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Preparation of Reduced Lactose Ice Cream Using Dried Rice Protein Concentrate

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Abstract: Dried rice protein concentrate (DRPC) is a by-product of rice milling industry. It contains low fat, low lactose, minerals, vitamins and rich protein. Effect of partial and complete replacing of skim milk powder (SMP) with DRPC on the acceptability and physiochemical properties of functional reduced lactose ice cream mix and its resultant product was investigated. Base ice cream mix was standardized to contain 8% fat, 11% solids not fat, 15% sugar and 0.3% stabilizer. Skim milk powder was used as source of solid not fat (SNF) in control ice cream mix, while DRPC was added as a substitute of SMP at a ratio of 20, 40, 60, 80 and 100%. Physical, chemical and organoleptic properties of mixes and final products were determined. Results showed that ash and lactose contents were significantly decreased with increasing the ratio of added DRPC in the blend. The different ratios of DRPC had no significant effect on pH value, total solids and fat content, while it caused gradual increase in the values of TN, crude fiber, specific gravity, weight per gallon, freezing point, viscosity, overrun and melting resistance of resultant products. On the other side, using of DRPC in preparing reduced lactose ice cream mixes resulted in improvement of the flow curves as compared with control mix. Sensory evaluation revealed that treated samples prepared by replacing 20, 40 and 60% were more acceptable and palatable. It could be concluded that reduced-lactose-ice cream could be prepared by substituting SMP with DRPC up to 60% with good functional properties and more acceptability It is a good way to introduce low lactose-ice cream product especially for individuals who suffering from lactose intolerance.

Key words: Broken rice · Rice protein concentrate · Reduced lactose ice cream

INTRODUCTION

Functional dairy products have recently emerged as a novel sector of health - enhancing products. The target of functional products is largely dependent on the ingredients used. The functional foods are now officially recognized as foods for specific health use [1]. The American Dietetic Association has stated that functional foods can include those foods that are whole, fortified, enriched or enhanced, while nutraceuticals are isolated components that can be incorporated into foods to enhance health at levels not usually obtainable from normal foods [2].

In specific view, ice cream is the most popular frozen dairy product consumed nearly by all levels of society, especially children. The major ingredients in the ice cream formula backbone are sweetener, stabilizer and/or emulsifiers, beside milk fat, milk solids not fat that contains milk protein, minerals and lactose sugar [3]. Lactose is the main carbohydrate in milk and dairy product. It is present at approximately 7.3% in ice cream [4]. Lactose is characterized by low water solubility and, when it presents in combination with sucrose , especially frozen dairy products, it crystalizes faster than sucrose [5], leading to the defect known as grittiness [6].

Lactose stimulates the intestinal absorption and retention of calcium. It is digested in the small intestine, where β-galactosidase (lactase), hydrolyses lactose into glucose and galactose. In lactose intolerant individuals, the ingested lactose is only partially hydrolyzed, or it is not hydrolyzed at all [7, 8]. Therefore, presence the lactose in different dairy products may be

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reducing the consumption of dairy products by those individuals. Accordingly, they are suffering from diarrhea, gas and bloating after consumption dairy products. The condition, which is also called lactose malabsorption, is usually harmless, but its symptoms can be uncomfortable [9].

Different ways were used to overcome the effects of lactose intolerance, such as removal of lactose from dairy products by the action of β-galactosidase, or by fermentative microorganisms that utilize the lactose as a substrate and by combining meals with exogenous β-galactosidase [8]. Other ways could be used for avoiding this problem such as recombination the dairy products that contain high level of lactose by using some other lactose-free food ingredients which give the same properties in the final product. Among these ingredients, rice protein powder may be used as a good source of solids not fat and characterized with -free lactose for enhancing the functional properties of ice cream. Furthermore, replacing SMP by DRPC in ice cream preparation would decrease the cost of ice cream production.

Broken rice is a by-product of rice milling industry. It is a very good source of different bioactive compounds such as protein, minerals and some vitamins. Furthermore, it characterized by free lactose. Therefore, broken rice has many uses such as preparing rice protein concentrate that could be used as an important ingredient for manufacture of many low-cost, low-lactose and low-fat food products. Rice proteins are considered valuable because they are colorless, rich in essential amino acids, possess a bland taste and are hypoallergenic and hypocholesterolemic [10].

