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Low Fat Ice Cream with Using Orange Juice or Its By-Products as Sustainable Functional Ingredient

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Abstract: This research aims to investigate the effect of using orange by-products as sustainable 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% fat; the first was made without any additives as a control low fat (CLF). Orange juice (OJ) was used at ratios 8, 12 and 16 % to act as T_1, T_2 and T_3 respectively. Orange peel (OP) was used at ratios 2, 4 and 6% to act as T_4, T_5 and T_6 respectively. While, whole orange pulp (WOP) was used at ratios 3, 6 and 9 % to act as T_7, T_8 and T_9 respectively. Full fat ice cream had higher rheological characteristics, pH value and higher sensory properties with slower melting rates and had the highest production cost than other low fat ice cream treatments. Using OJ increased the flavour scores, total phenolic compounds and antioxidant scavenging activity than CLF with significant higher rheological characteristics than CLF. While using OP or WOP caused an increase for the rheological characteristics, melting resistance and higher sensory properties with lower production cost. It can be concluded that using 4% OP in low fat ice cream improved rheological characteristics, body & texture scores and total acceptability scores. While using 6% WOP 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 28.02% as compared to full fat ice cream.

Keywords: Functional Ice cream, Orange juice, Peel, low fat ice cream, Antioxidant activity, Rheological properties, Sensory 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 (Dresselhuis *et al*., 2008; Turgut and Cakmacki, 2009). It is a common view that high saturated fat intake is correlated with several chronic diseases such as obesity, cardiovascular diseases and cancer (Rolon *et al*., 2017). 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 (Aime *et al*., 2001). Accordingly, the food industry is facing the challenge of probing for new alternatives for fat without any quality loss (Rolon *et al*., 2017).

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 (Steijns, 2003)

Sustainability provides both an opportunity and a challenge to the dairy sector. It is an opportunity, because the possibility of using food processing by-products for its bioactive healthy compound and nutrients has created added value benefit (Sharma *et al*., 2015). However, the challenge is 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 (Godfray *et al*., 2010; Fan and Brzeska, 2016).

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 (Granato *et al*., 2010). 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 (Menrad, 2003; Urala and Lähteenmäki, 2007).

Orange as one of the most important fruit of family Rutaceae which has a well-known promising source of multiple beneficial nutrients for human such as active phytochemicals, vitamin C, folic acid, potassium and pectin (Gorinstein *et al*., 2004). Role of several citrus fruits in deterrence of life threatening diseases have been approved (Guimaraes *et al*., 2009). It was used Egyptian orange (*Citrus sinensis*) as one of the major orange verities for juice production. Global production of orange fruit has significantly increased during the past few years and has reached 49.6 million tons in the years 2020–2021 (USDA, 2021). About 34% of orange quantities were used for juice production, yielding about 44% peel as by-product (Li *et al*., 2006). Therefore, about 7.4 million ton of peel is produced every year.

Processing of citrus byproducts potentially represents a valuable phenolic compounds and dietary fibre source, owing to the large amount of peel

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produced. Orange by-products, which are generally accumulated as waste in the environment, may be act as potential nutraceutical resources beyond its low cost and easy availability such a waste is capable of offering significant low-cost nutritional dietary supplements. Using of these bioactive rich orange residues can provide an efficient, inexpensive, and environment friendly platform for the production of novel nutraceuticals for the improvement of several traditional dairy products (Rafiq *et al*., 2018).

Crizel *et al*. (2014) tried to use orange peel fiber as a novel fat replacer in light lemon ice cream. Using orange fiber in reduced fat ice cream increased the hardness, gumminess, and springiness values, but it did not affect the adhesiveness and odor of the samples. The samples with 1.0% of orange peel fiber showed lower melting rate values than those of the control ice cream. The overall acceptance of the ice cream with 1.0% of pre-treated orange peel fiber had no significant effect as compared with the control ice cream (80%). The orange fiber proved a promising ingredient in food processing since it can be used to increase bioactive compounds content, such as fiber and carotenoids.

Siddhu *et al*. (2017) tried to develop a fruit based by-products in kulfi, ice cream like dessert known in India, by addition ratios 3, 4 and 5% of pineapple, orange and pomegranate by-products and followed its impacts on the quality characteristics. Addition of fruit by-products decreased pH values, enhanced % protein, fiber, viscosity, body & texture characteristic and organoleptic properties as compared to control. From the sensory evaluation, it was found that 4% combination of orange by-product incorporated in kulfi was found higher than all treatment combination.

