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Effects of Green Banana Flour on the Physical, Chemical and Sensory Properties of Ice Cream

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Summary

In the present study, possible effects of the addition of banana flour at different mass fractions (1 and 2 %) are investigated on physical (overrun, viscosity), chemical (dry matter, fat and ash content, acidity, pH, water and oil holding capacity and colour), mineral content (Ca, K, Na, P, S, Mg, Fe, Mn, Zn and Ni) and sensory properties of ice cream. Fibre-rich banana pieces were found to contain 66.8 g per 100 g of total dietary fibre, 58.6 g per 100 g of which were insoluble dietary fibre, while 8.2 g per 100 g were soluble dietary fibre. It can be concluded from these results that banana is a valuable dietary fibre source which can be used in food production. Flour obtained from green banana pulp and peel was found to have significant ($p<0.05$) effect on the chemical composition of ice creams. Sulphur content increased while calcium content decreased in ice cream depending on banana flour content. Sensory results indicated that ice cream sample containing 2 % of green banana pulp flour received the highest score from panellists.

Key words: dietary fibre, green banana, ice cream

Introduction

Banana (*Musa* spp.) is a plant species that grows in tropical and subtropical regions and is one of the main food supplies all over the world (*1,2*). Banana peel and unripe banana fruit are rich in dietary fibre and indigestible carbohydrates, proteins, essential amino acids, cellulose, hemicelluloses, lignin, starch, resistant starch, polyunsaturated fatty acids and potassium (*1,3–10*). This fruit also contains antioxidant compounds including polyphenols, catecholamines and carotenoids (*9,11–14*). Large quantities of green banana waste such as below-grade fruit or fruit with skin defects are turned into flour for the export industry (*10,15*). Nowadays, industrial flour production from green banana is of interest in view of its nutritional value, especially the high quantity of resistant starch (approx. 40.9–58.5 %; *16*) and dietary fibre (6.0–15.5 %; *3,10*), as well as bioactive compounds like phenolic acids (*10, 15*).

In the last years, some innovatively produced food types have attracted great attention of consumers for their health benefits, such as protection from diet-related diseases (*17*). Ice cream can fulfil such a function by serving as a means of delivering pro- and prebiotics (*18–20*). Dietary fibre can have several functional properties as prebiotic agents. Potential use of green banana pulp and peel flour may vary according to their chemical and functional properties (*1,2,4*). Among several advantages of using fruit fibre in ice cream production can be the improvement of the structure of ice cream due to their fibrous framework and melting properties, reduction of recrystallization, resulting in prolonged shelf life, and enhancement of the ice cream viscosities, allowing freezing at higher overrun, causing no negative effect on the ice crystal sizes, and leading to a more homogenous air bubble formation in the ice cream (*21,22*).

Ice cream producers are trying to develop new flavours and since they can add to a better taste and aroma, some fruits are added to enrich the ice cream (*23*). Green banana, in this respect, is acceptable to be a suitable source of dietary fibre and an ingredient for the food in-

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dustry. However, there is not enough data dealing with the functionality of dietary fibre in ice creams (*24*).

In spite of being a valuable nutritional component, the lack of use of green banana fibre in human diet constitutes a real nutritional loss because green banana fibre contains extractable bioactive compounds which can be used as value-added materials. Also, studies of the development of new products from green banana fibre are limited. The objective of the present study is to evaluate the functional properties of green banana fibre obtained from its peel and pulp for possible enrichment of the quality and nutritional content of ice cream.

Materials and Methods

Materials

Cow's milk and cream were purchased from the Research and Application Farm of Atatürk University, Erzurum, Turkey. Green banana fruits, sugar, salep and emulsifier (mono- and diglycerides) were purchased at the markets in Erzurum, Turkey, while skimmed milk powder was purchased from a commercial company, Pinar Dairy Products Co. (Istanbul, Turkey).

Preparation of green banana peel and pulp flour

The green banana peel was stripped off after the fruit (5 kg) was dipped in water and washed. The pulp was cut into transverse slices approx. 2 mm thick, and the slices of pulp and peel were dipped in 0.5 % (by mass per volume) citric acid solution for 10 min, drained and dried at 60 °C overnight to reduce enzymatic browning of the material. After draining and drying, pulp and peel slices were milled to produce flour in a Mill Laboratory (Thomas-Wiley, Model 4, Thomas Scientific, Swedesboro, NJ, USA) and passed through 60 and 40 mesh screens, respectively. As the result of the process, two types of flour were produced: flour obtained from green banana peel and flour obtained from green banana pulp (Fig. 1; 2). Both types were placed in impermeable plastic bags and stored at 18 °C for later analysis. Flour yield was calculated by dividing the amount of flour produced by the amount of green banana used, and the results were expressed as g of flour per kg of banana.

