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Functional properties and nutritional quality of ice cream enriched with Jerusalem artichoke flour

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Abstract

In the last years, some innovatively produced food types have attracted great attention of consumers for their health benefits, such as protection from diet related diseases. Ice cream can fulfill such function by serving as a means of delivering pro- and prebiotics. This study conducted to improve the functional properties of ice cream by incorporating Jerusalem artichoke tuber JAT powder. Incorporation of JAT flour into basic ice cream mix at three levels 10, 20 and 30% of the mixes weight on the physicochemical properties and sensory characteristics of samples were determined. Functional constituents, i.e. inulin, fiber and micro-essential minerals were increased with the greater level of JAT inclusion. Incorporation of JAT with ice cream raised the melting resistance, overrun, viscosity of ice cream. It can be concluded that the enrichment of ice cream with JAT up to 20% will provide consumers health benefits and could be introduced to markets as functional ice cream.

Keywords: Jerusalem artichoke tuber, Functional ice cream, inulin, prebiotic.

1. Introduction

Ice cream is a valuable food containing high nutritive constituents for human health. It has cooling effect, hence it is commonly preferred in the hot summer days by consumers of all ages. There are many kinds of ice cream available in the market and in the recent years, the researches on ice cream technology focus on the development of new ice cream formulations Therefore, new varieties of ice cream are coming out targeting the health conscious consumers, and also new manufacturing processes giving more value for money spent by the consumers [15]. There were 240 different types of ice cream with high quality consumed in any season [26].

There are various studies reported in the literature related to addition of new food ingredients for the development of new ice cream formulations. Different ingredients such as cola extracts [10], soy protein [14], flaxseed oil [17], citrus fiber , hazelnut skin and flour [9] were studied as a new ingredient for the development of new ice cream formulation with peculiar flavor, taste, and texture characteristics. Also, numerous ice cream formulations with functional properties have been developed, for example, probiotic ice cream and yogurt ice cream [2], ice cream enriched with dietary fiber, Citrus fiber, i.e. [11], green banana flour [27] and ice cream containing natural antioxidants, black tea and herbal teas [20], Pomegranate by-products [7] and processed amla [18].

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Ice cream can be defined as a smooth, sweet, cold dessert food prepared from a frozen mixture of milk products and flavorings, containing a minimum of 10% milk fat [21]. The mixture is homogenized after pasteurization and aged to improve the physical properties before the freezing process. In recent years, the light has focused on foods rich in nutraceuticals and functional properties. From this point of view, the consumer's trend has been toward foods with more natural antioxidants, dietary fibers, natural colorants, minerals, vitamins, low calories, low cholesterol, and low fat and free of synthetic additives, etc. While ice cream could be poor in some of these characteristics, JAT one of the good natural sources of these nutraceuticals and functional components. Commercially ice cream is made from a mixture of milk and other ingredients such as fat milk, non–fat solids including proteins, lactose, sweeteners, stabilizers and emulsifiers, in addition to flavors and colorants. Although ice cream is rich in calories, it is poor in dietary fibers and some of natural antioxidants such as taurine, vitamine C, colors and fibers. This ingredient also plays an important role in flavor and in the solid structure formation during freezing, establishes the consistency, appearance and resistance to ice cream melting [16].

Jerusalem artichoke (*Helianthus tuberosus* L.) is a native plant of the North American plains cultivated for different purposes in many countries. Jerusalem artichoke is a natural raw material. Its tuber contains high amount of dietary fiber namely inulin and fructo-oligosaccharides "FOS" [13]. Inulin has both nutritional and functional attributes, particularly beneficial to individuals with Type 2 diabetes, obesity and reduced risk of a colorectal cancer. Furthermore, inulin facilitates the digestion of high protein diets, retards fat absorption, and provides roughage preventing constipation, remains in digestive tract providing satiety without carrying of extra calories, lowers blood cholesterol and triglycerides, helps with blood glucose control for diabetics and decreases incidence of colon cancer [4]. In addition, inulin and "FOS" improve bioavailability of minerals such as calcium, magnesium and iron, increase activity of beneficial live active cultures and inhibition of harmful bacteria in the digestive tract.