Aiming to enhance the quality characteristics of low fat ice cream (1% fat), a trail was done focusing on using orange by-products as sustainable ingredients on the physiochemical, rheological characteristics, phenolic compounds, Antioxidant scavenging activity, melting rate, cost of production and sensory properties were followed during 30 days of freeze storage.

MATERIALS AND METHODS

Materials:

Mature orange fruit; seedless Baladi 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™, 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.

Methods

Preparation of Orange juice or peel or whole pulp:-

Orange fruits were washed many times using tap water, heated 75ºC/2 min., cooled, dried and then divided into two portions. First was used to prepare whole orange pulp (WOP) 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, fruits were cut into two portions, pressed to extract the juice. The juice (OJ) was freshly prepared as soon as its use in ice cream, blended, homogenized at 6000 rpm/min for 3 minutes to prepare orange juice. While orange peel was blended and homogenized at 6000 rpm/min for 5 minutes to prepare orange peel (OP). The resultant homogenous orange juice, peel and whole were kept at 5ºC until used.

Manufacture of ice cream:-

Ice cream mixes (Table 1) were prepared according to the method described by Marshall and Arbuckle (1996). Skim milk powder was first mixed with sugar and Lacta 9090 to generate a "dry mix". Water 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 orange 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 -20ºC 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% fat, 13% S.N.F, 15% sugar and 0.5% and Lacta 9090. Treatments included the following:-

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

T_1, T_2 and T_3: low fat ice cream made with 8, 12 and 16 % orange juice (OJ) respectively. While T_4, T_5 and T_6: low fat ice cream made with 2, 4 and 6% orange peel (OP) respectively. On the hand, T_7, T_8 and T_9: low fat ice cream made with 3, 6 and 9% whole orange pulp (WOP) 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%)	OJ	OP	WOP
C	15	0.50	62.75	9.75	12	0	0	0
CLF	15	0.50	68.19	13.31	2	0	0	0
T_1	15	0.50	60.19	13.31	2	8	0	0
T2	15	0.50	56.19	13.31	2	12	0	0
T3	15	0.50	52.19	13.31	2	16	0	0
T4	15	0.50	66.19	13.31	2	0	2	0
T5	15	0.50	64.19	13.31	2	0	4	0
T6	15	0.50	62.19	13.31	2	0	6	0
T7	15	0.50	65.19	13.31	2	0	0	3
T8	15	0.50	62.19	13.31	2	0	0	6
T9	15	0.50	59.19	13.31	2	0	0	9

OJ: orange juice; OP: orange peel; WOP: Whole orange pulp

Methods:-

Analysis of OJ, OP and WOP

The moisture, fat, protein, ash, total carbohydrates and total fiber contents of OJ, OP or WOP were determined according to methods (AOAC, 2007). The values of pH of different samples were measured using Jenway 3505 with spear electrode no. 29010. The colour of OJ, OP and WOP 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. Vitamin C content was determined as described by Sadashivam and Manickam (1992). Determination of vitamin C content of samples was carried out thrice and the average value was considered as vitamin C content of orange fraction. Total flavonoids quantitation was estimated according to the method described by Wang *et al*. (2007) and was expressed as mg as catechin equivalent/g.

Determination of total phenolic compounds, and antioxidant activity

Five grams of OJ, OP or WOP 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, 1965). 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)/100 g 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, 1997; Burits and Bucar, 2000). 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:

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

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.* (2009) 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 (1996)**.** 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 10ºC and shear rates ranging from 23.3 to 232.5 s^{-1}. 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, 1996), melting rate (Segall and Goff, 2002). 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.* (2007) 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	OJ	OP	WOP
Price (L.E) / Kg	55	1	9	68	60	7	3	5

OJ: orange juice; OP: orange peel; WOP: Whole orange pulp

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 (1967) 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 orange juice (OJ) and its byproducts (OP& WOP):

The proximate analysis of different Orange juice (OJ) or its byproducts (Table 3) indicated that OJ had small percentage of fiber (0.12%), 0.58% of protein and 0.41% of ash and nearly absent fat % content (0.05%). The obtained results of OJ total solids and total soluble solids were 12.91 and 11.05% respectively. Most of total soluble solids were total sugars. Similar results were reported by Shravan *et al*. (2018) and Abobatta (2019). While orange peels (OP) contained the highest content of fibers (11.76%) with good percentage of protein (2.46%), higher fat and ash contents (1.42%, 0.73%) consequently as compared to OJ and WOP. On the other hand, OP had the lowest total soluble solids% and total sugar%. Similar findings were reported by Mosa and Khalil (2015) and Sir Elkhatim *et al*. (2018). The OJ had the lowest pH value (3.92), while the OP had the highest pH value (4.38). On the other hand, WOP had a moderate pH value and recorded as 4.21. Generally, all pH values of orange juice or its byproducts were acidic due to the presence of organic acids.

