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Research Article

Functional Low Fat Ice Cream Manufactured with Pomegranate By-Products or Its Juice

[1]Khalil, R.A.M.; [1]El-Safty, M.S.; 1Ahmed, H.A.; [2]Wafaa A. Mahmoud and [2]Shimaa Sh. Mohammed

[1]Department of Dairy, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt.

[2]Department of Dairy, Food Science and Technology Institute, Agricultural Research Center, Giza, Egypt

Abstract

Background and Objective: The aim of this study was to investigate the effect of adding pomegranate by-products as functional ingredient with compared by its juice on the physicochemical, rheological, melting rates, total phenolic compounds, antioxidant scavenging activity, sensory characteristics and cost of production of low fat ice cream. Control 6% fat was made for comparison the impact of several additives on low fat quality characteristics. All other low fat ice cream treatments were made with 1.5% fat; the first was made without any additives as a control low fat (CLF). Pomegranate juice (PJ) was used at ratios 10, 15 and 20% to act as T1, T2 and T3 respectively. Pomegranate peel (PP) was used at ratios 3, 6 and 9% to act as T4, T5 and T6 respectively. While, whole pomegranate pulp (WPP) was used at ratios 4, 8 and 12% to act as T7, T8 and T9 respectively. Control ice cream had higher rheological characteristics, pH value and higher sensory properties with lower melting down rates and had higher production cost than those made from low fat ice cream. Using PJ increased the flavour scores, total phenolic compounds and antioxidant scavenging activity than CLF with lower rheological characteristics than CLF. While using PP or WPP caused an increase for the rheological characteristics, melting resistance and higher sensory properties with lower production cost. It can be concluded that using 3% pomegranate peel in low fat ice cream improved rheological characteristics, body & texture scores and total acceptability scores without a noticeable effect on flavour scores. While using 8% whole pomegranate pulp improved the quality characteristics of the resultant low fat ice cream with total acceptability scores close as possible to full fat counterpart with reduction of the production cost by 23.13% as compared to full fat ice cream.

Key words: Functional Ice cream, Pomegranate juice, Peel, low fat ice cream, Antioxidant activity, Rheological properties, Organoleptic properties, Cost of production

INTRODUCTION

Ice cream is an aerated highly nutritive, complex food, containing proteins, fat, sugars, minerals, and different flavours. Milk fat has long been recognized as a critical parameter for the formation and support of structural characteristics of ice cream as well as for the perceived textural quality[1, 2]. It is a common view that high saturated fat intake is correlated with several chronic diseases such as obesity, cardiovascular diseases and cancer[3]. Reduction of the fat content in ice cream mixes led to a product of high melting rate, inferior body texture with fewer visible air bubbles and lower richness in taste as compared to full fat ice cream[4]. Accordingly, the food industry is facing the challenge of probing for new alternatives for fat without any quality loss[3].

Consumption of dairy products is associated with nutritional and beneficial health effects. Also, dairy products have served as vehicles for functional food ingredients over the last 20 years, such as phytochemical compounds and probiotic bacteria. Furthermore, dairy products have been rich sources for the development of a large number of health promoting food ingredients[5].

Generally, using food processing by-products for its bioactive healthy compound and nutrients has created added value benefit[6]. Also a challenge to enhance food security and nutrition situation based on novel application of available food processing by-products without sacrificing the environment and to render the concept of sustainable functional foods into marketable products that is acceptable to consumers[7,8].

The development of novel food and/or functional food products is increasingly challenging, as it has to fulfill the consumer's expectations for products that are simultaneously palatable and healthy[9]. Compared to conventional foods, the development of functional components and technological solutions can be demanding and expensive, and needs of a tight strategy between research and business. All this occurs in a context where functional food markets are continuously changing[10,11].

Pomegranate (*Punica granatum* L.) is an important tree of the tropical and subtropical regions of the world. The edible part of the fruit is called arils which were found to be a rich source of polyphenols as gallic acid, chlorogenic acid, protocatechinuie acid, caffeic acid, coumaric acids, ferulic acid and catechin[12]. Pomegranate contains phytochemicals compounds which identified to be flavonoids, condensed tannins and hydrolysable tannins[13,14]. Pomegranate fruit have been used to increase the functionality and antioxidant activity of foodstuffs[15,16]. Additionally, pomegranate juice with yoghurt had negative effect on its rheological characteristics[17,18].

It was thought that inclusion of pomegranate juice or its by-products in ice cream mix can improve the quality of low fat ice cream and decrease the production cost of the product. The aim of this study was to investigate the effect of adding pomegranate by-products on the physicochemical, rheological, total phenolic compounds, antioxidant scavenging activity, sensory characteristics and cost of production of low fat ice cream.

MATERIALS AND METHODS

Study area: The study was carried out at the Department of Dairy, Faculty of Agriculture, Suez Cananl University, Ismailia, Egypt from October 2019-August, 2020.

Materials: Mature pomegranate fruit; Wonderful variety, was purchased from the local market, Ismailia governorate, Egypt. Fresh cream (50% fat and 4.5% SNF) was obtained from the Pilot Plant of Dairy Department, Faculty of Agriculture, and Suez Canal University. Imported skim milk powder (97% TS, product of Dairy America^{TM}, USA), commercial grade sugar (sucrose) and vanilla were obtained from the local market, Ismailia governorate. Lacta 9090 (mix of mono & diglyceride, carrageenan, guar gum, carboxy methyl cellulose (CMC), cow gelatin and locust bean gum) was obtained from Misr Food Additives – MIFAD. 2, 2-diphenyl-1-picrylhydrazyl (DPPH) was purchased from Sigma Chemical Co. (Saint Louis, MO, USA). Solvents and all other chemicals used were of analytical grade.