Rice protein is gaining a lot of interest in the food industry due to its unique properties such as protein solubility, emulsifying and foaming properties. Therefore, rice protein is an economic source of high-quality plant-based protein that can exhibit excellent functional properties and important bio-functions. Moreover, rice protein has been used as a food ingredient in many food products such as infant foods, meat ball, cake batters, noodles, biscuit, frozen desserts and confectionaries, bread and gluten-free products [11].

So, this work has been planned to utilize the broken rice for preparation of dried rice protein concentrate and investigate its effect as a substitute of skim milk powder to produce functional low lactose ice cream Study the physical, chemical, rheological and sensorial properties of the resultant ice cream was also a target.

MATERIALS AND METHODS

Materials:

- Skim milk powder (97% TS) made in Poland was obtained from the local market of Cairo, Egypt.
- Fresh buffalo's milk which used for preparation fresh cream (60% fat) was obtained from the herd of the dairy cattle at Faculty of Agriculture, Ain Shams University, Cairo, Egypt.
- Broken rice which used for preparation DRPC was obtained from Crops Research Institute, Agriculture Research Center, Ministry of Agriculture, Giza, Egypt
- Commercial grade sugar was obtained from Sugar and Integrated Industries Co., Hawamdia, Egypt.
- Sodium carboxy methyl cellulose CMC (BDH chemicals Ltd Poole; England), vanilla (Boehringer Manheim GMB, Germany) were obtained from the local market of Cairo.

Experiments

Preparation of Dried Broken Rice Protein Concentrates: Dried broken rice protein concentrate was prepared from broken rice in National Company for Maize Products, 10^{th} of Ramadan City, Industrial Zone A1, El-Sharkia, Egypt as fallow: Broken rice was purified to remove the damage rice and impurities, then washed and soaked in distilled water at room temperature with a ratio of (1:1) for 2 hours. After that, the soaked water was removed. Broken rice was milled and treated with α-amylase enzyme (1Kg enzymes: 1000 Kg milled rice) for 20 min at 100°C. The treated broken rice was passed through a cloth filter to separate the sugars. The resulted concentrated protein was re-washed with distilled water to remove the remaining sugars and separated again by a cloth filter. After that it dried in a laboratory oven at 60 ± 2°C until weight equilibrium has been achieved. The dried rice protein concentrate was milled (Glen Creston mill No. 820238, England) and sieved to obtain dried rice protein concentrate (DRPC). The rice protein concentrate powder samples were kept in tightly closed glass container at -18°C until use.

The chemical composition of SMP and dried rice protein concentrate (DRPC) used in the manufacture of different ice cream samples is given in Table (1).

Preparing of Functional Reduced Lactose Ice Cream Made with Different Levels of Dried Rice Protein Concentrate: Ice cream sample was manufactured according to Arbuckle [12]. Base ice cream mix was

Table 1: Chemical composition (%) of skim milk powder (SMP) and dried rice protein concentrate (DRPC) used in the manufacture of different ice cream samples

	SMP	DRPC
Moisture	4.05[a]	4.15[a]
Protein*	35.75[b]	74.95[a]
Fat	0.80[b]	5.30[a]
Ash	8.16[a]	1.90[b]
crude fibers	ND	2.41
Lactose	50.84	ND

ND: Not detected

*Total nitrogen (% TN x 6.38 for SMP or x 5.95 for DRPC)

Table 2: The ice cream formula using different levels of dried rice protein concentrate powder (Kg/100kg mix)

	Treatments*					
Ingredients	C	T1	T2	T3	T4	T5
Sucrose	15	15	15	15	15	15
Stabilizer (CMC)	0.3	0.3	0.3	0.3	0.3	0.3
Cream (60% fat, 3.6% SNF)	13.4	13.4	13.4	13.4	13.4	13.4
Skim milk powder (96% TS)	10.8	8.64	6.48	4.32	2.16	--
D R P C (96% TS)	-	2.16	4.32	6.48	8.64	10.8
Water	60.5	60.5	60.5	60.5	60.5	60.5
Total	100	100	100	100	100	100