Table (3): The gross chemical composition, pH, phytochemical, antioxidant activity and colour reading of orange juice, peel and whole fruit*

Chemical / physical characteristics		Orange juice (OJ)	Orange peel (OP)	Whole orange pulp (WOP)
Total solids %		12.91	24.35	17.02
Total soluble solids %		11.05	4.32	6.55
Fat %		0.05	1.42	0.75
Total Sugars %		10.94	4.13	6.12
Dietary Fiber %		0.12	11.76	5.79
Protein %		0.58	2.46	1.58
Ash %		0.41	0.73	0.54
pH		3.92	4.31	4.12
Vitamin C (mg/100g)		58.92	111.69	82.12
Flavonoids (mg as catechin equivalent/g)		32.5	83.2	56.54
Total Phenolic compounds (mg GAE /100 gm)		115.2	293.6	186.1
Antioxidant activity %		61.50	81.17	70.7
Colour reading	***L***	57.67	31.46	49.26
	a	16.09	5.26	11.57
	b	52.21	22.24	37.9

* Average of three replicates

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 (Silva *et al*., 2006). Total phenolic compounds value (TPC), flavonoids, vitamin C of OP were 293.6 mg GAE/100 gm, 83.2 mg as catechin equivalent/g and 111.69 mg/100 gm and the corresponding values for OJ was 115.2 mg GAE/100 gm, 32.5 mg as catechin equivalent/g and 58.92 mg/100 gm. So, the antioxidant scavenging activity of orange peel was significantly higher than orange juice. On other hand, it was found that the whole fruit (WOP) contained a moderate values between juice and peel. Similar finding were reported by Sir Elkhatim *et al.* (2018) for antioxidant capacity and TPC of orange whole, peel and pulp. Babbar *et al.* (2011) explained the differences between DPPH antioxidants properties for orange peel and orange fruit as a result of synergistic effects of different constituents such as phenolic compounds, vitamin C, carotenoids, and pigments.

Generally, the colour reading parameters for orange peel had lower whiteness (*L*), yellowness (*b*) and redness (*a*) values than those of orange juice showing its natural colour. Colour of orange juice is provided by carotenoids, which belong to one of the main classes of natural pigments (Meléndez-Martínez *et al*., 2005). Whole orange (WOP) showed moderate colour reading characteristics than both OJ and OP. similar findings were reported by Fernandez-Vazquez *et al*. (2011). These results referred to that orange juice or its byproducts can be used as functional ingredient with attractive colour, high phenolic compounds, vitamin C, flvonoids and antioxidant activity and fiber content.

Properties of ice cream mix

The physical properties and pH values of different ice cream mixes are presented in Table (4). 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% fat compared to full fat one. Similar findings were reported by Khalil and Blassy (2019).

Table (4): Effect of using different ratios of orange 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 (ºC)	pH value
C	1.0855^{J}	4.924^{J}	-2.28^{A}	6.43^{A}
CLF	1.1130^{F}	5.049^{F}	-2.35^{B}	6.34^{B}
T_1	1.1070^{G}	5.022^{G}	-2.40^{E}	6.19^{G}
T_2	1.1043^{H}	5.010^{H}	-2.42^{F}	6.14^{H}
T_3	1.1016^{I}	4.997^{I}	-2.44^{G}	6.09^{I}
T_4	1.1158^{D}	5.062^{D}	-2.36^{C}	6.27^{C}
T_5	1.1191^{B}	5.077^{B}	-2.38^{D}	6.25^{D}
T_6	1.1258^{A}	5.107^{A}	-2.40^{E}	6.23^{E}
T_7	1.1149^{E}	5.058^{E}	-2.38^{D}	6.23^{E}
T_8	1.1174^{C}	5.069^{C}	-2.40^{E}	6.21^{F}
T_9	1.1199^{B}	5.081^{B}	-2.42^{F}	6.19^{G}

* 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% fat) ice cream.
T_1-T_2-T_3: as CLF with 8, 12 and 16 % orange juice (OJ) respectively.
T_4-T_5-T_6: as CLF with 2, 4 and 6% orange peel (OP) respectively.
T_7-T_8-T_9: as CLF with 3, 6 and 9% whole orange pulp (WOP) respectively.

