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Research Article

Functional Low Fat Ice Cream with Using Inulin or β-Glucan

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Abstract

Background and Objective: This research aims to investigate the effect of using 0, 1, 2 and 3 % of inulin as dietary fibers fat replacer or 0.25 and 0.50% β-glucan as a stabilizer replacer in functional low-fat ice cream (1.5% fat) on the physicochemical, rheological, melting rates, total phenolic compounds (TPC), antioxidant scavenging activity (AA) and sensory characteristics. Control 6% fat was made for comparison the impact of several additives on the quality characteristics. The full fat ice cream had higher rheological characteristics, pH value and higher sensory properties with slower melting rates than other low fat ice cream treatments. Using different ratios of inulin or β-glucan increased the specific gravity, weight per gallon, freezing point depression with decreased pH values of different ice cream mixes. Ice cream contained different ratios of inulin or β-glucan increased % overrun, TPC and AA with slower melting rate as compared to control low fat ice cream. Sensory evaluation revealed using inulin improved significantly the body and texture and slightly the flavor scores with lower melting rates and gained significantly higher total acceptability scores than control low fat. While using β- glucan partially or completely instead of stabilizer in low fat ice cream enhanced the body and texture with lower melting rate but its impact on flavour were very limited. It can be concluded that using 2-3% inulin in low fat ice cream enhanced its quality characteristics and get nearly the same total acceptability scores of control ice cream. Owing to the higher price of inulin, it is favorable to use 2% inulin to get higher acceptability score for low fat ice cream with lower production cost.

Key words: Functional Ice cream, Inulin, β-glucan, low-fat ice cream, Antioxidant activity, Rheological properties, Sensory properties

INTRODUCTION

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 several health-promoting food ingredients[1].

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[2, 3]. It is a common view that high saturated fat intake is correlated with several chronic diseases such as obesity, cardiovascular diseases and cancer[4]. 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[5]. Accordingly, the food industry is facing the challenge of probing for new alternatives for fat without any quality loss[4].

The development of novel food and/or functional food products is increasingly challenged, as it has to fulfill the consumer's expectations for products that are simultaneously palatable and healthy[6]. 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[7, 8].

Consumption of dietary fibres play vital role in the reduction, prevention and treatment of chronic diseases such as gastrointestinal disorders, bowel, obesity, diabetes, cardiovascular disease and cancer as well as promotes physiological performance as lowering blood triglycerides and glucose control[9]. The recommended dietary fibre intake of 25–30 g/day can help to overcome the fibre deficit diet and correlated to several physiological and metabolic effects[10].

Inulin is a heterogeneous blend of fructose-polymers which found in nature primarily as storage carbohydrates in plants. It is basically a linear fructan (polysaccharide in nature) composed of fructosyl units (beta (2-1) linkage) and usually contains one terminal glucose moiety alpha (1-2 linkage) per molecule[11]. It can be extracted from several plants such as chicory and Jerusalem artichoke for industrial production[12]. The pH value of commercial inulin is about 5.53. Regarding to colour, too much variation exists between the colours of inulin samples because of the presence of variable amounts of phenolic compounds in different sources. Generally, it varies from white to brownish–yellow colour. So, inulin can be used in several countries without any limits in different food applications[13].

In addition, inulin has several techno-functional properties in food systems such as gelation property, gel integrity, prebiotic, dietary fibre and foaming ability. So, it used successfully as fat replacer in dairy products as dairy. Also, it imparts several therapeutic and nutritional which can improve health and reduce the risk of several diseases such as hyperglycemia, hypercholesterolemia, colorectal cancers, irritable bowel diseases and cardiovascular diseases[14, 15]. Several applications were used inulin in ice cream with more than 1.5% fat as fat replacer [16,17,18,19, 20].

β-Glucan is a soluble dietary fiber based on polysaccharide fragments. It can be derived from barley, oat and other cereals. It contains linear chain glucose polymer (1-3), (1-4)-β-D-glucans, which are partially soluble polysaccharides and β–glucan concentration were significantly affected by environmental conditions[21, 22]. Hull-less barley strains contains higher starch, β-Glucan contents than hull barley strains. So, hull-less barley grains is more suitable for food processing because of the presence of more bioactive nutrients[23].