Preparation of pomegranate juice or peel or whole pulp:-

Pomegranate fruits were washed many times using tap water, heated 75ºC/ 2 min., cooled, cut persistent calyx and then divided into two portions. First was used to prepare whole pomegranate pulp (WPP) though cutting into small parts and blended (using Braun PowerMax MX 2000 Blender, Germany), followed by homogenization at 6000 rpm/min for 5 minutes. Second portion was cut into several parts to separate the peel and arils. Arils were blended, homogenized at 6000 rpm/min for 5 minutes to prepare pomegranate juice (PJ) and removed the insoluble fraction. While pomegranate peel was blended and homogenized at 6000 rpm/min for 5 minutes to prepare pomegranate peel (PP). The resultant homogenous pomegranate juice, peel and whole were kept at 5 ºC until used.

Manufacture of ice cream:-

Ice cream mixes (Table 1) were prepared according to the method described by Marshall and Arbuckle[19]. Skim milk powder was first mixed with sugar and Lacta 9090 to generate a "dry mix". Fresh skim milk was preheated to 40°C, fresh cream was added, temperature was raised to 65°C and the "dry mix" was slowly added with gentle stirring. The mixture was heated for 80°C/ 5 min., followed by cooling to 4-5°C. Vanilla powder was added during cooling and aging at 5°C to both control and control low fat ice cream. While other treatments used pomegranate juice or peel or whole pulp were added after aging and before pre-freezing. Eleven treatments were carried out. The resultant treatments were stored at -20 ºC for 30 days. Treatments were planned as follows:

C: 6% fat, 10% solids not fat (S.N.F), 15% sugar and 0.5% and Lacta 9090 as control ice cream. While all other low fat treatments included 1.5% fat, 13% S.N.F, 15% sugar and 0.5% and Lacta 9090. Low fat treatments included the following:-

CLF: as previously mentioned without any additives as control low fat ice cream.

T_1, T_2 and T3: low fat ice cream made with 10, 15 and 20 % pomegranate juice (PJ) respectively. While T_4, T_5, and T6: low fat ice cream made with 3, 6 and 9 % pomegranate peel (PP) respectively. On the hand, T_7, T_8 and T_9: low fat ice cream made with 4, 8 and 12% whole pomegranate pulp (WPP) respectively.

The different mixes were aged for 2 hrs, freezed and whipped in the ice cream maker (Taylormate™ Model 152, Taylor Company, Blackhawk Blvd, USA). The ice cream was collected at an exit temperature of −5.5 °C, placed in 100 ml plastic cups, covered, hardened at −25 °C for one day and stored at −18°C until analyzed. All ice cream treatments were prepared in three replicates.

Table (1): Formulations used for making 100 kg of different Ice cream treatments.

Treatments	Ingredients (kg)							
	Sugar	Lacta 9090	Water	Skim milk powder	Cream (50%)	pomegranate juice (PJ)	pomegranate peel (PP)	Whole pomegranate pulp (WPP)
C	15	0.50	62.75	9.75	12	0	0	0
CLF	15	0.50	68.24	13.26	3	0	0	0
T_1	15	0.50	58.24	13.26	3	10	0	0
T2	15	0.50	53.24	13.26	3	15	0	0
T3	15	0.50	48.24	13.26	3	20	0	0
T4	15	0.50	65.24	13.26	3	0	3	0
T5	15	0.50	62.24	13.26	3	0	6	0
T6	15	0.50	59.24	13.26	3	0	9	0
T7	15	0.50	64.24	13.26	3	0	0	4
T8	15	0.50	60.24	13.26	3	0	0	8
T9	15	0.50	56.24	13.26	3	0	0	12

Methods:-

Analysis of PJ, PP and WPP

The moisture, fat, protein, ash, total fiber and total carbohydrates contents of PJ, PP or WPP were determined according to methods (AOAC[20]). The values of pH of different samples were measured using Jenway 3505 with spear electrode no. 29010. The colour of PJ, PP and WPP was measured with a light reflectance spectrophotometer (Minolta, CR 300, Osaka, Japan) Measurements were recorded in L (lightness), +a (redness) and +b (yellowness) CIE (Commission Internationale de I'Eclairage) colour coordinates. The total anthocyanins was extracted and determined according to Wrolstad *et al.*[21]. Half gram of the sample was mixed with 15 ml of extraction solvent (0.01% V/V HCl in methanol) and the pigments were extracted by homogenization. Extract was firstly filtered and measured the absorbance at 530 nm against blank which was the extraction solvent. The anthocyanin content was calculated by the following equation:

Anthocyanins content (mg cyaniding chloride/ g) =
(AxM_{wt} x volume of the extract x1000)/ (30000x1000x wt of the sample (g)

Where A= the absorbance at 530 nm, M_{wt}= the molecular weight of cyanidin chloride = 322.7 g and 3000 = molar extinction coefficient.