Adding of different percentages of OJ (8, 12 and 16%) 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 OJ (1.045, result not tabulated). On the other hand, addition of orange peel or whole orange pulp 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 OP and WOP (1.28 and 1.196, results not tabulated) as compared to that of control low fat mix (1.1130). Similar findings were noticed by Elango *et al*. (2017) for low fat ice cream with adding dietary fiber sources.

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 (Hartel, 2001). Results showed that full fat ice cream mix exhibited the highest freezing point (Table 4) 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 (Hartel, 2001), which may explain the significant difference in FPD between full fat ice cream and other low ice cream mixes.

Addition of OJ significantly ($p<0.01$) raised the FPD of low fat ice cream because of the sugar and ash contents of OJ causing higher freezing point depression with the added ratio. So, T_3 had the lower freezing point than both T_1 and T_2. Also, using both orange peel (OP) and whole Orange pulp (WOP) had lower freezing point depression than the control low fat ice cream; the lower FPD were proportionally affected by the used ratio. These results were correlated to OP and WOP contents of sugars and ash contents, as well as its fibers contents. Soukoulis *et al.* (2009) reported that the percentage of fiber used in ice cream making affected significantly the freezing point.

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 OJ, OP and WOP in low fat ice cream mix significantly decreased its pH values which may be attributed to the lower pH of OJ, OP and WOP (3.92; 4.31 and 4.12 respectively, Table 3). Similar finding was reported by Ayar *et al*. (2018) who used freeze-dried orange pomac in ice cream.

The rheological parameters of different mixes

The rheological parameters (Table 5) of different ice cream mixes expressed as apparent viscosity, plastic viscosity, consistency coefficient index and yield stress of full fat ice cream mix were significantly ($p<0.01$) higher than control low fat ice cream. This may be due to milk fat as a critical factor for the formation and support of structural characteristics of ice cream as well as the probable formation of fat crystals; the stabilizers also complete their hydration process and/or the complete proteins adsorption at the fat/water interface (Turgut and Cakmacki, 2009). On the other hand, it was found that flow behaviour index had an opposite trend to all the rheological characteristics.

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

Treatments	Apparent viscosity (mPas)	Plastic viscosity (mPas)	Yield stress (N/m^2)	Flow behavior index	Consistency coefficient index (mPas)
C**	350.0^{A}	191.2^{A}	4.76^{A}	0.520^{J}	126.7^{A}
CLF	256.1^{J}	136.5^{H}	3.04^{K}	0.612^{A}	77.3^{I}
T_1	262.1^{I}	140.1^{G}	3.09^{J}	0.609^{B}	78.5^{I}
T_2	267.2^{H}	144.6^{F}	3.14^{I}	0.603^{C}	80.4^{H}
T_3	275.3^{G}	150.4^{E}	3.20^{H}	0.598^{D}	82.8^{G}
T_4	291.2^{F}	163.1^{D}	3.75^{F}	0.579^{E}	87.6^{F}
T_5	316.1^{D}	172.4^{C}	4.04^{D}	0.562^{G}	99.5^{D}
T_6	334.4^{B}	183.5^{B}	4.43^{B}	0.540^{I}	118.2^{B}
T_7	268.3^{G}	151.8^{E}	3.49^{G}	0.591^{D}	85.5^{G}
T_8	313.6^{E}	162.7^{D}	3.95^{E}	0.572^{F}	93.7^{E}
T_9	325.4^{C}	176.3^{C}	4.26^{C}	0.556^{H}	108.7^{C}

* A, B, C, D, E, ……: values with the same letter among the treatments are not significantly different ($p<0.01$).
** see Table 4.

Using substantial ratios of OJ in low fat ice cream increased significantly its rheological parameters except the flow behavior index than those of control low fat ice cream. This may be due to the lower pH of orange juice which increased the interactions between protein matrixes with stabilizers cause higher rheological characteristics. Similar findings were noticed by El-Samahy *et al.* (2015) who made low fat ice cream with cactus fruit pulp as a natural antioxidant source.