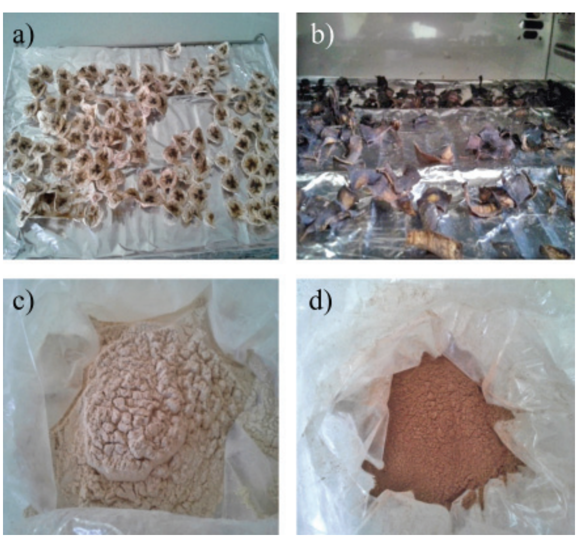

Fig. 1. Images of: a) dried green banana pulp, b) dried green banana peel, c) flour obtained from green banana pulp, and d) flour obtained from green banana peel

Chemical and physical composition of dietary fibre

Moisture was measured using gravimetric heating ((130±2) °C for 2 h) and 2 to 3 g of sample. Standard methods were used to analyse ash (*25*), while flour pH was determined with a pH meter (Mettler-Toledo AG, Schwerzenbach, Switzerland). Flour suspension (10 %, by mass per volume) was stirred for 5 min, stored for 30 min and filtered. The pH of the filtrated mixture was measured (*26*) and the viscosity of flour samples was calculated according to Fagbemi (*27*). The green banana flour was dispersed in water at 8 % (by mass per volume) using a magnetic stirrer (1000 rpm) and heated from 30 to 95 °C in a shaking water bath (Memmert GmbH, Schwabach, Germany) and kept at this temperature for 20 min. Viscosity measurement was performed using a digital Brookfield viscometer, model DV-II (Brookfield Engineering Laboratories, Stoughton, MA, USA). The colour of the flour was monitored using Chroma Meter CR–200 colourimeter (Minolta, Osaka, Japan). Mass fractions of insoluble dietary fibre and soluble dietary fibre were assessed using the method of Prosky *et al.* (*28*). The total dietary fibre was calculated as the sum of insoluble and soluble dietary fibre. The total starch was determined by using the method of Goñi *et al.* (*29*).

Total phenolic content of green banana peel and pulp flour was determined according to Bunzel *et al.* (*30*). A mass of approx. 0.9 g of sample was added to 50 mL of aqueous solution of NaOH (1 mol/L) in vacuum in the dark at 25 °C for 18 h. Acidity of this mixture was increased by adding 9.5 mL of HCl (pH<2). Then, the mixture was centrifuged for 15 min at 12 000×*g* (6 °C). The total phenolic content was evaluated using Folin-Ciocalteu method (*31*).

Water and oil holding capacity

A volume of 25 mL of distilled water or commercial olive oil was mixed with 1 g of dry sample. The mixture was stirred and incubated at 40, 60 or 80 °C for 1 h. Tubes were centrifuged at 3000×*g* for 20 min and then the supernatant was poured out. After that, the tubes were drained for 10 min by putting them at the angle of 45°. The residue was weighed and water holding capacity (WHC, in g of water per 100 g of sample) and oil holding capacity (OHC, in g of oil per 100 g of sample) were calculated (*1*).

Ice cream manufacture

The ice cream samples were prepared in the Pilot Plant of Food Engineering Department, Agriculture Faculty, Atatürk University, Erzurum, Turkey. First, fat content of cow's milk was adjusted to 6 % by adding cream and the prepared milk was separated into five equal portions of 2 kg. Skimmed milk powder 125 g, sugar 405 g, stabilizer (salep) 16.2 g and emulsifier (mono and diglycerides) 6.75 g were added to these milk samples. Flour samples obtained from both banana peel and pulp were also added to the milk samples (65 °C) at two different mass fractions (1 and 2 %). The final mixtures were subjected to pasteurisation at 85 °C for 20 min and stored at 4 °C for 24 h, after which they were placed in an ice cream machine at −5 °C to freeze (Ugur Cooling Machineries Co., Nazilli, Turkey) and then at −22 °C for 24 h to harden. They remained at −18 °C during all physical, chemical, mineral and sensory analyses. Ice cream samples were produced in duplicate.