Determination of total phenolic compounds, and antioxidant activity

Five grams of PJ, PP or WPP were mixed with 50 ml of 50% ethanol and stirred at room temperature for 1 h and filtered through whatman No. 1 filter paper. The total phenolic compounds were determined in the ethanolic extract as described by Singleton and Rossi[22]. Briefly, 1.5 ml of 10-fold diluted Folin–Ciocalteau reagent and 1.2 ml of sodium carbonate (7.5% w/v) were added to 0.3 mL of the ethanolic extract, mixed well and allowed to stand for 30 min. Absorbance of the reaction mixture was measured using a spectrophotometer (6505 UV/Vis, Jenway LTD., Felsted, Dunmow, UK) at 765 nm using gallic acid as a standard. Results were expressed as mg of gallic acid equivalents (GAE)/ 100g of the sample.

The antioxidant activity of PJ, PP or WPP was evaluated by using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assay (Cuendet and Potterat[23]; Burits and Bucar[24]). One hundred microliters of the ethanolic extract were added to 5 ml of a 0.004 % (w/v) of DPPH in methanol. The mixture was vortexed for 15 s and then left to stand at room temperature for 30 min. Absorbance was checked at 517 nm against a blank (ethanol). The DPPH radical-scavenging activity was calculated using the following formula:

DPPH radical – scavenging activity (%) = $[(1 - A_1 / A_0) \times 100]$

Where A_0 is the absorbance of the control and A_1 is the absorbance of the sample

For the ice cream samples, extraction of phenolic compounds and antioxidant activity were carried out according to Li *et al.*[25] with some modifications as follows: addition of 20 mL of the solvent (15 ml 1N HCl and 85 ml ethanol 95%) to 10 g of ice cream in 50-mL brown bottles and shaking for 90 min at 30°C in a rotary shaker (Julabo D-7633 Labortechmik, GMBIT, Jeelback / wast Germany) set at 200 rpm. Then, the mixture was centrifuged at 2500 g (ICE PR-7000 centrifuge, International Equipment Company) for 45 min at 5°C. The supernatant fluids were analyzed for TPC and DPPH scavenging activity as described earlier.

Analysis of the ice cream mix and ice cream:

Ice cream mixes were analyzed for specific gravity, weight per gallon of ice cream mix in kilograms and freezing point according to Marshall and Arbuckle[19]**.** The rheological properties of ice cream mix were measured after 2 hrs of aging using a Brookfield viscometer (Brookfield Engineering Laboratories, USA), equipped with a SC4-21spindle. Measurements were done at 10 ºC and shear rates ranging from 23.3 to 232.5/s. All rheological properties were performed in triplicates. Dynamic viscosity (at 50 rpm), consistency coefficient index, plastic viscosity, flow behaviour index and yield stress were drawn from measured values of shear stresses and apparent dynamics viscosity.

The ice cream samples were analyzed for overrun, specific gravity and weight per gallon (Marshall and Arbuckle[19]), melting rate[26]. The sensory attributes of fresh ice cream from different treatments were assessed by 10 panelists of the staff members of Dairy Department, Faculty of Agriculture, Suez Canal University. The Ice cream samples were tempered at -15°C to -12°C before sensory evaluation. Scoring was carried out according to Gafour *et al.*[27] for flavour (50 points), body and texture (30 points), melting properties (10 points) and colour (10 points).

Cost of production

The cost of production of different mixes (Table 2) was calculated according to the available prices of raw materials used in ice cream making in the Egyptian market.

Table (2): The common prices of raw materials used in preparation of different ice cream mixes.

Raw material	Skim milk powder	Water	Sugar	Cream 55%	Lacta 9090	Pomegranate juice (PJ)	Pomegranate peel (PP)	Whole Pomegranate pulp (WPP)
Price (L.E) / Kg	55	1	9	68	60	10	3	7

Statistical analysis

All measurements were done in triplicates, and analysis of variance with one factorial (treatments) were conducted by the procedure of General Linear Model (GLM) according to Snedcor and Cochran[28] using Costat under windows software version 6.311 and least significant difference (LSD) test were employed to determine significant difference at p<0.01.

RESULTS AND DISCUSSION

Chemical composition of pomegranate juice (PJ) and its byproducts (PP& WPP):

The proximate analysis of different pomegranate juice (PJ) or its byproducts (Table 3) indicated that PJ had small percentage of fiber (0.16%), moderate percentage of protein and ash (1.18%, 0.56%) and nearly absent fat % content (0.03%). The total solids and total soluble solids of PJ were 15.34 and 13.05 % respectively. Most of total soluble solids were reducing sugars. While pomegranate peels (PP) contained the highest content of fibers (crude 5.21%+ soluble 9.10%) with higher percentage of protein (3.95%), fat (0.45%) and ash content (0.71%) as compared to PJ and WPP. On the other hand, PP had the lowest total soluble solids% and reducing sugar%. Similar findings were reported by Farag *et al.*[29]. The PJ had the lowest pH value (4.02), while the PP had the highest pH value (4.15). On the other hand, WPP had a moderate pH value and recorded as 4.09. Generally, all pH values of pomegranate juice or its byproducts were acidic due to the presence of organic acids. The low pH of pomegranate is favorable for longer shelf life of the final product.

The antioxidant activity of plant extracts has now mainly ascribed to the concentration of the phenolic compounds and by increasing the concentration of phenolic compounds or degree of hydroxylation of the phenolic compounds, their DPPH radical scavenging activity increases[30]. Polyphenols are the major class of pomegranate fruit phytochemicals, including flavonoids (anthocyanins), condensed tannins (proanthocyanidins) and hydrolysable tannins; ellagitannins and gallotannins[13].