While using orange peel (OP) or whole orange pulp (WOP) in low fat ice cream mix caused a gradual increase for all the rheological characteristics except flow behavior index after two hours of aging. The rates of increase in the rheological parameters were influenced by the percentage of added OP or WOP. These results may be due to the thickening effect of the soluble fibers due to the three dimensional conformation of the hydrated biopolymers (Soukoulis *et al*., 2009). Similar findings were reported by Ayar *et al*. (2018). Similar results were found for enhancing textural parameters of lemon ice cream with using orange fiber (Crizel *et al*., 2014).

Properties of Ice Cream

Physiochemical properties of ice cream

Changes in the physical properties of different ice cream treatments as affected by using orange juice or its byproducts are showed in Table (6). 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 (Goff *et al.* 1999).

Table (6): Effect of using different ratios of orange 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}	53.18^{A}
CLF	0.796^{A}	3.611^{A}	39.82^{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 (4).

Using gradual ratios of orange juice (OJ) decreased specific gravity and weight per gallon and slight higher overrun as compared to untreated low fat ice cream as a result of the parallel increases for all the rheological characteristics as a result of the acidic nature of orange juice. So, using 8-16% orange juice caused significant increases for the overrun of the resulted ice cream treatments. Similar findings were noticed by Aishwariya *et al*. (2019).

Adding substantial ratios of orange peel (OP) or whole orange peel (WOP) 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 OP or WOP. 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 rheological characteristics of treated samples with OP and WOP causing higher availability of air into ice cream mix (Table 5). The development of overrun % was more pronounced for OP treated ice cream than these of WOP treated samples as a result of the more interactions between fibers, protein matrix and stabilizer causing higher viscosity values. Similar findings were reported by Crizel *et al*. (2014) who used orange fiber as novel fat replacer in lemon ice cream. Same trend was observed by Akalın *et al*. (2018) who used orange fiber in probiotic ice cream.

The overrun of the experimental ice cream samples increased with the addition of the orange fibers, compared with the control as a result of increasing the incorporation of air into ice-cream attributing to their rheological properties. It was reported that dashers of batch freezers could incorporate more air into samples with higher viscosity (bahram and goff, 2013).

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 (Goff *et al*., 1999). Similar finding were reported by Khalil and Blassy (2017 and 2019). While using 8-16% orange juice in low fat ice cream had higher melting rate than control low fat ice cream as a result of the lower freezing point among treatments. Similar trend was observed by Aishwariya *et al*. (2019). Using both of OP and WOP in low fat ice cream showed lower melting values during storage as compared to these used OJ. As the percentage of dietary orange fibres increased as the melting resistance increased. As added soluble or insoluble fibers of ice cream increases as rheological characteristics and melting resistance increases. Soluble components of fibers contributed to the enrichment of liquid phase and reduced freezing point and available water in frozen form which may be attributed to increased melting resistance on an increase in the concentration of fiber (Muse and Hartel, 2004). Crizel *et al*. (2014) reported no significant differences between ice cream with 1.5% orange fiber added and control ice cream for melting resistance. Similar findings was reported by Akalin *et al*. (2018) who studied the effect of different dietary fibers sources including orange fibers on the quality characteristics of probiotic ice cream.