C: control ice cream mix made without DRPC, containing 11% SNF from skim milk powder (SMP)

T1, T2, T3, T4 and T5: treatments with SMP substitution at levels of 20, 40, 60, 80 and 100% with DRPC

standardized to contain 8% fat, 11% solids not fat (SNF), 15% sugar and 0.3% stabilizer (CMC). Skim milk powder was used as source of solids not fat in control ice cream mix. Dried rice protein concentrate was added as a substitute of skim milk powder in the base mix at a ratio of 20, 40, 60, 80 and 100% in mixes for T1, T2, T3, T4 and T5 ice cream products, respectively. The required amounts of sugar, stabilizer, cream (60% fat & 3.6% SNF), skim milk powder (96% DM) or DRCP (96% DM) and water which used to adjust the different ice cream mixes are presented in Table (2).

The mixes were heat-treated at 90°C for 5 min, then cooled to 5°C and kept at the same temperature over-night. After aging, 0.01% vanilla was added to control and all the treatment mixes. Each mix was frozen in an experimental ice cream batch freezer (Taylor, Model, 1039, USA). This machine was automatically controlled to stop whipping when ice cream was frozen. The resultant products were packed into PVC cups, covered and hardened at -26°C / 24 hr. Three replicates were carried out for every treatment. Changes in the physical, chemical, rheological and organoleptic properties of mixes and the resultant frozen products were determined.

Analytical Methods: Total solids, fat, total nitrogen, ash, crude fiber and lactose contents in different samples were determined as described in AOAC [13]. The pH values of ice cream mixes were measured to nearest 0.01 units using Beckman pH meter type 7010, with combined glass electrode (Electric Instruments, Limited). Specific gravity of mixes and final products was determined according to Winton [14]. The weight per gallon of mixes and final products was calculated according to Arbuckle [12]. Freezing point of ice cream mixes was measured as described by Pearson [15], using Digital thermometer (Digitemp D 200/20, Germany). The melting resistance and overrun percentage of the resultant frozen products were determined as described by Akin *et al*. [16].

Viscosity was measured using a rotational coaxial viscometer (RHEOTEST II-Medingen, Germany) at shear rates ranging from 1.000 to 437.4 sec^{-1} according to Toledo [17] at 20±1°C. Apparent viscosity of different samples was calculated at share rate 48.6 s^{-1}.

The sensory properties of different ice cream samples were assessed by the regular taste panel of the staff-member (15) at Food Science Department, Faculty of Agriculture, Ain Shams University. Scoring of ice cream samples were carried out according to Arbuckle, [12], for flavor (45 points), body & texture (30 points), melting quality (15 points) and Color (10 points).

Statistical analysis was performed according to SAS [18] using General Linear Model (GLM) with the main effect of treatments. Duncan's multiple range was used to separate among means of three replicates at significant level of 5% ($P \leq 0.05$).

RESULTS AND DISCUSSION

Physicochemical Properties of the Functional Ice Cream Mixes: Physiochemical properties of ice cream mixes containing different levels of DRPC are presented in Table (3). Replacement of skim milk powder with DRPC had no significant effect on total solids and fat contents among all treatments. But slight changes in total solids and fat percentage of different ice cream mixes could be observed, related to the slight differences in weight of formula ingredients and moisture content in the product.

Ash content was decreased with increasing the ratio of added DRPC in the ice cream blend. This decrease might be due to lower ash content (1.9%) in DRPC compared to SMP (8.16%). Similar results are also obtained by El-Zeini *et al.* [19].

Increasing the ratio of added DRPC in the blend of ice cream caused proportional increase in crude fiber values. This increase could be due to the higher fiber content in DRPC.

On the other hand, using DRPC as protein substitute in ice cream mix had no significant effect on pH value of the mix. Slight differences but not significant in pH values among all treatments are mainly due to the DRPC added to the recipes. These data agreed with the results obtained by Akesowan [20] who mentioned that substitution of skimmed milk powder with soy protein isolate from 0 to 75% did not change pH values of ice cream samples compared to control sample.