Results refereed to that pomegranate juice had 191.6 mg GAE/100 gm total phenolic compounds (TPC) with antioxidant scavenging activity 39.41% as a result of its contents of TPC and anthocyanin. While pomegranate peel contained the highest TPC with 889.5 mg GAE/100 gm with 66.5% antioxidant scavenging activity. Whole pomegranate pulp contained TPC and antioxidant activity were 557.3 mg GAE/100 gm and 55.3% respectively. Tzulker *et al.*[31] reported that the antioxidant activity of pomegranate aril juice correlated to its contents of TPC and it was being related to the level of anthocyanins. While the antioxidant activity of pomegranate peel was basically correlated to its content of total phenolic compounds[29]. Similar findings were reported to TPC and antioxidant scavenge activity by Mahmoud and Ibrahim[32] who found that TPC of pomegranate juice ranged between 159.8 – 231.5 mg GAE/ 100 gm while pomegranate peel extract had TPC ranged from 868 to 1546 mg GAE/100 gm. Table (3) shows that pomegranate peel contained higher values of total phenolic compounds (TPC) and antioxidant scavenging activity but lower total anthocyanin expressed as mg cyandin-3-glycoside/kg than these of pomegranate juice. Similar findings were reported by Farag *et al.*[29] and Souleman and Ibrahim[34]. Pomegranate peel is a valuable waste of juice processing industry and rich source in biomolecules of immune health significance 92% of antioxidant present in the pomegranate peel[33]. On other hand, it was found that the whole fruit (WPP) contained a moderate values between juice and peel. Tzulker *et al.*[31] showed that the antioxidant activity was dramatically and significantly increased in homogenates prepared from the whole fruit than that found in juices prepared from the arils alone.

Table (3): The gross chemical composition, pH, phytochemical, antioxidant activity and colour reading of pomegranate juice, peel and whole fruit (average of three replicates).

Chemical / physical characteristics		Pomegranate juice (PJ)	Pomegranate peel (PP)	Whole Pomegranate pulp (WPP)
Total solids %		15.34	30.54	22.02
Total soluble solids %		13.05	4.21	9.21
Fat %		0.03	0.45	0.25
Reducing Sugars %		12.85	3.42	8.48
crude Fiber %		0.16	5.21	2.41
Insoluble Fiber%		0.04	9.10	3.89
Protein %		1.18	3.95	2.21
Ash %		0.56	0.71	0.66
pH		4.02	4.15	4.09
Anthocyanin (mg cyandin-3-glycoside/kg)		22.36	10.47	13.34
Total Phenolic compounds (mg GAE /100 gm)		191.6	889.5	557.3
Antioxidant activity %		39.41	66.45	53.87
Colour reading	*L*	42.18	43.41	36.66
	a	30.35	27.40	24.55
	b	2.15	22.36	6.52

Generally, the colour reading parameters for pomegranate peel had higher whiteness (*L*) and yellowness (*b*) but lower redness (*a*) values than those of pomegranate juice showing its natural colour. Whole pomegranate (WPP) showed moderate colour reading characteristics than both PJ and PP. similar findings were reported by Abdel-Salam *et al.*[35]. These results referred to that pomegranate juice or its byproducts can be used as functional ingredient with attractive colour, high phenolic compounds, anthocyanin and antioxidant activity and fiber content.

Fractionation of the TPC of pomegranate juice or its byproducts

The different phenolic compounds presented in pomegranate juice or its byproducts were analysed by HPLC were presented in Table (4). Data referred to that there were differences in concentrations of the total phenolic compounds and the most abundant fractions in PJ were poly phenols such as gallic acid, ellagic acid and sinapic acid. Gil *et al.*[13] found that the antioxidant activity of pomegranate juice caused by its contents of hydrolyzable tannins, anthocyanins and ellagic acid derivatives.

While the most phenolic compounds presented in pomegranate peel were poly phenols such as gallic acid, ellagic acid, cateachin, syringic acid, apigenin and caffeic acid. The current results are in accordance with those obtained by Abdel-Rahim *et al.*[36] and Rowayshed *et al.*[37] and Mahmoud and Ibrahim[32]. While whole pomegranate (WPP) contained both phenolic compound fractions of PJ and PP making it a valuable natural antioxidant source for food processing.

Table (4): The phenolic compound fractions (µg/g) by HPLC for pomegranate juice or its byproducts.

Phenolic Compounds concentrations	Pomegranate juice (PJ)	Pomegranate peel (PP)	Whole pomegranate pulp (WPP)
Gallic acid	39.31C	235.19A	256.70B
Protocatechuic acid	0.10C	1.08B	5.43A
Cateachin	0.00C	14.56A	8.79B
Caffeic acid	1.17B	1.74A	0.80C
Syringic acid	0.63C	13.50B	22.50A
Sinapic acid	3.82A	0.00C	1.65B
Ellagic acid	10.75C	171.26A	108.77B
Cinnamic acid	0.00C	0.26B	0.92A
Qurecetin	0.00B	0.00B	0.55A
Apigenin	0.84C	8.56A	3.49B

* A, B, C, D, E, ……: values with the same row for different forms of pomegranate are not significantly different ($p<0.01$).