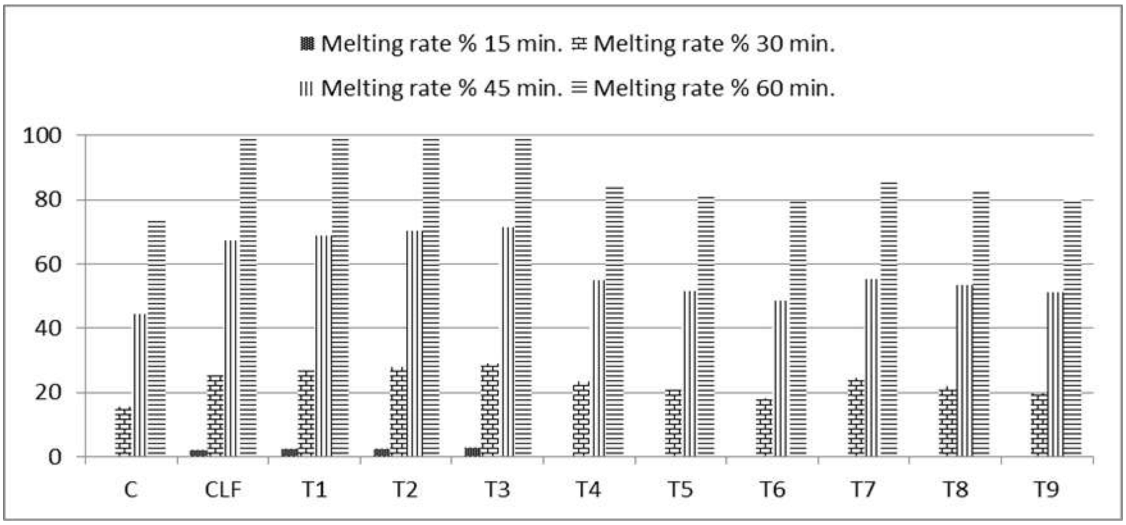
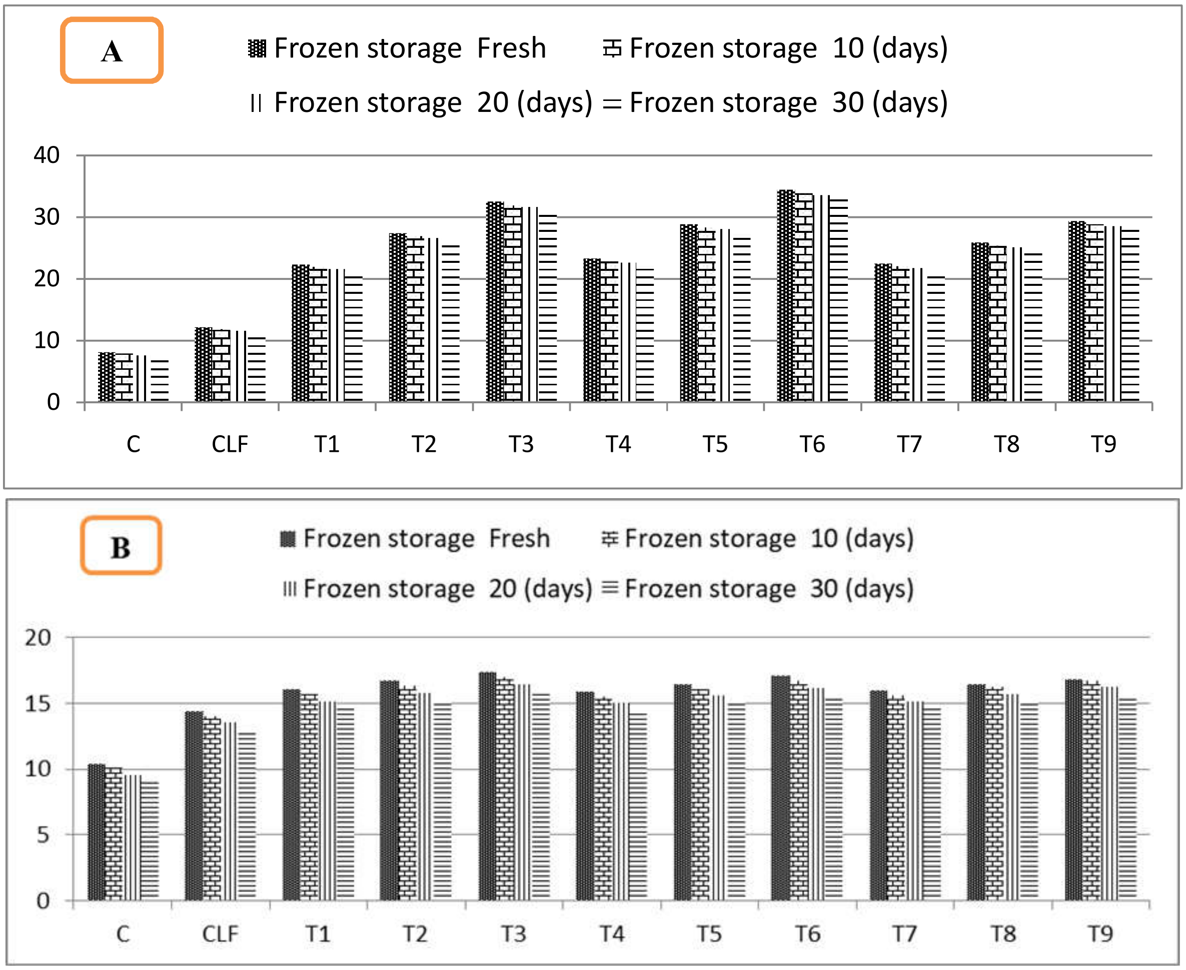


Fig (1): Effect of using different ratios of orange juice, peel and whole fruit on the melting rate % at 25 ºC of different ice cream mixes (average of three replicates)

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 by using orange as whole or a juice or its by-products are shown at Figs. (2 A, B). Full fat ice cream had lower TPC and AA than those of control low fat ice cream. 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 (Lindmark-

Mansson and Akesson, 2000). Similar findings were reported by Khalil and Blassy (2016). Addition of OJ 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). This may be due to the phenolic compounds of orange juice as well as its contents of ascorbic acid and carotenoids contents which causing the antioxidant scavenging properties (AL-Juhaimi and Ghafoor, 2013).