Ice cream analysis

Dry matter, fat, ash and mineral contents, acidity (°SH), pH, colour, total phenolic content, WHC and OHC were determined in the scope of the chemical analyses. Dry matter, fat and ash contents, °SH and pH of ice cream samples were determined using the method of Demirci and Gündüz (*32*). Mineral contents (Ca, K, Na, P, S, Mg, Fe, Mn, Zn and Ni) of ice cream samples were detected by means of an inductively coupled plasma optical emission spectrophotometer (Optima 2100 DV ICP-OES, PerkinElmer, Shelton, CT, USA) following the method described by Güler (*33*). Samples were decomposed in a microwave oven (Berghof speedwave MWS–2, Eningen, Germany). A mass of 0.5 g of ice cream sample was weighed into the digestion vessels. To each sample 10 mL of concentrated nitric acid were added and the mixtures were kept at 210 °C and 1.2 Pa·s for 10 min. Carousels were taken out of the oven, then 30 % hydrogen peroxide (2 mL) was added into the samples and a second digestion was applied at 195 °C and 6.5 Pa·s for 5 min. The vessels were capped immediately after the addition of oxidants. The digestion process was ended by diluting the samples with distilled water and filtering them through Whatman no. 42 filter paper (GE Healthcare Life Sciences, Maidstone, UK). All diluted digests were analysed using Optima 2100 DV inductively coupled plasma optical emission spectrophotometer (PerkinElmer).

Physical analyses were conducted to determine the overrun and viscosity of ice cream samples. Overrun was detected by the method proposed by Jimenez-Florez *et al.* (*34*) and calculated using the following equation:

$$\text{Overrun}=[V(\text{ice cream})-V(\text{mix})/V(\text{mix})]\cdot 100 \qquad /1/$$

where V is volume.

Time period (in s) from the first dripping to complete melting was determined using the method of Güven and Karaca (*35*). Samples of 25 g were heated to melt at room temperature (20 °C) by putting them on a beaker capped with a 0.2-cm wire mesh screen.

Viscosity of the ice cream samples was measured at 4 °C using a digital Brookfield viscometer, model DV-II (Brookfield Engineering Laboratories). Before viscosity measurement, air bubbles were removed from samples by stirring (*36*).

The colour parameters of ice cream samples were determined by measuring L^* (brightness, 0 black, 100 white), a^* (+ red, – green) and b^* (+ yellow, – blue) values with Chroma Meter CR-200 colourimeter (Minolta), which was calibrated using a white reference plate under standard daylight (C) and the standard observer at 2°.

Sensory assessment

Eight professional panellists from the Food Engineering Department at Atatürk University, Erzurum, Turkey, evaluated the ice cream samples using a score test for flavour, body and texture, colour and appearance, resistance to melting and general acceptability. Hardened ice cream samples were tested at a serving temperature of −10 °C and given scores for their sensory characteristics in a scale ranging from 1 (poor) to 9 (excellent). Warm water and bread were also served to the panellists to cleanse their palates before each sample. All panellists were preferred to be non-smokers and have had prior tasting experience of a variety of dairy products including milk, cheese and ice cream and had previously used flavour profile procedures adapted from Roland *et al.* (*37*).

Statistical analysis

A total of five experimental groups were formed: two types of flour (from green banana peel and from green banana pulp), two fibre mass fractions (1 and 2 %), and a control group without the fibre. Data obtained were statistically analysed using the SAS software package (*38*). PROC ANOVA was used for variance analysis and significance level was determined using Duncan's multiple range tests (*39*).

Results and Discussion

Mean yield of green banana peel and pulp flour was calculated to be 40.3 and 172 g/kg, respectively. The pulp was found to give larger amount of flour than peel. Table 1 shows the gross chemical composition of the cow's milk, skimmed milk powder, cream and banana used in the production of ice cream samples.

Table 1. The gross chemical and physical properties, and mineral contents of raw milk, skimmed milk, cream and green banana

Analysis	Milk	Skimmed milk powder	Cream	Green banana
w(dry matter)/%	11.37	95.17	65.00	70.19
w(fat)/%	3.50	1.00	63.76	0.18
w(ash)/%	0.67	n.d.	n.d.	0.35
Acidity/°SH	5.81	n.d.	13.98	3.30
pH	6.40	n.d.	4.95	5.00
w(minerals)/(mg/kg)				
Ca	1224.00			729.18
K	1397.00			1492.54
Mg	91.67			101.40
P	869.54			918.00
Na	327.90			265.60
Fe	13.56			42.06

n.d.=not determined

Chemical and physical characteristics of flour samples

For chemical characterization of flour samples produced from green banana peel and pulp moisture, colour, total phenolic, ash and fat contents, WHC and OHC were determined and for physical characteristics viscosity and overrun were measured (Table 2). Green banana peel flour was found to have higher moisture content (11.06 %) than the green banana pulp flour (9.87 %).