β-Glucan has health benefits such as cholesterol, plasma lipid of human reduction, decrease the blood glucose and coronary heart disease with the consumption of dietary fiber is due to gel formation inside human body[22,24]. So, it can be act as a nutraceutical ingredient in several functional food applications.

Abdel-Haleem and Awad[25] investigated the partial substitution of skim milk solids with 1, 2, 3 and 4% hulless barley flour and 0.4% barley ß-glucan as a complete substitution of stabilizer on the quality characteristics of low fat ice cream (4% fat). The results showed that using barley flour increased significantly total solids, fiber and %fat, while % protein and % ash decreased significantly in ice cream mixes. While using barley 0.4% β-glucan showed the same manner of control. Addition of β-glucan increased specific gravity therefore the overrun percent was slightly decreased in the resultant ice cream with decreasing the sensory scores and melting resistance. The substitution of skim milk powder with 1 and 2 % barley flour enhanced sensory attributes of ice cream samples. While, ice cream made with beta glucan achieved mild score and acceptability.

Aljewicz *et al.*[26] determined the effect of using 0.5 and 1% of two types of β-glucan on the quality characteristics of low-fat ice cream. Results indicated that (1–3)(1–4) β-Glucan isolated from oats is more suitable for calorie-reduced ice cream making with functional characteristics similar to the control ice cream.

Aiming to enhance the quality characteristics of low fat ice cream (1.5% fat), a trail was done focusing on using different ratios of inulin as dietary fibers based fat replacer and β-glucan as a partial or complete stabilizer on the physiochemical, rheological characteristics, phenolic compounds, Antioxidant scavenging activity, melting rate and sensory properties were followed during 30 days of freeze storage.

MATERIALS AND METHODS

Study area: The study was carried out at the Department of Dairy, Faculty of Agriculture, Suez Canal University and Ismailia, Egypt from February 2019- June, 2020.

Materials: Inulin is a mixture of oligo- and polysaccharides which are composed of fructose units linked by a beta-1, 2-bond, mainly with an end-standing glucose unit. The degree of polymerisation (number of monosaccharide units) ranges between 3 and 60. It occurs naturally in chicory made under commercial name Orafti, Beneo Co., England. Beta- glucan 70% extracted from *Saccharomyces cerevisae* by Kuber Impex Ltd, India. 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

Manufacture of ice cream:-

Ice cream mixes (Table 1) were prepared according to the method described by Marshall and Arbuckle[27]. 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. Treatments included the following:-

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

T_1, T_2 and T_3: as CLF with 1, 2 and 3%% inulin respectively. While T_4 : as CLF with using 0.25% Lacta 9090 and 0.25 % β-glucan. On the other hand, T_5: as CLF with using 0.5% % β-glucan instead of Lacta 9090.

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)
C	15	0.50	62.75	9.75	12	0	0
CLF	15	0.50	68.24	13.26	3	0	0
T_1	15	0.50	67.24	13.26	3	1	0
T2	15	0.50	66.24	13.26	3	2	0
T3	15	0.50	65.24	13.26	3	3	0
T4	15	0.50	68.24	13.26	3	0	0.25
T5	15	0.50	68.24	13.26	3	0	0.50

Methods:-

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[27]. 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[27]), melting rate[28]. 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 and 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.*[29] for flavour (50 points), body and texture (30 points), melting properties (10 points) and colour (10 points).

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[30]. 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[31]; Burits and Bucar[32]). 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.*[33] 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.

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[34] 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

Properties of ice cream mix

The physical properties and pH values of different ice cream mixes are presented in Table (2). 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[35].

Adding of different percentages of inulin increased significantly the specific gravity and weight per gallon values than control low fat ice cream (CLF). The rate of increase was dependent on the used ratio of inulin. So, the highest specific gravity was found in T_3 which treated by 3% inulin. Similar findings were reported by Abd El-Khair *et al.*[36]. While partial or complete substitution of stabilizer with β-glucan increased significantly both specific gravity and weight per gallon values than control low fat ice cream (CLF). Same trend were found by Abdel El-Haleem and Awad[37].

