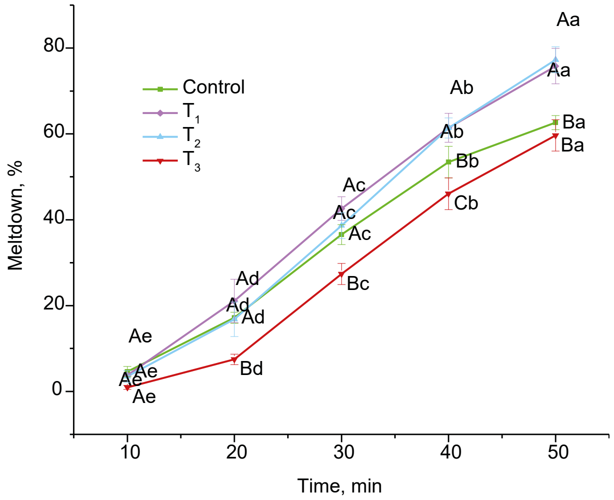

Fig. 3. The meltdown of ice cream formulated with different levels of concentrated golden berry juice. Means ±SD (n = 3) with the same capital letter (between treatments) and small letter (between time) are not significantly different ($P \leq 0.05$). Control – ice cream mixture without concentrated golden berry juice, T_1 – ice cream mixture with 3% concentrated golden berry juice, T_2 – ice cream mixture with 6% concentrated golden berry juice, T_3 – ice cream mixture with 10% concentrated golden berry juice

Some of the important desired quality parameters of frozen ice cream are slow melting and good shape retention (Goff et al., 1993). The melting of ice cream (g/100 g) formulated with different levels of golden berry juice powder is presented in Figure 3. After 10 min, the addition of CGBJ had no significant effect ($P > 0.05$) on the amount of melted ice cream as compared to plain ice cream; the melted amount of T_3 was the lowest ($P > 0.05$). Similarly, Erkaya et al. (2012) found that the first dripping time and complete melting time prolonged as the Cape gooseberry contents increased in the ice cream samples ($P < 0.05$). After 20 and 30 min, slight differences were observed in the amount of melted ice cream among T_1, T_2 and the control ice cream ($P > 0.05$). After 40 min, the melted amount of T_1 and T_2 was higher than that of the control ice cream ($P < 0.05$). Inversely, the melted amount of T_3 was the lowest; the difference was significant only at 20, 30 and 40 min ($P < 0.05$). These results reflect that the addition of the CGBJ at not more than 6% may slightly reduce the complete melting time of ice cream, while the addition of 10% CGBJ causes a significant increase ($P < 0.05$) in the melting resistance as compared to the control ice cream. The lower melting time could be due to increased viscosity fat destabilization and overrun as well as the lower freezing point (Muse and Hartel, 2004; Bajad et al., 2016). Increasing levels of destabilized fat increases the fat network which decreases the melting rate and aids retention of shape during melting (Tharp et al., 1998). Ice creams with high consistency coefficients had a greater resistance to flow (Marshall et al., 2003).

The sensory properties of plain and CGBJ-fortified ice cream are listed in Table 4. Ice cream formulated with CGBJ had variable sensory scores with different concentrations. The addition of CGBJ had no adverse effect ($P > 0.05$) on the appearance, body and texture and flavor scores. The T_2 had higher sensory scores, especially in flavor (8.57 ±0.53). It had a smooth texture,

Table 4. Sensory properties of ice cream formulated with different levels of concentrated golden berry juice

Ice cream treatments	Appearance	Melting quality	Body and texture	Flavor
Control	8.28^{a} ±0.48	8.36^{a} ±0.39	8.18^{a} ±0.48	7.85^{ab} ±0.69
T_1	7.86^{a} ±0.69	7.95^{a} ±0.45	8.00^{a} ±0.58	7.42^{bc} ±0.22
T_2	8.42^{a} ±0.53	8.32^{a} ±0.29	8.00^{a} ±0.57	8.57^{a} ±0.53
T_3	6.57^{b} ±0.78	6.27^{c} ±0.42	6.42^{b} ±0.97	6.71^{c} ±0.95

Means ±SD (n = 21) with the same letter (in column) are not significantly different ($P \leq 0.05$). Control – ice cream mixture without concentrated golden berry juice, T_1 – ice cream mixture with 3% concentrated golden berry juice, T_2 – ice cream mixture with 6% concentrated golden berry juice, T_3 – ice cream mixture with 10% concentrated golden berry juice.

orange color and a pleasant (mango) flavor. The yellow-orange color of golden berry juice is due to natural pigments such as carotenoids, which are affected by the stage of maturity of the fruit (Olivares-Tenorio et al., 2016). Inversely, T_3 received the lowest sensory scores compared with other ice cream samples ($P < 0.05$). It was characterized by a rough texture and a sour astringent taste. As the level of CGBJ increased, the acidity content (Table 1) and fat destabilization increased, whereas overrun decreased. These characteristics may have had an adverse effect on the sensory properties of the resultant ice cream. A similar trend was found in *Alma* ice cream by Goraya and Bajwa (2015) who found that mouthfeel and flavor scores dwindled with an augmented level of *Alma* powder incorporation.

CONCLUSION

CGBJ can be used as a natural source in the production of ice cream to enhance its physical properties, nutritive value, and flavor. The addition of CGBJ improves the viscosity, overrun, melting resistance and sensory attributes of the resultant ice cream. Also, CGBJ can be successfully used in the manufacture of ice cream as a good source of nutritive components including antioxidant components, vitamins and some elements, especially K, Fe, and Zn.

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