As can be seen in Table 2, ash content of green banana peel and green banana pulp flour was found to be 4.4 and 3.10 %, respectively. Rodríquez-Ambriz *et al.* (*1*) found that banana flour had an ash content of 4.4 %, while Juárez-Garcia *et al.* (*40*) found this rate to be 4.7 %. These findings are in agreement with the findings of the present study. Pulp taken from green banana contains high rate of starch: 73.4 % (*40*), 77.0 % (*41*) and 76.8 % (*1*), which is also supported by the findings in the present study (60.6 % in green banana peel flour and 73.8 % in green banana pulp flour).

With the increase in temperature, mean value of WHC also showed an increase in all flour samples. The green banana pulp flour had significantly higher WHC at 60 and 80 °C than at 40 °C. During its preparation amylase was probably released, which has the capacity of binding water molecules effectively, thus its WHC is higher than that of banana peel flour. The WHC value of green banana peel flour (4.46 g of water per g of dry sample at 40 °C) obtained in the present study is higher than that reported by Rodríguez-Ambriz *et al.* (*1*) in banana flour (2.5 g of water per g of dry sample). Alkarkhi *et al.* (*2*) reported WHC values of banana flour samples to range between 1.4 and 8.2 g of water per g of dry sample.

Table 2. Chemical and physical properties of green banana peel and pulp flour

Parameter	Green banana peel flour	Green banana pulp flour
w(dry matter)/%	(11.06±0.08)	(9.87±0.02)
w(ash)/%	(4.4±0.2)	(3.10±0.09)
pH	(4.51±0.02)	(4.84±0.01)
Viscosity/(Pa·s)	(4.5±0.4)	(3.2±0.9)
L^*	(38.02±0.02)	(77.5±0.7)
a^*	(5.64±0.06)	(3.49±0.01)
b^*	(20.13±0.04)	(13.54±0.05)
w(SDF)/%	(8.2±0.1)	(8.8±0.1)
w(IDF)/%	(58.6±1.2)	(40.8±0.3)
w(TDF)/%	(66.8±1.3)	(49.6±0.4)
w(total starch)/%	(60.6±0.6)	(73.8±0.3)
WHC 40	(4.46±0.01)	(3.25±0.05)
WHC 60	(4.87±0.02)	(5.20±0.02)
WHC 80	(5.60±0.04)	(6.42±0.01)
OHC 40	(0.4±0.0)	(0.4±0.0)
OHC 60	(0.57±0.01)	(0.42±0.01)
OHC 80	(0.9±0.3)	(0.68±0.01)
w(total phenolics)/(g per 100 g)	(0.8±0.0)	(0.61±0.01)

L^*=lightness, a^*=redness (+), b^*=blueness (–); SDF=soluble dietary fibre, IDF=insoluble dietary fibre, TDF=total dietary fibre, WHC=water holding capacity (g of water per g of sample at 40, 60 and 80 °C), OHC=oil holding capacity (g of oil per g of sample at 40, 60 and 80 °C)

Oil holding capacity is among the important functional properties of banana flour and an increase was also observed in the majority of samples with the increase of temperature, ranging from 0.4–0.9 to 0.4–0.7 g of oil per g of dry sample at 40–80 °C in both types of flour. When compared to the results of previous studies, these values are lower than that (2.2 g of oil per g of dry sample) found in the study of Rodríquez-Ambriz *et al.* (*1*), while they are in agreement with those obtained from banana flour containing 0.5 and 1.3 g of oil per g of dry sample (*2*).

In the present study, mean L^* value ranged from 38.02 to 77.5. By monitoring the samples it was found that the flour obtained from the peel had darker colour than that from the pulp. Due to the possible existence of some browning enzymes like polyphenol oxidase and the occurrence of Maillard reaction (*42*), significant colour change was observed during peel drying process, resulting in the production of dark brown powder from the peel. Alkarkhi *et al.* (*2*) reported an L^* value between 37.6 and 74.2, which is in agreement with the results obtained in this study.

Mean viscosity ranged from 3.2 to 4.5 Pa·s. Such a range in the presence of starch is associated with the gelatinisation and pasting characteristics. In the cases when green banana flour is used, viscosity and texture may be improved due to the starch gelatinisation. Alkarkhi *et al.* (*2*) reported viscosity values between 4.1 and 8.8 Pa·s.