Figs (2: A, B): Effect of using different ratios of orange 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 treatments

Using OP in low fat ice cream increased both TPC and AA of low fat ice cream than untreated low fat ice cream but these values significantly affected by used ratio in ice cream mixes. While TPC and antioxidant scavenging activity of low fat ice cream using whole orange pulp had a moderate values than these made with WOP or OJ. The highest TPC and AA was found for using 16% orange juice followed by using 6% orange peel as well as 9% whole orange pulp followed by the lower ratios of orange juice, orange peel and whole orange pulp. Generally, all TPC and antioxidant scavenging activity 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 (2016 and 2019).

Cost of production:

Table (7) 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% fat decreased the used cream in the mix causing a 30.3% reduction of the production cost. Using substantial amounts of orange juice at ratio 8, 12 and 16% in low fat ice cream decreased the production cost with 25.74, 23.47 and 21.19% as compared with control full fat ice cream respectively.

While using orange peel at ratios 2, 4 and 6% decreased the cost of production cost to 30.05, 29.79 and 29.54% respectively as a result of the lower price of orange 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 orange pulp at ratios 3, 6 and 9% decreased the cost of production cost to 29.16, 28.02 and 26.88%, respectively as a result of lower price of whole orange pulp is lower than its juice only.

Table (7): Effect of using different ratios of orange 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	1101.24	30.30
T1	1173.24	25.74
T2	1209.24	23.47
T3	1245.24	21.19
T4	1105.24	30.05
T5	1109.24	29.79
T6	1113.24	29.54
T7	1119.24	29.16
T8	1137.24	28.02
T9	1155.24	26.88

* see Table (4).

Sensory properties of ice cream

Table (8), shows the different characteristics if ice cream treatments as affected by using orange juice, peel or whole fruit. Results referred to that full fat ice cream gained the highest scores for acceptability, richness mouth feel 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 (Dresselhuis *et al*., 2008). Decreasing the fat from ice cream resulted in a cooler and more watery body & texture product with few visible air bubbles.

Table (8): Effect of using different ratios of orange 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^{J}
T_1	43	22	8	8.5	81.5^{I}
T_2	44	22	7.5	8.5	82^{H}
T_3	46	22	7.5	9	84.5^{G}
T_4	42	26	9	8.5	85.5^{F}
T_5	43.5	28	9	8.5	89^{C}
T_6	42.5	27.5	9	9	88^{D}
T_7	43.5	25.5	9	8.5	86.5^{E}
T_8	45	27.5	9	8.5	90^{B}
T_9	45.5	26.5	9	9	90^{B}
After 20 days of freeze storage					
C	47	28	9	8.5	92.5^{A}
CLF	39	21.5	8	8	76.5^{J}
T_1	42	21.5	8	8.5	80^{I}
T_2	43	21.5	7.5	8.5	80.5^{H}
T_3	45	21.5	7.5	9	83^{G}
T_4	41.5	25.5	9	8.5	84.5^{F}
T_5	43	27.5	9	8.5	88^{C}
T_6	42	27	9	9	87^{D}
T_7	43	25	9	8.5	85.5^{E}
T_8	44.5	27	9	8.5	89^{B}
T_9	45	26	9	9	89^{B}

* 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 (4)