Total protein content of ice cream mixes was significantly increased with increasing the levels of DRPC in the blend. The highest protein content of ice cream mix was recorded for T5 sample (two-fold increase) compared to the control sample, as can be seen in Table (3). These results are in consistent with those obtained by Jain and Rai [21] who mentioned that ice cream contained soy protein isolate had significantly higher percentage of protein compared with the control and the percentage of increase in protein content was due to the substitution of skimmed milk powder with soy protein isolate in the pre-mix.

El-Zeini *et al.* [19] pointed out that a proportional replacement (1, 2, 3 and 4%) of milk solid nonfat with whey protein isolate in ice cream formula resulted in a significant increase of protein contents of ice cream mixes.

Lactose content of ice cream mix was significantly different ($P = 0.05$) among all treatments. A trend of reduction in lactose content was observed as the protein content of the mix was increased. Replacing skim milk powder with DRPC had an effective means of reducing lactose level in the final product (Table 3). The percentage of lactose reduction was proportional with added DRPC. Lactose content decreased by 97.24% when SMP substituted with 100% of DRPC in ice cream mix, as can be seen in Fig. (1). Moreover, the use of DRPC and the reduction of lactose content from 21.27% to 97.24% in the functional reduced lactose ice cream is an effective, inexpensive, economical and simple method to overcome the complications of lactose intolerance. Dry rice protein concentrate with a minor lactose concentration should allow to be used at high concentrations without increasing development of grittiness in ice cream. These results confirmed by those obtained by El-Zeini *et al.* [19] who found that lactose values decreased by increasing the substitution level of whey protein isolate in ice cream mixes according of less content of lactose in whey protein isolate than in skim milk powder.

Tsuchiya *et al.* [22] used β-galactosidase with ($0.5\ gL^{-1}$) to hydrolysis of lactose in the milk base used in ice cream preparation. The authors found that the percentage of lactose hydrolysis ranged between 86.59-97.97% in the ice cream formulations. They also suggested that ice cream produced with 100 % milk powder/whey powder replacement and lactose hydrolysis treatment is technologically feasible, the lactose content of ice cream was decreased by 91%, allowing the consumption of this product by lactose intolerance individuals. However, Abbasi and Saeedabadian [6] used β-galactosidase (1.5 ml per liter of milk for 240 min at 39°C) to hydrolysis lactose to more than 75% in milk used in preparation of low lactose and low sugar ice cream.

On the other side, specific gravity is one of the important physical properties of the ice cream. It gives some information about the quality of the resultant ice cream such as body and texture, incorporated air and melting quality of ice cream. It is also depending on the formula components as well the ability of the mix to retain air bubbles in ice cream matrix. The replacement of skim milk powder with DRPC in ice cream mixes, resulted in increase of specific gravity values in proportional to the replacement ratio in comparison to the control ice cream mix, which indicates more air incorporation in the body of ice cream with more constructive protein membranes. The increase in specific gravity values of ice cream mixes with adding DRPC could be due to the higher specific gravity of DRPC than SMP. Weight per gallon of all ice cream mixes was closely related to their specific gravity normal values.

Table 3: Physicochemical properties of the functional reduced lactose ice cream mixes made with different levels of DRPC

		Treatments*				
Character assessed	Control	T1	T2	T3	T4	T5
Total solids (%)	34.32^{a}	34.40^{a}	34.48^{a}	34.56^{a}	34.58^{a}	34.61^{a}
Fat (%)	8.1	8.0^{a}	8.1^{a}	8.1^{a}	8.2^{a}	8.2^{a}
Total nitrogen%	0.919^{f}	1.180^{e}	1.441^{d}	1.703^{c}	1.956^{b}	2.227^{a}
Total protein (%)	5.86^{f}	7.43^{e}	8.95^{d}	10.43^{c}	11.81^{b}	13.25^{a}
Ash (%)	1.309^{a}	1.111^{b}	0.915^{c}	0.725^{d}	0.541^{e}	0.372^{f}
Crude fiber (%)	ND	0.10	0.16	0.25	0.32	0.40
Lactose %	7.24^{a}	5.70^{b}	4.34^{c}	2.98^{d}	1.70^{e}	0.20^{f}
pH values	6.34^{a}	6.32^{a}	6.30^{a}	6.30^{a}	6.29^{a}	6.29^{a}
Specific gravity (g/cm^{3})	1.0931^{b}	1.0994^{b}	1.1034a^{b}	1.1180^{a}	1.1285^{a}	1.1356^{a}
Weight per gallon / Kg	4.139^{b}	4.162^{b}	4.177^{ab}	4.233^{a}	4.273^{a}	4.230^{a}
Freezing point (°C)	-2.84^{a}	-2.67^{ab}	-2.50^{b}	-2.30^{bc}	-2.16^{c}	-2.01^{c}