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[38]. Results showed that full fat ice cream mix exhibited the highest freezing point (Table 2) 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[38], which may explain the significant difference in FPD between full fat ice cream and other low ice cream mixes.

Using different ratios of inulin in low fat ice cream rose significantly ($p<0.01$) the FPD of low fat ice cream because of its additional contents of sugar and ash contents causing higher freezing point depression with the added ratio. So, T_3 had lower freezing point than both T_1 and T_2. In ice creams, sugars and ash contents are responsible for the freezing point depression[39]. For using β-glucan partially or completely substation caused also an increase for the freezing point depression. Similar results were found by Abdel El-Haleem and Awad[37] for reduced fat ice cream made with β-glucan.

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. Similar findings were found by Khalil and Blassy[35]. Addition of either inulin or β-glucan decreased the pH value of the resultant ice cream mixes. Similar findings were reported by Pintor *et al.*[17] and Aljewicz *et al.*[26] for using inulin as fat replacer in reduced fat ice cream and β-glucan in reduced fat ice cream respectively.

Table (2): Effect of using different ratios of inulin and β-glucan 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	1.0870^{E}	4.931^{E}	-2.28^{A}	6.42^{A}
CLF	1.1127^{D}	5.048^{D}	-2.35^{B}	6.33^{B}
T1	1.1152^{C}	5.059^{C}	-2.37^{C}	6.30^{G}
T2	1.1188^{B}	5.075^{B}	-2.39^{D}	6.28^{D}
T3	1.1216^{A}	5.088^{A}	-2.40^{E}	6.26^{E}
T4	1.1134^{D}	5.051^{D}	-2.36^{BC}	6.32^{B}
T5	1.1158^{C}	5.062^{C}	-2.37^{C}	6.30^{C}

* 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.

The rheological parameters of different mixes

The rheological parameters (Table 3) 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[3]. On the other hand, it was found that flow behaviour index had an opposite trend to all the rheological characteristics.

Using substantial ratios of inulin in low fat ice cream increased significantly its rheological parameters except the flow behavior index than those of control low fat ice cream. The increase of the viscosity of low-fat ice cream mixes with inulin may be due to the interactions of this dietary fiber and liquid components of the ice cream mix. This effect is caused by both the contribution of soluble solids to the aqueous phase and by the water-binding effect of inulin which can form a gel-like network that modify the viscosity mix[40].

While partial or complete substitution of stabilizer with β-glucan increased significantly the rheological characteristics except the flow behavior index than those of control low fat ice cream. Din *et al.*[24] explained this phenomenon by the additional β-glucan starch which promotes gelatinization in the final product. Similar findings were reported by Abdel El-Haleem and Awad[37].

Table (3): Effect of using different ratios of inulin and β-glucan on the rheological characteristics of different ice cream mixes

	Rhelogical characteristics				
Treatments	Apparent viscosity (mPas)	Plastic viscosity (mPas)	Yield stress (N/m^2)	Flow behavior index	Consistency coefficient index (mPas)
C	348.5^{A}	191.2^{A}	4.75^{A}	0.520^{E}	127.8^{A}
CLF	257.6^{E}	135.3^{E}	3.04^{E}	0.612^{A}	76.2^{E}
T1	278.7^{D}	147.9^{D}	3.47^{D}	0.602^{B}	89.3^{D}
T2	298.3^{C}	159.8^{C}	3.79^{C}	0.596^{C}	96.4^{C}
T3	321.5^{B}	165.5^{B}	3.98^{B}	0.587^{D}	112.6^{B}
T4	273.2^{D}	144.1^{D}	3.42^{D}	0.600^{B}	87.8^{D}
T5	294.1^{C}	155.9^{C}	3.72^{C}	0.594^{C}	94.8^{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 different ratios of inulin or β-glucan are showed in Table (4). 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[41].

Using gradual ratios of inulin caused gradual increases for overrun with a decrease trend for specific gravity of ice cream and weight per gallon as compared to untreated low fat ice cream as a result of the parallel increases for all the rheological characteristics. This increase in low fat ice cream treated with inulin was reported by Akalin *et al.*[16]. Higher apparent viscosity would lead to more efficient break down of incorporated air cells and to smaller air cell size of ice cream mix during freezing, resulting in higher overrun values[42,43].