Properties of ice cream mix

The physical properties and pH values of different ice cream mixes are presented in Table (5). All Low-fat ice cream mixes had higher specific gravities and weight per gallon values than that containing 6% fat. These results due to the high contents of solids not fat and low fat contents of these mixes containing 1.5 % fat compared to full fat one. Similar findings were reported by Khalil and Blassy[38]. Adding of different percentages of PJ (10, 15 and 20%) significantly decreased the specific gravities and weight per gallon values than control low fat ice cream (CLF) may be because the low specific gravity of PJ (1.045, result not tabulated). On the other hand, addition of PP or WPP significantly increased both the specific gravity and weight per gallon values of low fat mixes and the rate of decrease was proportional to added ratio. This could be attributed to the higher specific gravity of PP and WPP (1.280 and 1.196, results not tabulated) as compared to that of low fat mix without additives (1.1124). Similar findings were reported by Ismail *et al.*[39].

The freezing point depression (FPD) is a critical parameter in ice cream production as it influences the initial and gradual growth of the mean size of the formed ice crystals and also their native thermodynamic instability[40]. Results showed that full fat ice cream mix exhibited the highest freezing point (Table 5) than other low fat ice cream mixes. Generally, the freezing point is depressed as the serum phase concentration is increased or as the solutes molecular weight is decreased[40], which may explain the significant difference in FPD between full fat ice cream and other low ice cream mixes.

Table (5): Effect of using different ratios of pomegranate juice, peel and whole fruit on the physical properties of different ice cream mixes (average of three replicates)

Treatments	Specific gravity (gm/ml)	Weight per gallon (Kg)	Freezing point (°C)	pH value
C	1.0851^{J}	4.925^{J}	-2.28^{A}	6.42^{A}
CLF	1.1124^{F}	5.051^{F}	-2.35^{B}	6.35^{B}
T1	1.1057^{G}	5.027^{G}	-2.40^{F}	6.21^{G}
T2	1.1023^{H}	5.005^{H}	-2.42^{H}	6.15^{I}
T3	1.0989^{I}	4.993^{I}	-2.45^{I}	6.09^{J}
T4	1.1192^{C}	5.082^{C}	-2.37^{C}	6.27^{C}
T5	1.1258^{B}	5.111^{B}	-2.39^{E}	6.25^{D}
T6	1.1325^{A}	5.140^{A}	-2.41^{G}	6.23^{E}
T7	1.1149^{E}	5.060^{E}	-2.38^{D}	6.24^{D}
T8	1.1174^{D}	5.072^{D}	-2.40^{F}	6.22^{F}
T9	1.1199^{C}	5.085^{C}	-2.42^{H}	6.19^{H}

* A, B, C, D, E, ……: values with the same letter among the treatments are not significantly different ($p<0.01$).
** C: control full fat ice cream & CLF: control low fat (1.5% fat) ice cream & T1-T2-T3: as CLF with 10, 15 and 20 % pomegranate juice (PJ) respectively& T4-T5-T6: as CLF with 3, 6 and 9% pomegranate peel (PP) respectively & T7-T8-T9: as CLF with 4, 8 and 12% whole pomegranate pulp (WPP) respectively.

Addition of PJ significantly ($p<0.01$) increased the FPD of low fat ice cream because of the sugar and ash contents of PJ causing higher freezing point depression with the added ratio. So, T3 had lower freezing point than both T1 and T2. Also, using both pomegranate peel (PP) or whole pomegranate pulp (WPP) had higher freezing point depression than these made with PJ, with respect to the ratio added. These results were correlated to its contents of sugars and ash contents, as well as its fibers contents. Soukoulis *et al.*[41] reported that the percentage of fiber used in ice cream making affected significantly the freezing point. Similar findings were reported by Ismail *et al.*[39]. Full fat ice cream mix had significantly higher pH value than other low fat treatments. This may be due to the differences in solids not fat. Addition of PJ, PP and WPP in low fat ice cream mix significantly decreased its pH values which may be attributed to the lower pH of PJ, PP and WPP (4.02; 4.15 and 4.09 respectively, Table 3). Similar finding was reported by Siddhu *et al.*[42] who made kulfi, frozen Indian dairy dessert made of pomegranate pomace. Similar findings were reported by Ismail *et al.*[39].

Table (6): Effect of using different ratios of pomegranate juice, peel and whole fruit on the rheological characteristics of different ice cream mixes (average of three replicates)

Treatments	Rhelogical characteristics				
	Apparent viscosity (mPas)	Plastic viscosity (mPas)	Yield stress (N/m^2)	Flow behavior index	Consistency coefficient index (mPas)
C	348.9^A	188.9^A	4.76^A	0.521^K	126.9^A
CLF	255.0^H	136.0^H	3.04^H	0.612^D	77.5^H
T1	230.3^I	128.0^I	2.97^I	0.623^C	70.8^I
T2	225.4^J	121.0^J	2.85^J	0.652^B	68.9^J
T3	218.2^K	116.3^K	2.74^K	0.684^A	66.3^K
T4	277.1^F	147.8^F	3.57^F	0.582^F	84.9^F
T5	312.5^D	158.7^D	3.98^D	0.569^H	96.5^D
T6	345.4^B	170.0^B	4.39^B	0.554^J	115.6^B
T7	264.1^G	143.1^G	3.44^G	0.596^E	80.6^G
T8	304.3^E	150.9^E	3.89^E	0.578^G	91.4^E
T9	335.3^C	163.4^C	4.19^C	0.561^I	107.8^C

* A, B, C, D, E, ……: values with the same letter among the treatments are not significantly different ($p<0.01$).