C: control ice cream mix made without DRPC, containing 11% SNF from skim milk powder (SMP)

T1, T2, T3, T4 and T5: treatments with SMP substitution at levels of 20, 40, 60, 80 and 100% with DRPC

Means with same letter within the row are not significantly different at $p \leq 0.05$

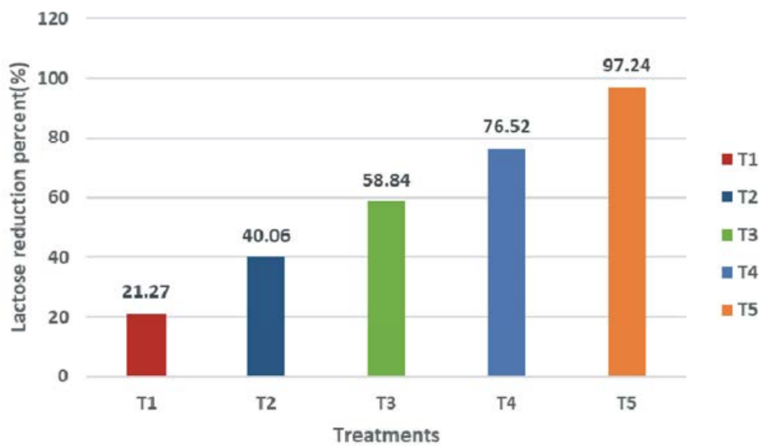

Fig. 1: Lactose reduction percentages of the functional reduced lactose ice cream mixes made with different levels of DRPC
T1, T2, T3, T4 and T5: the functional reduced lactose ice cream mixes made with substitution skim milk powder by DRPC at levels of 20, 40, 60, 80 and 100%, respectively

In general, freezing point of ice cream mixes depends on concentration of soluble constituents and varies with any change in composition. Ice cream mix freezing point reflects the number of molecules in solution, with the most prevalent constituent being sugar [12]. Variation in freezing points can alter the recrystallization rate at a specific storage temperature in ice cream [23].

Addition of DRPC as a substitute of SMP in ice cream blend caused a significant increase in freezing point of the mix. The lowest freezing point in control sample may be due to the high soluble contents of control ice cream mix compared to other treatments which containing DRPC as a substitute of SMP. These results agreed with those obtained by El-Zeini *et al.* [19] who revealed that the ice cream mixes recorded higher freezing points with substituting skim milk powder by whey protein isolate. The high freezing point in treatments with whey protein isolate could be due to its lower lactose and other true solution solutes with high protein contents [24].

Soukoulis *et al.* [25] pointed out the addition of apple fiber or 4% inulin influences freezing point depression in a similar way to hydrocolloids, which generally increase the freezing point temperature of ice cream mixes and was accompanied by a significant increase of effective molecular weight, suggesting the contribution of pectin and other polysaccharides in the compositional profile of solutes. The trend of these data agrees with the data obtained with [26, 27].

Flow Behavior of Functional Ice Cream Mixes: Viscosity is a measure of the fluid's resistance to flow. It describes the internal fraction of a moving fluid. Shear stress and