Studies on the development of new dairy products from *Jerusalem artichoke* tubers are limited. using JAT for the production of new yoghurt with high biological value [13], also it used in soft cheese manufacture [22]. To our knowledge, there is lack of publication regarding the enrichment of ice cream using Jerusalem artichoke tubers. Therefore, the objectives of the present study were to investigate the possible use of *Jerusalem artichoke* for the production of ice cream and to characterize the ice cream product in terms of the rheological, sensory properties and physicochemical characteristics.

2. Materials and Method

2.1.Materials:

*2.1.1.Source of ice cream ingredients***.** Fresh cow's milk (4% fat) was obtained from private farm., Cow's skim milk powder (97% TS, product of Dairy America™) , Commercial grade sugar, vanillin and Cream (25% fat) were obtained from the local market. Gelatin, emulsifier (mono- and di-glycerides) were obtained from Misr Food Additives- MIFAD.

2.1.2.Source of JAT flour. Jerusalem artichoke tubers (*Helianthus tuberosus* L.) harvested in December 2014 were obtained from the Experimental Station, Agriculture Research Center, Dokki, Giza, Egypt.

2.2. Methods:

2.2.1. Processing of Jerusalem artichoke tubers powder. Jerusalem artichoke tubers were washed with tap water and any deteriorated parts were removed, then the tubers were sliced in dividedly to reasonable thickness by conventional food slicing machine. The sliced tubers were immersed immediately in boiling water for 5 min, following by immediate dipping in cold citric acid solution (1%) to inhibit polyphenol oxidases activity. After that slices of tuber were dried in a fan oven at 54°C until samples reached constant weight, then the dried slices were powdered using hammer mill and sieved through 40-mesh sieve. Then the obtained Jerusalem artichoke tubers powder was kept at -18°C until use.

2.2.2.Preparation of basic Ice Cream Mix. The basic ice cream mix was prepared according to the Egyptian standards of ice cream [12]. The formula of ice cream mixes is shown in Table (1).

Four mixes were prepared, control mix (free of JAT powder), 10% JAT-fortified mix (T1), 20% JAT-

fortified mix (T2) and 30% JAT-fortified mix (T3). The JAT was added as replacement agent of skim milk powder and sucrose solids at levels mentioned, which means that all formula has the same total solids. They were iced in ice cream machinery (−5 °C) and hardened at−22 °C for one day.

Table 1. Ice cream mix formulations

Ingredients	Amount/100g			
	Control	T1	T2	T3
Whole milk	46.3	46.3	46.3	46.3
Cream	32.5	32.5	32.5	32.5
Skim milk powder	4.6	4.54	2.48	0.42
Sucrose	16	14	14	14
Vanilla flavor	0.1	0.1	0.1	0.1
Gelatin	0.5	0.5	0.5	0.5
JAT powder	0	2.06	4.12	6.18

2.2.3.Ice cream processing. The ice cream was prepared according to the method of [27].The ice cream was processed as follows: the required amounts of skim milk powder was mixed with gelatin, sucrose and the required amounts of JAT powder and then added slowly to the liquid ingredients (milk and cream) at 45°C under vigorous agitation. The basic mixes were pasteurized at 80°C for 10 minutes in water bath and then cooled to 4°C in ice bath with the cooled basic mixes in a blender for 2 minutes. After that all mixes were aged for 24 hours at 4°C before frozen, after aging the amount of vanilla was added. The mixes were frozen in cream machine (Taylor-male, Model156, Italy). The produced ice cream was packaged in cups (100cc) and placed in a freezing cabinet at –18°C for 24 hours at least before assessment of chemical and Technological Properties, and stored at −18 °C.