The overrun of the experimental ice cream samples increased with the addition of the inulin or β-glucan, compared with CLF as a result of increasing the incorporation of air into ice-cream. It was reported that dashers of batch freezers could incorporate more air into samples with higher viscosity[44].

Table (4): Effect of using different ratios of inulin and β-glucan on the physical properties of the resultant ice cream (average of three replicates)

Treatments	Specific gravity (gm/ml)	Weight per gallon (Kg)	% overrun
C**	0.703^{E}	3.189^{E}	54.62^{A}
CLF	0.794^{A}	3.602^{A}	40.14^{G}
T_1	0.784^{B}	3.557^{B}	42.24^{E}
T_2	0.773^{C}	3.507^{C}	44.73^{C}
T_3	0.765^{D}	3.470^{D}	46.61^{B}
T_4	0.787^{B}	3.570^{B}	41.47^{F}
T_5	0.779^{C}	3.534^{C}	43.23^{D}

* A, B, C, D, E, ……: values with the same letter among the treatments are not significantly different ($p<0.01$).
** see Table (2).

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[41]. Similar finding were reported by Khalil and Blassy[35,45]. While using different ratios of inulin in low fat ice cream tended to have lower melting rate than control low fat ice cream. The lower melting values of these treatments could be related to their rheological properties since it showed higher values for viscosity and consistency index. This may be due to replacing the loss of fat in low fat ice cream matrix with inulin polydextrose[46]. Similar findings were reported by Junyusen *et al.*[47] and Paula *et al.*[20].

Substituting the stabilizer partially or completely with β-glucan showed lower melting values as compared to control low fat ice cream. As the percentage of dietary fibres increased as the melting resistance increased. Muse and Hartel[48] found that melting rate increases as the level of fat destabilization diminishes, the consistency coefficient decreases, and the ice crystal size increases. Therefore, the higher consistency index and viscosity of ice creams containing fiber compared with the other samples may have been responsible for their reduction in melting rate. Similar findings were reported by Abdel-Haleem and Awad[25].