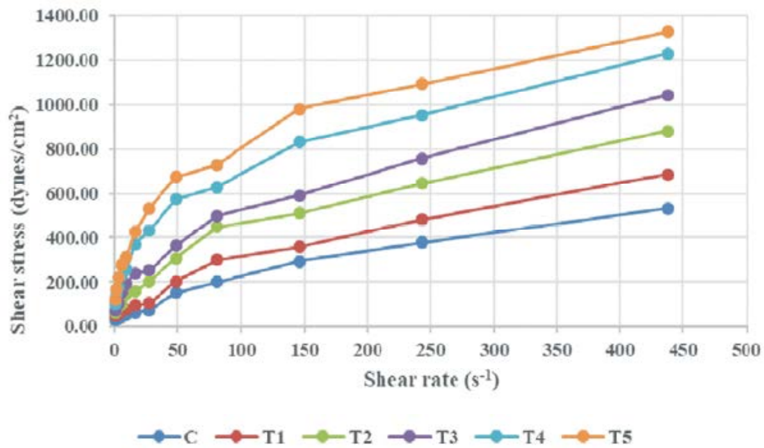

Fig. 2: Flow behavior of functional reduced lactose ice cream made with different levels of dried broken rice protein concentrate

C: control ice cream mix made without DRPC, containing 11% SNF from skim milk powder (SMP); T1, T2, T3, T4 and T5: functional reduced ice cream mixes made with substitution skim milk powder by DRPC at 20, 40, 60, 80 and 100% respectively.

shear rate curves (the flow behavior) of different functional reduced lactose ice cream mixes made with different levels of DRPC as a substitute of SMP substitute are illustrated in Fig. (2). There were significant differences in the flow behavior among all treatments and control. It could be seen that the relationship between shear stress and shear rate was non-liner in all mixes. Also, there was a strong relationship among the flow behavior and the type of ingredient used in different mixes.

Preparation of functional reduced lactose ice cream mixes with different levels of DRPC as a substitute of SMP resulted in the improvement of the flow curve as compared with control mix. This increase in flow curve indicated that, the gradual increase in ratio of replaced SMP with DRPC in the blend of ice cream caused gradually increases in apparent viscosity of mixes. The increase in apparent viscosity could be due to the increase of protein content in liquid phase in mixes made with adding DRPC compared with control. Increasing the protein in ice cream formula may caused absorbing higher amounts of free water in ice cream formula during aging and therefore may increase the viscosity. Moreover, the high-water absorption capacity (WAC) of rice protein could be play an important role in increasing the viscosity of ice cream mix treatments compared with control mix.

Zhang *et al*. [28] stated that, rice protein has good WAC which could be used in products requiring high water absorption. Similar results were confirmed by the study of Friedeck *et al.* [29] who observed that the higher viscosity of fortified ice cream mixes with soy protein isolate was attributable to the difference of soy protein isolate (>90% protein) used to substitute for nonfat dry milk (35-36% protein and 51-52% carbohydrate); consequently, higher protein levels of added soy protein isolate samples resulted in higher viscosities. Akesowan [20] also reported that, increasing of soy protein isolate level from 25 to 50% resulted in considerably higher viscosity, which may be explained as water binding property of soy protein isolate with liquid component to form a gel-like network to modify the rheology of the ice cream.

Also, the increase in apparent viscosity may be due to the interactions of the fibers (in DRPC) and liquid components in the ice cream mixes. These results agreed with the results obtained by El-Nagar and Kuri [30] who found that, the viscosity was increased in the low-fat frozen yoghurt mixes made with various concentrations of soluble fibers (inulin).

Also, Soukoulis *et al.* [25] found that, the content of fibers in insoluble compounds increased significantly the viscosity and the shear thinning behavior of the model solutions and ice creams, due to the increase of total solids and the formation of networks comprised of hydrated cellulose and hemicellulose. Furthermore, addition of rice flour increased viscosity of ice cream mix [31]. In addition, higher viscosity of optimized ice cream could be due to the addition of soy protein isolate and inulin which gives thickness to ice cream [21].

Das Graças Pereira *et al.* [32] found that the substitution of skim milk powder for soy extract (51.58% protein) leads to an increase in the ice cream mix's viscosity and as well leads to an increase in the matrix phase's viscosity after the temperature decreases. This increase in viscosity behaves possible a larger amount of air incorporation. The increase of the matrix viscosity leads to, in addition to a greater overrun value, a higher level of micro dispersion and stabilization of air bubbles [33].