2.2.4. Chemical analysis. For each parameter, samples were analyzed in three replicates. The total solids/moisture, protein and ash were analyzed by heating a 5g sample in a muffle furnace at 100°C for 1 hour, 200°C for 2 hours and 550°C overnight [3]. Titratable acidity, expressed as percentage of lactic acid, was determined by mixing 10 g of ice cream sample with 20 mL of distilled water and titrating with 0.1 N NaOH using phenolphthalein as an indicator to an end-point of faint pink color. The measurements were done according to [3]. Fat content of milk and cream was estimated using Gerber's method [6] and that of Jerusalem artichoke tubers powder and its products using Soxtec (Foss instrument, Sweden). The pH of samples was determined using pocket pH meter (Instrument 8021). which was previously calibrated with pH 7.0 and 4.0 standard buffers. The fiber content was determined using Fibertec (Foss instrument, Sweden). Inulin was determined according to [24]. All analysis were carried out in Triplicate at 20°C.

2.2.5. Minerals analysis. The samples were dry ashed at 550°C and then the minerals analysis were determined as follow: Calcium, Sodium, Iron and Potassium of the prepared ice cream were determined according to [3]. The samples were wet digested using a Nitric acid and per chloric acid mixture (HNO_3, $HClO_4$, 2:1 v/v). Iron and Calcium were determined in the digested sample using a GBC Atomic Absorption 906 A. Sodium and Potassium were determined by flame photometer 410 .

2.2.6. Overrun of ice cream (%). was calculated according to [1] by application of the following equation:

Overrun % = Weight of mix - Weight of the same volume of ice cream / Weight of ice cream mix *100.

2.2.7.The viscosity of the mixes: was measured at 20°C using The Brookfield viscometer (Model RVDVII, Brookfield Engineering Laboratories , INC., MA, USA). Viscometer reading was recorded in centipoises (mPas) The viscometer was operated at 20 rpm (spindle number 4) [3].

2.2.8.Complete melting times: was measured according to [19]. 25 g of tempered samples were left to melt (at room temperature, 20°C) on a 0.2 cm wire mesh screen above a beaker. Complete melting times of samples were determined as seconds.

2.2.9. Sensory evaluation: Control ice cream along with experimental samples incorporating variable levels of processed Jerusalem artichoke tubers powder were evaluated by the staff members and semi–trained panelists. Before evaluation ice cream samples were moved from the hardening cabinet and placed in a freezer with a temperature ranging from –15 to –12°C in order to temper the samples uniformly. Scoring was carried out according to [23], for flavor (45) and body and texture (30).

2.2.10. Statistical analysis: The data were analyzed statistically using SPSS statistical software program version 16 (SPSS Inc., Chicago, IL, USA) Analysis of variance (ANOVA) and Duncan's Multiple Range Test was used to determine significant differences among results.

3. Results and Discussion

3.1.Chemical composition of Jerusalem artichoke tubers:

The chemical composition of Jerusalem artichoke tubers flour calculated on the basis of dry matter was shown in (Table 2). The results indicated that the moisture content of JAT powder was 7.32% ± 0.2. This low moisture content is reflected on the high total solids content. The components of total solids were 74.57± 3.1 , 7.60 ± 0.7, 3.81 ± 0.1 and 5.12 ± 0.4 for total carbohydrates, crude protein, crude fiber and ash, respectively. This result was in line with the results mentioned by [13], who found the chemical composition of JAT were: 6.8±0.11, 84.6±011, 2.6±0.02, 4.4±0.03 and 5.2±0.01 g/100 g, for moisture, total carbohydrate, crude protein, crude fiber and ash respectively. The high carbohydrate content of Jerusalem artichoke tubers is mainly in the form of inulin. Jerusalem artichoke tubers contains high amount of dietary fiber namely inulin and fructo-oligosaccharides [13].

To date inulin has been increasingly used as functional ingredients in processed food due to its unique characteristics.

Also, the tubers are the source of fiber which is the most appreciable components of Jerusalem artichoke tubers. Results in Table (2) showed that the fiber content was 3.81% ± 0.1.

Although the high inulin content is the case why Jerusalem artichoke tubers are used for obtaining functional food, also the high biological value of protein and balanced amino acids composition of the tubers is worth to underline. In this study, the protein content of the tubers was 7.60% ± 0.7, which is in agree with [8] and higher than that reported by [13]. These differences in tuber composition might be related to the variety of the tubers. From these results, it could be concluded that Jerusalem artichoke tubers is a rich source of inulin, fibers and crude protein. And it could be concluded that, JAT have level of inulin high enough to be utilized commercially. These substances are added to milk products in order to support the viability of probiotic strains and to increase health benefits of the consumers.