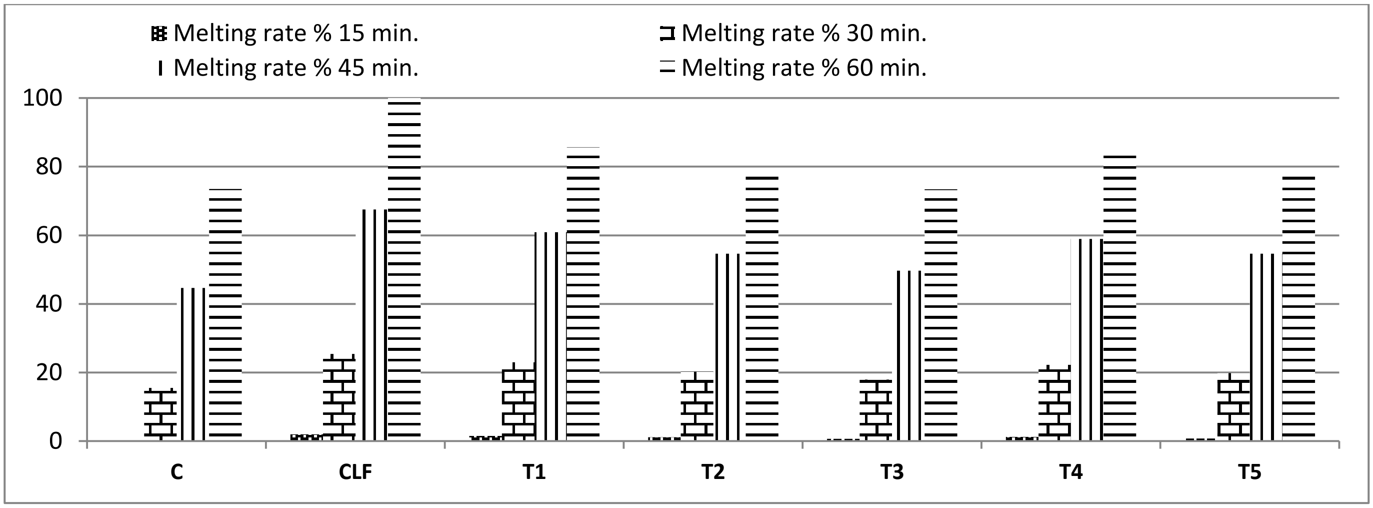
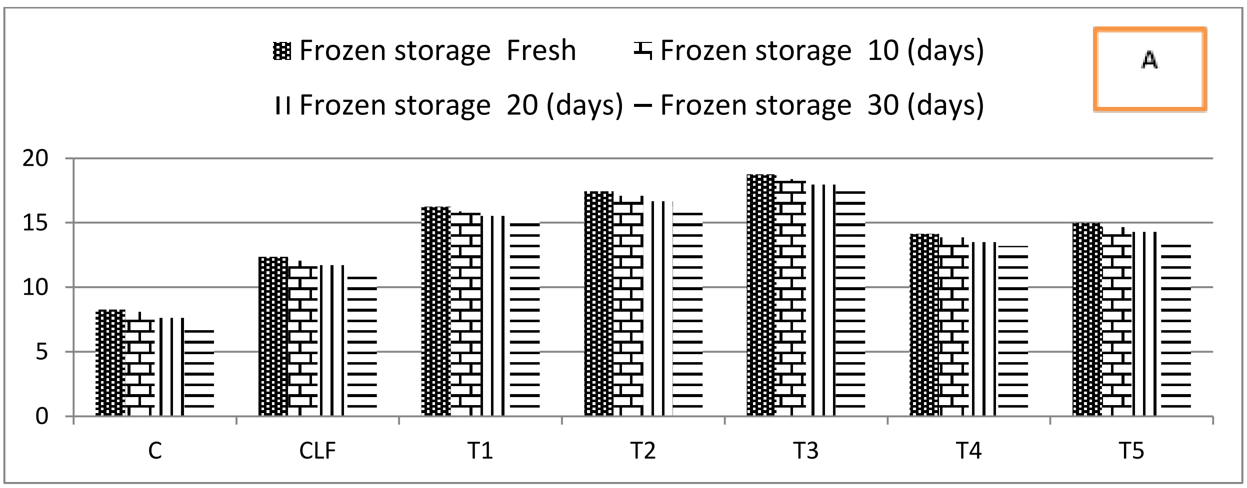
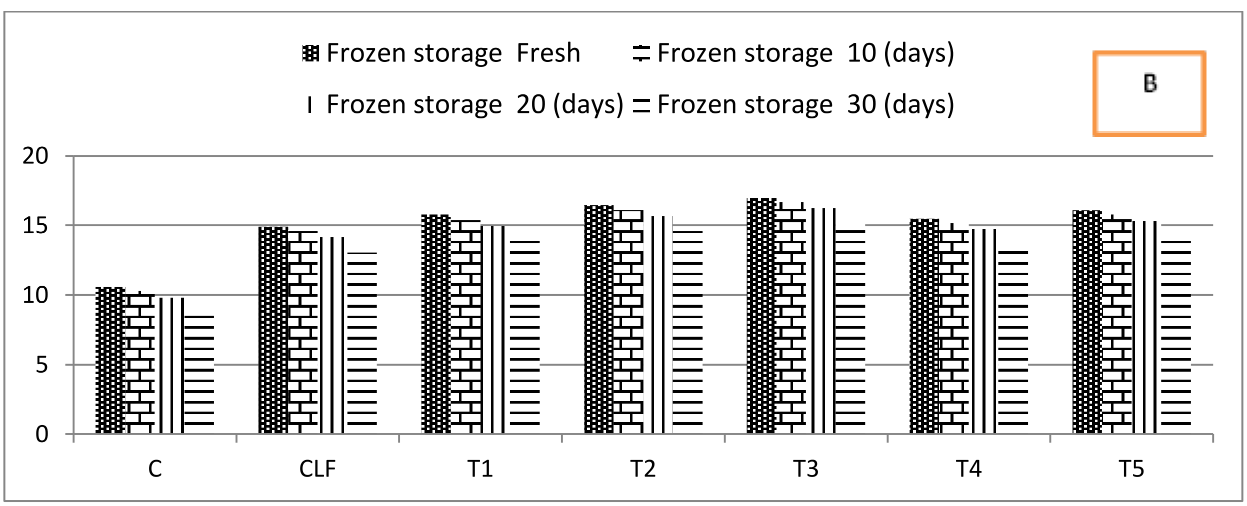