Antioxidants play an important role in the prevention of oxidative stress-related diseases. Quantitatively, the main dietary antioxidants are polyphenols, followed by vitamins and carotenoids (*43*). Goñi *et al.* (*44*) informed that polyphenols associated with polysaccharides and proteins in cell walls are significant constituents of dietary fibre. Table 2 shows polyphenolic contents of green banana peel and pulp flour types. Green banana peel flour was found to have a higher content of polyphenols (0.8 g per 100 g).

Total dietary fibre (TDF) content in the banana peel flour was found to be 66.8 g per 100 g (Table 2), majority of which was represented by insoluble dietary fibre (IDF; 58.6 g per 100 g) while the rest were soluble dietary fibre (SDF; 8.2 g per 100 g). Compared to this finding, in fibre-rich fraction of chia (*Salvia hispanica*), Vázquez-Ovando *et al.* (*45*) reported TDF, IDF and SDF contents to be 3.01, 56.46 and 53.45 g per 100 g respectively, while in orange peel, TDF, IDF and SDF were determined by Chau and Huang (*46*) to be 57, 47.6 and 9.4 g per 100 g respectively, and in guava these rates were 64.1, 55.2 and 8.9 g per 100 g respectively, found by Ruales and Zumba (*47*). Findings given above are in agreement with those found in the present study. Relatively higher IDF fraction found in banana flour suggests its possible applications in dietetic products.

Physical and chemical characteristics of ice cream samples

The results of physical and chemical analyses and mineral contents of ice cream samples are given in Tables

3 and 4. The dry matter content of control sample was lower than that of other samples at significant levels ($p<0.05$). The dry matter content of ice cream increased with the addition of green banana flour. As can be seen in Table 3, the addition of the dietary fibre affected significantly fat and acidity values ($p<0.05$). The pH values of ice cream samples were not statistically different, which may be affected by the pH of banana (pH=5.00).

Viscosity, accepted to be among the significant characteristics of ice cream mixture, may result in good body and texture properties in the production process of ice cream. From this point of view, it is important to measure the viscosity to determine how green banana flour may affect the characteristics of an ice cream mixture. It can be seen that the addition of green banana flour ($p<0.05$) affected the viscosity behaviour of ice cream samples significantly (Fig. 2). As shown in Fig. 2, the lowest viscosity value was obtained in control (C) sample and the highest in sample A (with 2 % banana peel flour added). These findings are in agreement with the results of Hwang *et al.* (*48*) of the ice cream samples with grape wine lees, Erkaya *et al.* (*49*) of ice cream samples with Cape gooseberry (*Physalis peruviana* L.) and Dervisoglu and Yazici (*22*) of ice cream samples with citrus fibre.

The L^* values of ice cream samples were close to each other but those of B1 and B2 samples were significantly higher than the others (Table 3). All of the samples taken into consideration were found to have negative greenness rates, while A1 and A2 samples seem to be similar to and sometimes higher than the others. Colour rates of the samples were affected favourably by an increase in the mass fraction of banana fibre ($p<0.05$). Samples had negative a^* values and that of A2 sample was significantly higher than of the other samples. The b^* values increased with the addition of banana peel fibre. Samples B1 gave the lowest b^* rate, while the highest rate was measured of sample A2. Dervisoglu and Yazici (*22*) reported that the addition of citrus fibre increased the colour properties

Table 3. Effect of the addition of green banana peel and pulp flour on the gross chemical composition and physicochemical properties of ice cream