3.2. Effect of incorporation of Jerusalem artichoke tubers on composition of ice cream:

The effect of incorporation of JAT at different levels on the composition of ice cream is shown in Table (3). The fat and protein content in ice cream were decreased with the addition of JAT compared with their content in control ice cream, and the rate of the decrease was in parallel with the JAT level. The low fat content in JAT is a responsible factor for the decrease in fat content in ice cream, [13] found that the fat content in JAT was 0.8 g/100g. On the other hand, fortification of ice cream with JAT had an increasing effect on ash, fiber and carbohydrate content of the ice cream and the increase was in proportional with the level of JAT incorporation. The high content of these ingredients in JAT powder [5,13], and in (Table 2) is the main factor responsible for the high content of ash, fiber and carbohydrate in JAT-fortified ice cream compared with their content in control ice cream.

Table 2. Chemical composition of raw materials

Components g/100g	Jerusalem artichoke tubers (JAT) g/100g	Milk %
Moisture	7.32±.2	87.76±3.5
Ash	5.12±0.4	0.76±0.03
Crude fiber	3.81±0.1	-
Crude protein	7.60±0.7	3.67±0.12
Ether Extract	1.58±0.03	-
Total carbohydrates	74.57±3.1	4.78±0.3
Inulin	70.79±3.45	-
Fat	-	4.0±0.1
pH	-	6.71±0.0
Acidity	-	0.17±0.01

Values are means ± SD (n= 3)

In addition to the effect of JAT on ice cream composition, the acidity and pH of ice cream has been also affected.

The acidity was increased and in parallel the pH was decreased in ice cream containing JAT compared with the acidity and pH of control ice cream (Table 3). The progressive decrease in pH and the increase in acidity of ice cream mix were in parallel with the increase in JAT level in mix. This changes in the magnitude of acidity and pH with the increase in JAT level reveal to that JAT has an acidifying effect on processed food. High content of carbohydrate in JAT may be the most responsible reason for decreasing the pH of ice cream mix. In the present study, although the pH value of the control ice cream was 6.42 and in turn the pH value of JAT-fortified ice cream was 5.98 no deleterious effect on protein stability was observed. aggregation of casein micelles were noted at pH values of 4.6 – 4.9 when kiwifruit was added into ice cream [25].

3.4. Effect of the addition of JAT on physical properties of ice cream:

The effect of incorporation of JAT in ice cream mix on properties of ice cream is shown in Table (5). Viscosity accepted to be among the significant characteristics of ice cream mixture, they result in good body and texture properties in the production process of ice cream. From this point of view, it is important to measure the viscosity to determine how JAT powder may affect the characteristics of an ice cream mixture. It can be seen that addition of JAT affected the ice cream viscosity (Table 5). The results indicated that the lowest, specific gravity, weight per gallon and viscosity values were obtained in control sample and the highest in sample T3 (30% JAT). Thus among the several advantages of JAT powder can be the improvement of viscosity of ice cream mix. These results could be due to reduce moisture with increase addition various amounts of JAT.

As can be seen in Table (5) the time period required for melting process to complete in ice cream samples in the present study was found to be longer in the case of ice cream fortified with JAT. The melting period was 4011 Sec for control ice cream sample compared with 4123 to 4223 Sec. for JAT-fortified ice cream. The effect of addition of JAT at level of 20% gave the longest melting time compared with fortification levels of 10 and 30% JAT. This results show to the high resistant of ice cream fortified with JAT against melting. It was suggested by [2] that the reason for slower melting of ice cream with added inulin might be the ability of inulin to prevent water molecules from moving freely. Slowing melting of ice cream with citrus fiber and green banana flour who are in agreement with the findings of this study [11,28].

Overrun and melting are associated with the volume of air involved in the manufacturing process. This property can shape the structure of the final product because the air present in the ice cream can provide light texture and affect some physical properties, such as melting and hardness. Although the addition of JAT increased the overrun compared with the overrun on control ice cream sample, the overrun was at maximum at 20% JAT fortification (Table 5). A great association was observed with the overrun and melting properties of ice cream fortified with JAT.