Fig (1): Effect of using different ratios of inulin and β-glucan on the melting rate % at 25 ºC of different ice cream mixes (average of three replicates).





Figs (2: A, B): Effect of using different ratios of inulin and β-glucan on the total phenolic compounds (A) expressed as mg GAE/ g and antioxidant scavenging activity% (B) of different ice cream treatments.

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 inulin or β-glucan are shown in 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[49]. Similar findings were reported by Khalil and Blassy[45]. Addition of inulin 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 inulin[50]. So, the highest total phenolic compounds and antioxidant scavenging activity were theses treated with 3% inulin throughout the freeze storage among treatments. While using β-glucan partially or completely instead of stabilizer caused significant increases for both total phenolic compounds and antioxidant scavenging activity. The functional claims associated with barley β-glucan with respect to polyphenol and antioxidant properties might be depends upon the isolation method and its level of purity[51].

Sensory properties of ice cream

Table (5) shows the different characteristics if ice cream treatments as affected by using inulin and β-glucan. 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[2]. Decreasing the fat from ice cream resulted in a cooler and more watery body & texture product with few visible air bubbles. Adding ratios of inulin in low fat ice cream improved significantly the body and texture and slightly the flavor scores without any colours with lower melting rates and gained significantly higher total acceptability scores than control low fat. The higher ratio of inulin used were correlated to higher body and texture as well as flavour scores and total acceptability scores. Similar findings were reported by Junyusen *et al.*[47] and Abd El-Khair *et al.*[36] who used inulin as fat replacer in low fat ice cream. Akbari *et al.*[18] reported that low fat ice cream contained inulin tended to have higher sensory scores as a result of water absorption by inulin, and hence the increase of unfrozen water content and consequently the decrease of the ice crystals in ice cream structure.

Table (5): Effect of using different ratios of inulin and β-glucan 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**	48.0	28.5	9.0	9.0	94.5^{A}
CLF	40.0	22.0	8.0	8.0	78.0^{G}
T_1	43.0	26.5	9.0	8.5	87.0^{D}
T_2	44.5	27.5	9.0	9.0	90.0^{C}
T_3	46.0	28.5	9.0	9.0	92.5^{B}
T_4	40.0	26.5	9.0	8.5	84.0^{F}
T_5	40.0	27.5	9.0	9.0	85.5^{E}
			After 20 days of freeze storage		
C	47.0	28.0	9.0	8.5	92.5^{A}
CLF	39.0	21.5	8.0	8.0	76.5^{G}
T_1	41.5	26.0	9.0	8.5	85.0^{D}
T_2	43.5	27.0	9.0	9.0	88.5^{C}
T_3	44.5	28.0	9.0	9.0	90.5^{B}
T_4	39.0	25.5	9.0	8.5	82.0^{F}
T_5	39.0	26.5	9.0	8.5	83.0^{E}

* 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)

It was noticed that addition of β- glucan partially or completely instead of stabilizer in low fat ice cream had significant effect on body & texture with lower melting rate but its impact on flavour were very limited. Similar results were reported by Abdel-Haleem and Awad[25] who found that ice cream made with beta glucan achieved mild flavour score and acceptability. 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.

SIGNIFICANCE STATEMENT

It can be concluded that using β- glucan partially or completely instead of stabilizer in low fat ice cream enhanced the body and texture with lower melting rate but this enhancement on flavour was limited. Also, using 2-3% inulin in low fat ice cream enhanced its quality characteristics and get nearly the same total acceptability scores of control ice cream. Owing to the higher price of inulin, it is favorable to use 2% inulin to get higher acceptability score for low fat ice cream with lower production cost.

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