Parameter	C	A1	A2	B1	B2
w(dry matter)/%	$(34.12\pm0.01)^{c}$	$(33.51\pm0.06)^{b}$	$(33.02\pm0.01)^{a}$	$(34.26\pm0.01)^{d}$	$(34.60\pm0.06)^{e}$
w(ash)/%	$(0.91\pm0.01)^{a}$	$(1.17\pm0.07)^{c}$	$(1.21\pm0.01)^{c}$	$(0.88\pm0.01)^{a}$	$(1.02\pm0.03)^{b}$
w(fat)/%	$(4.6\pm1.4)^{d}$	$(4.2\pm0.4)^{b}$	$(4.2\pm0.4)^{a}$	$(4.3\pm0.4)^{c}$	$(4.6\pm0.0)^{d}$
Acidity/%	$(0.2\pm0.1)^{e}$	$(0.12\pm0.03)^{a}$	$(0.13\pm0.03)^{b}$	$(0.14\pm0.03)^{c}$	$(0.2\pm0.0)^{d}$
pH	$(6.20\pm0.02)^{a}$	$(6.35\pm0.07)^{b}$	$(6.49\pm0.01)^{c}$	$(6.47\pm0.01)^{c}$	$(6.22\pm0.01)^{a}$
L^*	$(88.5\pm2.5)^{e}$	$(-77.6\pm0.9)^{b}$	$(-72.3\pm1.1)^{a}$	$(87.1\pm11.5)^{d}$	$(86.2\pm2.5)^{c}$
a^*	$(1.62\pm0.05)^{c}$	$(-4.54\pm0.05)^{d}$	$(-6.69\pm0.08)^{e}$	$(-0.29\pm0.02)^{a}$	$(-1.05\pm0.03)^{b}$
b^*	$(8.06\pm0.01)^{a}$	$(9.61\pm0.01)^{c}$	$(10.45\pm0.07)^{d}$	$(9.16\pm0.02)^{b}$	$(9.3\pm0.1)^{b}$
Overrun/%	$(40.5\pm1.2)^{c}$	$(31.7\pm1.7)^{b}$	$(29.8\pm0.9)^{ab}$	$(28.7\pm1.8)^{a}$	$(28.2\pm1.7)^{a}$
Melting ratio/(g/min)	$(0.4\pm0.3)^{b}$	$(0.5\pm0.0)^{c}$	$(0.47\pm0.02)^{bc}$	$(0.36\pm0.01)^{a}$	$(0.4\pm0.0)^{a}$

Mean values followed by different letters in superscript in the same row are significantly different ($p<0.05$). C=control (ice cream without banana flour), A1=1 % (by mass) banana peel flour added, A2=2 % (by mass) banana peel flour added, B1=1 % (by mass) banana pulp flour added, B2=2 % (by mass) banana pulp flour added

Table 4. Mineral content of ice cream samples containing banana flour

Mineral	w(mineral)/(mg/kg)				
	C	A1	A2	B1	B2
Ca	$(1844.4\pm12.5)^{e}$	$(1723.0\pm2.8)^{d}$	$(1547.5\pm2.1)^{c}$	$(1214.5\pm0.7)^{b}$	$(1129.0\pm1.4)^{a}$
K	$(1654.6\pm41.8)^{a}$	$(1905.0\pm7.1)^{c}$	$(2140.0\pm14.1)^{d}$	$(1716.5\pm12.0)^{b}$	$(1745.0\pm2.8)^{b}$
Na	$(529.2\pm9.9)^{a}$	$(564.1\pm6.4)^{d}$	$(572.5\pm1.4)^{e}$	$(537.7\pm6.4)^{b}$	$(548.1\pm6.4)^{c}$
P	$(964.8\pm32.1)^{a}$	$(1369.6\pm14.8)^{d}$	$(1430.6\pm2.3)^{e}$	$(1091.3\pm9.4)^{b}$	$(1279.6\pm26.3)^{c}$
S	$(938.7\pm17.5)^{a}$	$(1015.0\pm7.1)^{c}$	$(1074.6\pm5.6)^{d}$	$(928.6\pm4.2)^{a}$	$(980.5\pm0.7)^{b}$
Mg	$(159.3\pm1.4)^{a}$	$(193.0\pm2.8)^{c}$	$(164.0\pm1.4)^{a}$	$(194.0\pm1.4)^{c}$	$(181.0\pm8.5)^{b}$
Fe	$(10.8\pm0.2)^{a}$	$(92.6\pm1.3)^{d}$	$(97.4\pm1.6)^{e}$	$(69.4\pm1.6)^{b}$	$(71.4\pm1.9)^{c}$
Mn	$(0.32\pm0.01)^{a}$	$(0.4\pm0.8)^{d}$	$(0.5\pm1.6)^{e}$	$(0.3\pm0.6)^{b}$	$(0.4\pm0.3)^{c}$
Zn	$(57.8\pm0.9)^{a}$	$(117.0\pm2.8)^{d}$	$(201.5\pm2.1)^{e}$	$(82.8\pm7.4)^{b}$	$(96.0\pm1.4)^{c}$
Ni	$(0.97\pm0.06)^{a}$	$(1.2\pm0.1)^{b}$	$(1.4\pm0.1)^{c}$	$(1.0\pm1.2)^{a}$	$(0.83\pm0.01)^{a}$

Mean values followed by different letters in superscript in the same row are significantly different ($p<0.05$). C=control (ice cream without banana flour), A1=1 % (by mass) banana peel flour added, A2=2 % (by mass) banana peel flour added, B1=1 % (by mass) banana pulp flour added, B2=2 % (by mass) banana pulp flour added