Properties of Ice Cream

Physiochemical properties of ice cream

Changes in the physical properties of different ice cream treatments as affected by using pomegranate juice or its byproducts are showed in Table (7). Generally, incorporation of air in ice cream mix during the pre-freezing process decreased significantly both the specific gravity and weight per gallon of the resultant ice cream. It was noticed that the specific gravity and weight per gallon of full fat ice cream (C) were significantly ($p<0.01$) lower than that of low fat ice cream (CLF). In addition, full fat ice cream had higher overrun % than control low fat one. This may be due to the high contribution of fat to the stability of air phase of ice cream during freezing and whipping[44].

Table (7): Effect of using different ratios of pomegranate juice, peel and whole fruit on the physical properties of the resultant ice cream (average of three replicates)

Treatments	Specific gravity (gm/ml)	Weight per gallon (Kg)	% overrun
C**	0.704^G	3.194 ^{G}	54.13^A
CLF	0.796^A	3.611 ^{A}	39.75^G
T_1	0.795^A	3.607 ^{A}	39.08^H
T_2	0.797^A	3.616 ^{A}	38.30^I
T_3	0.798^A	3.620 ^{A}	37.71^J
T_4	0.770^C	3.493 ^{C}	45.34^E
T_5	0.760^E	3.448 ^{E}	48.13^D
T_6	0.749^F	3.398 ^{F}	51.20^B
T_7	0.775^B	3.516 ^{B}	43.86^F
T_8	0.764^D	3.466 ^{D}	46.26^E
T_9	0.748^F	3.393 ^{F}	49.72^C

* A, B, C, D, E, ……: values with the same letter among the treatments are not significantly different ($p<0.01$).
** see Table (5).

Adding substantial ratios of pomegranate peel (PP) or whole pomegranate peel (WPP) decreased significantly the specific gravity and weight per gallon as compared to control low fat ice cream. The rate of decreases was dependent on the ratio used of PP or WPP. As the used ratio increased, both of the specific gravity and weight per gallon decreased gradually and increased its overrun %. This may be due to the higher mix viscosity of treated samples with PP and WPP causing higher availability of air into ice cream mix (Table 6). The development of overrun % was more pronounced for PP treated ice cream than these of WPP treated samples as a result of the more interactions between fibers, protein matrix and stabilizer causing higher viscosity values[41].

Melting rate of ice cream treatments

As shown in Fig. (1), melting rate which represents the weight loss of the tested samples during 60 min. at room temperature (27±1ºC). High quality product would show a relatively high resistance towards melting. The control full fat ice cream samples took longer time to melt and were softer than the other low fat ice cream treatments, probably due to the structural role of fat in ice cream microstructure and stabilization of air bubbles by fat[44]. Similar finding were reported by Khalil and Blassy[45].

Using ratios of PJ had no significant effect on the melting rate of the resultant ice cream as a result of deceasing pH values of these treatments may be correlated to the lower pH value of pomegranate juice 4.02 and higher freezing point depression. While using PP and WPP in low fat ice cream caused slower melting rates as compared to using PJ treatments due to differences in pH values and freezing point depression. So, the melting rate of PP treated ice cream had lower melting rate than these of WPP. Similar finding were noticed by Crizel *et al.*46 for ice cream made with orange peel fibers.

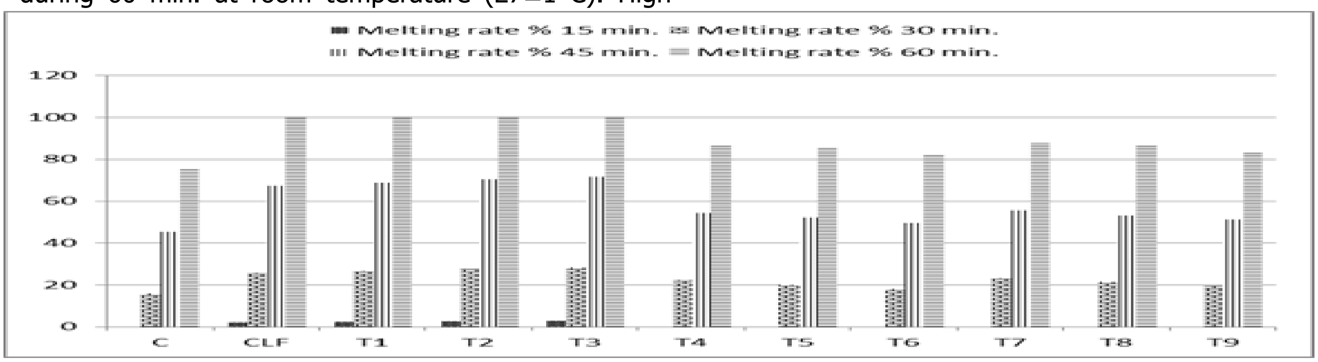
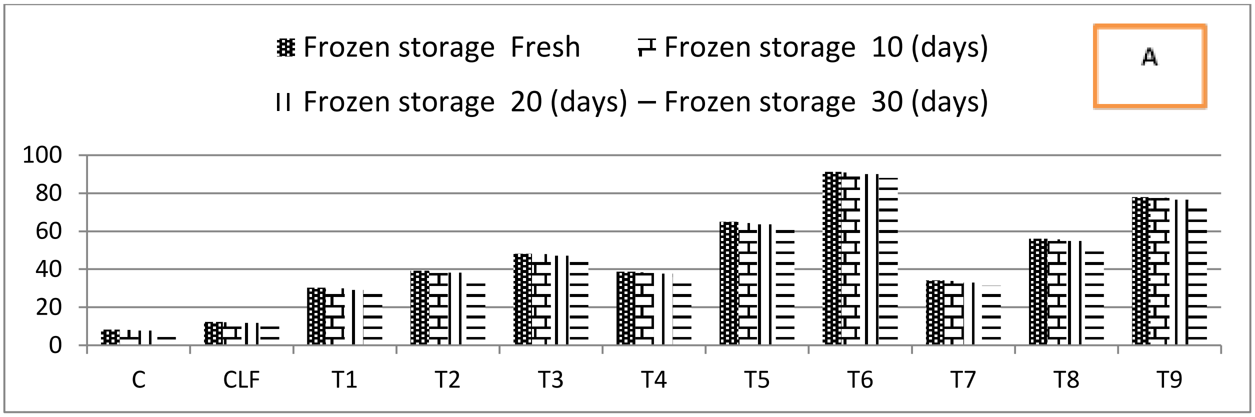