3.5.Sensory evaluation:

Results of the sensory evaluation of samples were shown in Table (6). Sensory properties of the ice cream samples were found to be affected by the addition of JAT. Panelists preferred the ice cream with addition of 20% JAT (T_2) rather than the control and other treatments. The addition of JAT had effects on body and texture and flavor. The acceptability of ice cream samples produced using 30% JAT had the lowest score. The results recorded a significant between all treatments.

Table 3. Effect of the addition of JAT on the main chemical composition and physicochemical properties of ice cream samples.

Ice cream samples	Control	T1(JAT 10%)	T2(JAT 20%)	T3(JAT 30%)
Ash%	0.62±0.0^{c}	0.89±0.0^{b}	1.02±0.01^{a}	1.27±0.01^{a}
Protein%	3.52±0.1^{a}	3.30±0.0^{b}	3.1±0.0^{b}	3.06±0.0^{b}
Fat%	10.30±0.4^{a}	9.02±0.4^{b}	8.90±0.4^{b}	8.82±0.5^{b}
Titratable acidity	0.18±0.25^{c}	0.195±0.23^{b}	0.20±0.1^{a}	0.21±0.60^{a}
Fibers%	0.60±0.1^{c}	0.76±0.0^{b}	0.85±0.1^{a}	0.88±0.1^{a}
Carbohydrates%	17.91±0.6^{c}	19.01±1.2^{b}	19.91±0.3^{b}	20.05±0.4^{a}
pH	6.42±0.04^{a}	6.14±0.04^{b}	6.1±0.04^{b}	5.98±0.07^{c}

*Letters (a,b and c) within the same row with different superscripts differed significantly ($p<0.05$).

Table 4. Effect of the addition of JAT on the minor elements of ice cream samples.

Ice cream samples	Minerals (mg/100g)			
	Fe	Ca	Na	K
Control	0.43±0.32^{b}	141.84±0.1^{c}	60.41±0.62^{c}	183.90±o.04^{b}
T1	0.56±2.36^{b}	144.65±0.1^{b}	70.08±0.78^{b}	189.14±0.03^{a}
T2	0.67±0.68^{a}	146.23±0.02^{a}	72.14±1.11^{a}	192.32±1.1^{a}
T3	0.68±5.33^{a}	146.42±0.21^{a}	73.01±1.14^{a}	192.41±0.08^{a}

* Letters (a,b and c) within the same column with different superscripts differed significantly ($p<0.05$).

Table 5. Effect of the addition of JAT on some properties of ice cream samples

Ice cream samples	Overrun%	Viscosity (mPas)	Complete melting times (seconds)
Control	46.46±4.61^{c}	296±4.61^{c}	4011±134^{c}
T 1	48.52±5.87^{b}	301±4.87^{c}	4123±144^{bc}
T2	49.69±2.87^{a}	325±5.87^{b}	4223±194^{a}
T3	47.37±6.93^{b}	334±4.93^{a}	4125±173^{bc}

* Letters (a,b and c) within the same column with different superscripts differed significantly ($p<0.05$).

Table 6. Effect of the addition JAT on organoleptic properties of resultant ice cream.

Organoleptic characteristics of ice cream	Ratio of added JAT			
	control	T1	T2	T3
Flavor (45)	42.3^{b}	42.6^{b}	43.1^{a}	42.0^{c}
Body and Texture (30)	28.2^{b}	28.7^{b}	29.1^{a}	27.8^{c}
Total scores (75)	70.5^{c}	71.3^{b}	72.2^{a}	69.8^{c}

*Letters (a,b and c) within the same row with different superscripts differed significantly ($p<0.05$).

4. Conclusion

Results of the present study indicated that incorporation of Jerusalem artichoke tubers improved the functional properties of ice cream. They increased inulin, fiber and ash content. The overrun, viscosity and melting resistance increased with enhanced inclusion of JAT. The overall acceptability scores were highest at 20% level of incorporation.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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