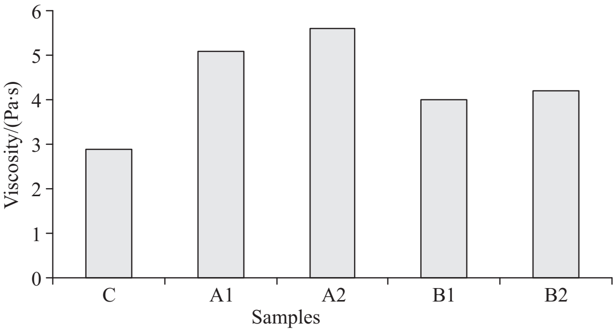

Fig. 2. Viscosity values of ice creams containing green banana flour. C=control (ice cream without banana flour), A1=1 % (by mass) banana peel flour added, A2=2 % (by mass) banana peel flour added, B1=1 % (by mass) banana pulp flour added, B2=2 % (by mass) banana pulp flour added

and these results are in agreement with the results of the present study.

Overrun and melting are associated with the volume of air involved in the manufacturing process. This property can shape the structure of the final product because the air present in the ice cream can provide light texture and affect some physical properties, such as melting and hardness (*50–52*). All of the ice cream samples in the present study showed much lower overrun values (28.2–40.5 %) than those reported in literature (80–120 %). Although the addition of green banana flour lowered the overrun rate of the ice cream samples ($p>0.05$), the control samples showed higher overrun rates than the samples containing green banana flour. Since the viscosity of ice cream increased with the addition of banana flour, it was possible that less air was incorporated in the ice cream mixture with green banana flour during batch freezing, which resulted in lower overrun than in the control (without green banana flour). The decrease of overrun rates of ice cream samples with banana flour was found to be in agreement with those presented in the related literature (*53*,*54*). The results of the study carried out by El-Samahy *et al.* (*55*) show that overrun decrease in ice cream with the addition of concentrated cactus pear pulp could be dependent on the increase in the viscosity of the mixture. Hwang *et al.* (*48*) reported that the overrun values of ice cream samples decreased significantly with the addition of grape wine lees. It was found by Sun-Waterhouse *et al.* (*56*) that the overrun rate of the ice cream containing green kiwifruit was 90.5 %, which is higher than that in the present study. Results similar to those in the present study were found by Erkaya *et al.* (*49*) in the ice cream with added Cape gooseberry (*Physalis peruviana* L.).

As can be seen in Table 3, the time period required for melting process to complete in ice cream samples in the present study was found to be significantly longer in samples A1 and A2. The ice cream sample A1 had the longest complete melting time (0.5 g/min), while sample B1 had the shortest complete melting time (0.36 g/min). It was suggested by Akın *et al.* (*36*) that the reason for slower melting of ice cream with added inulin might be the ability of inulin to prevent water molecules from moving freely. The mass fraction of the added banana peel flour (samples A1 and A2) affected the first dripping time positively (Table 3). Results of the present study indicate that the length of time until the first dripping was prolonged as a consequence of the increase in banana pulp content in the ice cream samples ($p<0.05$). Dervisoglu and Yazici (*22*) reported that ice cream samples with citrus fibre had longer dripping times. These findings are in agreement with the findings in the present study.

Mineral analyses are essential to determine the quality and safety of milk and milk products. Table 4 shows the changes in mineral content of ice cream samples. The addition of green banana flour decreased significantly the Ca content in the ice cream compared to control. This is not surprising because milk and milk products are also an important dietary source of calcium (*57*). The contents of K, Mg and P in ice cream samples increased significantly. The increase in the content of these minerals may be due to high mass fractions of K, Mg and P in banana. As seen in Table 4, K content in banana pulp was between 1716.5 and 1745.0 mg/kg. Sample A2 had the highest K mass