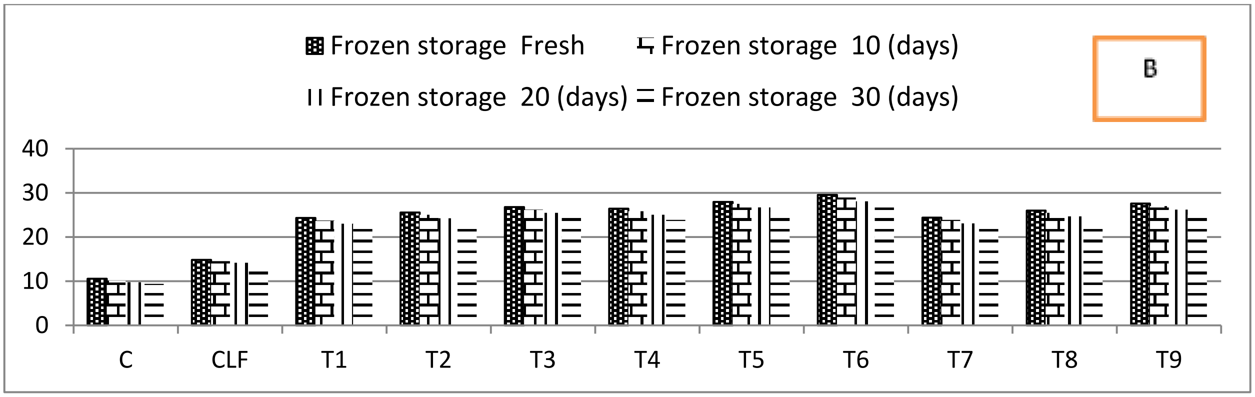
Fig (1): Effect of using different ratios of pomegranate juice, peel and whole fruit on the melting rate % at 25 ºC of different ice cream mixes (average of three replicates).

TPC and antioxidant activity of ice cream

The changes of TPC and the antioxidant scavenging activity (AA) of ice cream treatments during the frozen storage as affected by using AFP are shown at Figs. (2 A, B). Full fat ice cream had lower TPC and AA than those of low fat ice cream without fruit. This may be attributed to the differences in milk solids not fat which correlated to its contents of protein and other non-protein antioxidants. The protein group includes various kinds of enzymes, and also a number of proteins and peptides which had phenolic compounds and antioxidant activity power[47]. Similar findings were reported by Khalil and Blassy[45].

Addition of PJ increased significantly ($p < 0.01$) both TPC and antioxidant scavenging activity of low fat ice cream. Thus may be due to the additional TPC and AA of the fruit pulp (Table 3&4). So, using 20% PJ improved the TPC and antioxidant scavenging activity than the lower ratio. Also, using PP in low fat ice cream increased both TPC and antioxidant scavenging activity of low fat ice cream than WPP may be correlated to the differences found in TPC and antioxidant scavenging activity of PP and PJ (Table 3& 4) as well as the used ratio. Similar finding was reported by Siddhu *et al.*[42], and Ghazizadeh *et al.*[48]. The highest TPC and antioxidant scavenging activity were found by using 9% PP followed by using 6% PP or 12% WPP and the changes between two treatments were not significantly different. All TPC and AA for all samples tended to decrease significantly with extended frozen storage period. This may be to the possible oxidation process for the nutrients of ice cream samples. Similar findings were reported by Khalil and Blassey[45].





Figs (2: A, B): Effect of using different ratios of pomegranate juice, peel and whole fruit on the total phenolic compounds (A) expressed as mg GAE/ g and antioxidant scavenging activity % (B) of different ice cream mixes.