Adding orange juice (OJ) improved significantly the flavor but no clear effect on body & texture of low fat ice cream with higher melting rate and gained significantly higher total acceptability scores than control low fat. The higher ratio of OJ used were correlated to higher flavour scores and total acceptability scores. As the orange juice increased in the mix caused significantly higher total acceptability scores than the lower ratio. It was noticed that using 2-4% OP in ice cream making had significant effect on body & texture, flavor and melting resistance may be correlated to its rheological characteristics as compared to control low fat ice cream. This may be due to the increased viscosity of these treatments containing OP. Generally, low fat ice cream containing 4% OP gained total acceptability scores than using orange juice treatments. Increasing OP ratio to 6% caused a slight decrease for body & texture than that made with 4% slight flavour scores increase with higher melting resistance. So, using 4% enhanced the flavour, body & texture, colour and total acceptability scores as compared to untreated low fat ice cream. While increasing the used ratio of OP to 6% decreased the flavour scores and total acceptability scores as compared to use 4% OP in low fat ice cream. Several researchers found a linear correlation between using dried orange pomac in ice cream with lower flavour scores such as Ayar *et al*. (2018) and orange fiber by Akalin *et al*. (2018). On the other hand, using 3% whole orange pulp (WOP) in low fat ice cream caused a significant effect on both flavour and body & texture and consequently the total acceptability scores were significantly higher 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 6% WOP gained total acceptability scores near that of the full fat ice cream. Generally, the fresh values of treated ice creams were higher than these of aged low fat ice cream with orange juice or peel or whole fruit. This may be due to the higher oxidation rate than untreated ice creams.

The most acceptable treatments were using 6% whole orange followed 4% orange peel (OP) improved the total phenolic compounds, antioxidant scavenging activity, 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 28.02 and 29.54% as compared to full fat ice cream.

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صناعه ايس كريم منخفض الدهن باستخدام المنتجات الثانوية للبرتقال أو عصيره كمكون وظيفي مستدام

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يهدف هذا البحث إلى استخدام المنتجات الثانوية للبرتقال وما يحتويه من ألياف ومواد فينوليه ونشاط مضاد للأكسدة في صناعه ايس كريم وظيفي منخفض الدهن. حيث تم دراسة اثر استخدام مخلفات البرتقال بالمقارنة مع عصير البرتقال على الخواص الفسيوكيماوية، الريولوجية، المواد الفينولية الكلية، النشاط المضاد للأكسدة، الخواص الحسية و تكلفه الإنتاج للايس كريم منخفض الدهن. تم صناعه عينه المقارنة كأمله الدسم التي احتوت على ٦% دهن للمقارنة كما تم صناعه جميع معاملات الايس كريم منخفضة الدهن بحيث تحتوى على ١% دهن إحداها عينه مقارنه منخفضة الدهن بدون إضافات. تم أضافه عصير البرتقال بتركيزات ٨، ١٢ و ١٦% كما تم أضافه قشر البرتقال المجنس بنسب ٢، ٤ و٦% وكذلك تم تحضير لب البرتقال الكامل المجنس والتي تم إضافتها بنسب ٣، ٦ و ٩%. أوضحت النتائج إلى أن عينه المقارنة كاملة الدسم حازت على قيم أعلى من الصفات الريولوجية، الاس الهيدروجيني، الصفات الحسية مع أدنى قيم انصهار مع أعلى تكلفه إنتاج مقارنه مع جميع معاملات الايس كريم منخفض الدهن. استخدام عصير البرتقال لإنتاج ايس كريم منخفض الدهن أدى إلى زيادة درجات نكهة الايس كريم، المواد الفينولية الكلية، النشاط المضاد للأكسدة مع زيادة قيم معدل الانصهار عن عينه المقارنة منخفضة الدهن. بينما كان لاستخدام قشر البرتقال أو لب الفاكهة الكاملة المجنسة إلى تحسين قيم الصفات الريولوجية والمقاومة للانصهار وزيادة قيم المواد الفينولية الكلية، النشاط المضاد للأكسدة ودرجات التقييم الحسي مقارنه بعينه المقارنة منخفضة الدهن. يمكن التوصية باستخدام ٤% قشر البرتقال المجنس لصناعه ايس كريم منخفض الدهن (١% دهن) ذو درجات قبول حسي مرتفعه خاصة للقوام والتركيب. بينما كان لاستخدام ٦% لب البرتقال الكامل إلى تحسين الصفات القوام والتركيب وكذلك النكهة مما عمل على زيادة درجات التقييم الحسي بدرجات تقارب عينه المقارنة كاملة الدسم مع تخفيض تكلفه الإنتاج بنسبة ٢٨.٠٢%.

رقم الإيداع بدار الكتب
١٨٢٢٥ لسنة ٢٠١٣

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مجلة الإسماعيلية لعلوم وتكنولوجيا الألبان

جامعة قناة السويس

المجلد ٨ (١) ٢٠٢١

تصدرها:

الجمعية العلمية للعلوم الزراعية – جامعة قناة السويس – الإسماعيلية – جمهورية مصر العربية