Table 5. Sensory properties of ice cream samples containing green banana flour

Sensory property	Score				
	C	A1	A2	B1	B2
Colour	$(8.0\pm0.5)^{a}$	$(7.8\pm0.8)^{a}$	$(7.6\pm0.7)^{a}$	$(7.8\pm0.8)^{a}$	$(7.6\pm0.7)^{a}$
Body and texture	$(7.6\pm0.7)^{a}$	$(7.9\pm0.7)^{a}$	$(7.6\pm0.5)^{a}$	$(7.4\pm0.6)^{a}$	$(7.9\pm0.8)^{a}$
Resistance to melting	$(7.2\pm0.8)^{a}$	$(7.7\pm0.8)^{a}$	$(7.5\pm1.0)^{a}$	$(7.3\pm0.8)^{a}$	$(7.4\pm1.0)^{a}$
Taste	$(7.2\pm0.6)^{a}$	$(7.8\pm0.6)^{bc}$	$(7.3\pm0.5)^{ab}$	$(7.4\pm0.8)^{abc}$	$(7.9\pm1.0)^{c}$
Creaminess	$(6.9\pm0.8)^{a}$	$(7.9\pm0.8)^{b}$	$(7.8\pm0.8)^{b}$	$(7.6\pm0.8)^{b}$	$(7.4\pm0.7)^{ab}$
Mouthfeel	$(7.6\pm0.9)^{a}$	$(8.1\pm0.6)^{a}$	$(7.4\pm0.8)^{a}$	$(7.8\pm1.0)^{a}$	$(7.8\pm1.1)^{a}$
Gumming structure	$(7.1\pm0.6)^{a}$	$(7.9\pm0.8)^{b}$	$(7.4\pm0.6)^{ab}$	$(7.2\pm0.7)^{a}$	$(7.7\pm1.0)^{ab}$
Banana flavour	$(7.2\pm0.9)^{a}$	$(7.6\pm0.7)^{a}$	$(7.3\pm0.6)^{a}$	$(7.8\pm0.7)^{a}$	$(7.4\pm1.0)^{a}$
Unacceptable taste	$(7.8\pm1.0)^{a}$	$(7.9\pm0.6)^{a}$	$(7.7\pm0.7)^{a}$	$(8.0\pm1.0)^{a}$	$(8.1\pm0.9)^{a}$
General acceptability	$(7.3\pm0.7)^{a}$	$(7.8\pm0.7)^{ab}$	$(7.3\pm0.4)^{a}$	$(7.3\pm0.7)^{a}$	$(7.9\pm1.0)^{b}$

Mean values followed by different letters in superscript in the same row are significantly different ($p<0.05$). C=control (ice cream without banana flour), A1=1 % (by mass) banana peel flour added, A2=2 % (by mass) banana peel flour added, B1=1 % (by mass) banana pulp flour added, B2=2 % (by mass) banana pulp flour added fraction (2140.0 mg/kg). It is widely known that fruits and vegetables are important mineral sources. Sample A2 had the highest S mass fraction of 1074.6 mg/kg, while sample B1 had the lowest of 928.6 mg/kg. Dagdemir (*52*) reported that Na content of ice cream samples decreased significantly when vegetable marrow (*Cucurbita pepo* L.) was added. Erkaya *et al.* (*49*) found that Na content in samples containing Cape gooseberry (*Physalis peruviana* L.) increased, and the highest Na values were determined in the sample with 15 % Cape gooseberry at 638.6 mg/kg. In our study, Na values increased in the samples with added green banana fibre. The addition of green banana peel flour increased significantly the Na content of ice creams compared to the other samples. Sample A2 had the highest Zn content (201.5 mg/kg). It was stated by Wu *et al.* (*58*) that Zn can take some vital roles by serving as a nonenzymatic antioxidant and protecting cells from oxidative damage. Even if green banana flour contains small doses of Fe, Zn, Ni and Mn, which can contribute to the antioxidant activity of fruit (*59*), its addition to the ice cream seems to have increased significantly the contents of Fe, Zn and Mn ($p<0.05$). Similar results were reported by Erkaya *et al.* (*49*) in Cape gooseberry (*Physalis peruviana* L.) added to ice cream.

Sensory evaluations

Results of the sensory evaluation of samples on a scale from 1 (poor) to 9 (excellent) are shown in Table 5. Sensory properties of the ice cream samples were found to be affected significantly by the addition of 2 % banana peel flour (sample A2). Panellists preferred the ice cream with the addition of 2 % banana pulp flour (sample B2) rather than the control and other samples. The addition of banana flour had significant effects ($p<0.05$) on the scores for colour, body and texture, resistance to melting, taste, creaminess, mouth feel, gumming structure, banana flavour, unacceptable taste and general acceptability. The acceptability of ice cream sample produced using only 2 % banana peel flour (sample A2) had the lowest score.

Conclusion

The enrichment of ice cream with green banana flour is an effective way to enhance nutritional and physiological aspects of the final product by influencing its rheological and thermal properties. Banana fibre alone or with ice cream stabilisers was successfully used in the ice cream production. The addition of green banana flour affected moisture, acidity, fat and ash contents and viscosity positively, but meltdown, colour and overrun were affected negatively. Based on the results, it can be concluded that green banana flour can be used in the ice cream formulation successfully. Therefore, the data in our study may provide the basis for future research.

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