Cost of production:

Table (8) shows the production cost of different ice cream treatments calculated as its common prices in the local market. Full fat ice cream had the highest cost of production. Reduction of fat specification to 1.5 % fat decreased the used cream in the mix causing a 26.17% reduction of the production cost. Using substantial amounts of pomegranate juice at ratio 10, 15 and 20% in low fat ice cream decreased the production cost with 20.47, 17.62 and 14.78 % as compared with control respectively. While using pomegranate peel at ratios 3, 6 and 9% decreased the cost of production cost to 25.79, 25.41 and 25.03% respectively as a result of the lower price of pomegranate peel as by product than its juice. So, the production cost tended to decrease as compared with full fat control. But the rate of addition caused little increases for the production cost. On the other hand, using whole pomegranate pulp at ratios 4, 8 and 12% decreased the cost of production cost to 24.65, 23.13 and 21.61% respectively as a result of lower price of whole pomegranate pulp is lower than its juice only.

Table (8): Effect of using different ratios of pomegranate juice, peel and whole fruit on the cost of production of ice cream treatments (average of three replicates)

Treatments	Cost of production	% reduction of cost as compared to full fat one
C*	1580	---
CLF	1166.54	26.17
T1	1256.54	20.47
T2	1301.54	17.62
T3	1346.54	14.78
T4	1172.54	25.79
T5	1178.54	25.41
T6	1184.54	25.03
T7	1190.54	24.65
T8	1214.54	23.13
T9	1238.54	21.61

Sensory properties of ice cream

Table (9), shows the different characteristics if ice cream treatments as affected by using pomegranate juice, peel or whole fruit. Results referred to that full fat ice cream gained the highest scores for acceptability, richness mouthfeel and creamy taste. This may be attributed to milk fat functionality including fat destabilization, increased air incorporation and air cells stabilization, lubrication of oral tissue and improvement of mouth sensation[1]. Decreasing the fat from ice cream resulted in a cooler and more watery body & texture product with few visible air bubbles. Adding pomegranate juice (PJ) improved significantly the flavor but no clear effect on body & texture of low fat ice cream and gained significantly higher total acceptability scores than control low fat. The higher ratio of PJ used were correlated to higher flavour scores and total acceptability scores. It was noticed that addition of PJ in ice cream making had no significant effect on body & texture may be correlated to the same rheological characteristics as compared to control low fat ice cream (Table 6). While using pomegranate peel (PP) in low fat ice cream caused a significant effect on body & texture and total acceptability but with limited flavour scores than control low fat ice cream. This may be due to the increased viscosity of these treatments containing PP. Generally, low fat ice cream containing 3% PP gained body & texture scores close to the full fat ice cream. But increasing PP ratio to 6 or 9 % caused a grading loss of smoothness in body & texture. So, the total acceptability scores were significantly lower than the lower ratio. Similar findings were reported by Ismail *et al.*[39]. On the other hand, using whole pomegranate pulp (WPP) in low fat ice cream caused a significant effect on both flavour and body & texture and consequently the total acceptability than control low fat ice cream. This may be due to the higher rheological characteristics of treatments containing WPP. Generally, low fat ice cream containing 8% WPP gained body & texture scores close to the full fat ice cream. Increasing the used ratio of WPP to 12% caused a loss of smoothness in body & texture. So, the total acceptability scores were significantly lower than the lower ratio. Generally, the fresh values of treated ice creams were higher than these of aged low fat ice cream. This may be due to the higher oxidation rate than untreated ice creams.

Table (9): Effect of using different ratios of pomegranate juice, peel and whole fruit on the sensory properties of different ice cream mixes (average of three replicates)

Treatments	Flavour (50 points)	Body &Texture (30 point)	Melting properties (10 points)	Colour (10 points)	Total acceptability (100 points)
After 10 days of freeze storage					
C**	48	28.5	9	8.5	94^{A}
CLF	40	22	8	8	78^{G}
T_1	43	22	8	8.5	81.5^{F}
T_2	44	22	8	8.5	82.5^{E}
T_3	46	22	8	9	85^{D}
T_4	45	28.5	9	9	91.5^{B}
T_5	43	27.5	9	8.5	88^{C}
T_6	42	26.5	9	8.5	86^{D}
T_7	44	26.5	9	8.5	88^{C}
T_8	46	28	9	9	92^{B}
T_9	43	25.5	9	8.5	86^{D}
After 20 days of freeze storage					
C	47	28	9	8.5	92.5^{A}
CLF	39	21.5	8	8	76.5^{I}
T_1	42	21.5	8	8.5	80^{H}
T_2	43	21.5	8	8.5	81^{G}
T_3	45	21.5	8	9	83.5^{F}
T_4	44.5	28	9	9	90.5^{B}
T_5	42.5	26	9	8.5	86^{D}
T_6	41.5	25.5	9	8.5	84.5^{E}
T_7	43.5	26.5	9	8.5	87.5^{C}
T_8	45.5	27.5	9	9	91^{B}
T_9	43.5	25	9	8.5	86^{D}

* A, B, C, D, E, ……: values with the same letter among the treatments for total acceptability scores are not significantly different ($p<0.01$). & ** see Table (5)

SIGNIFICANCE STATEMENT

It can be concluded that using pomegranate juice in low fat ice cream caused an enhancement of flavour scores without a noticeable effect on both rheological characteristics and body & texture scores. While using 3% pomegranate peel in low fat ice cream improved rheological characteristics, body & texture scores and total acceptability scores without a noticeable effect on flavour scores. While using 8% whole pomegranate pulp improved the quality characteristics of the resultant low fat ice cream with total acceptability scores close as possible to full fat counterpart with reduction of the production cost by 23.13% as compared to full fat ice cream.

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