Properties of Resultant Functional Reduced Lactose Ice Cream: Physical properties of resultant ice cream as affected by adding different levels of DRPC are presented in Table (4). Incorporating DRPC in ice cream blend resulted in lower specific gravity value. The specific gravity value decreased with increasing the levels of added DRPC in ice cream mixes. The same trend was also observed in weigh per gallon of ice cream product. Overrun is the measurement of added air in frozen dessert products and is expressed as the percentage increase in volume due to the air addition [34]. The presence of air in the product provided a light texture of frozen dessert and as well influenced melting down and hardness of the final product [35]. The overrun in ice cream is directly related with the yield and gain and is involved in meeting legal standards. Too high overrun produces a fluffy and softer ice cream and too little produces a soggy, heavy product. The overrun differed significantly among the treatments as noticed in Table (4). Control ice cream had the lowest (50.15%) overrun whereas T5 had the maximum overrun (61.05%). This probably due to foaming capacity of DRPC leading to enhanced air bubbles resulting in excess volume of the frozen sample.

These results agreed with those of Patel *et al.* [36] who reported that the higher the protein, the greater the protein bubbles which trapping air inside and resulting in high overrun. Therefore, increased ratio of DRPC from 20 to 100%, more air was incorporated into the ice cream. Similarly, El-Zeini *et al.* [19] reported that an increase in ice cream overrun by substitution of skim milk powder with whey protein isolate. The overrun increase in treatments containing whey protein isolate could be related to the high foaming ability of ice cream mixes.

Moussa *et al.* [37] reported that, overrun percent of resulting probiotic ice cream was affected by different factors, such as the state and nature of proteins, acidity and freezing point in mixes. These results are in parallel with those obtained by Yadav *et al.* [38] who mentioned that the total protein content of Indian rice cultivars was significantly correlated positive with foaming capacity.

Melt down is an important property of ice cream affecting its sensory quality. Ice cream should melt down to a liquid of smooth consistency, revealing of a rich ice cream. It is also important that the ice cream is not too hard or should not melt quickly. Fig. (3) illustrates the influence of incorporation of DRPC at different levels on melting resistance of ice cream under study. Melting resistance of ice cream samples containing DRPC increased significantly ($P \leq 0.05$) with increasing rate of addition of DRPC. It can be seen from the results that T5 (100% replacing Skim milk powder with dry rice protein concentrate) had significantly lowest melt down compared with control and other treatments. Therefore, the melting resistance of different ice cream samples was in order T5 > T4 > T3 ≈ T2 ≈ T1 > C.

These differences may be attributed to the differences in compositional analysis and their effect on mix properties. Melting resistance of ice cream samples added with DRPC becomes slower and prevented from melting, it could be due to the water binding capacity of the DRPC through it forms a stable gel network which immobilized the free movement of the water molecules among other molecules of the ice cream mix. Melting resistance of resultant ice cream samples is mainly affected by freezing point and viscosity of mixes [37].

Arbuckle [12] reported that, increasing the viscosity of ice cream mix may increase the melting resistance in resultant ice cream. In general, the greater the viscosity, the resistance to melting and smoothness increase [39]. These results are in accordance with those obtained by Patel *et al.* [40] who found that increasing level of gelatinized ragi (Finger millet) starch addition to ice cream mix resulted in increase in melting resistance and Mohan *et al.* [41] suggested that ragi starch may act as a stabilizer due to its high capacity for binding water.

Furthermore, it was found that substitution skimmed milk powder with soy protein isolate in ice cream mix showed lowest melting compared to the control ice cream which showed faster melting [20]. Sakuri *et al.* [42] found that ice creams with low overruns melted quickly, whereas ice creams with high overruns began to melt slowly and had a good melting resistance which was attributed to a reduced rate of heat transfer due to a larger volume of air and more tortuous path through which the melting fluid must flow.

When considering melting property, the increment in viscosity appeared to be related to melt down properties of ice cream samples containing DRPC. The control ice cream was observed to be the fastest melting ice cream while the 100% DRPC substitution ice cream was the lowest. These results indicated that increased addition of

Table 4: Properties of functional reduced lactose ice cream made with different levels of DRPC

		Treatments*				
Character assessed	Control	T1	T2	T3	T4	T5
Specific gravity (g/cm^3)	0.7280^a	0.7205^a	0.7163^{ab}	0.7106^{ab}	0.7074^b	0.7051^b
Weight per gallon Kg	2.756^a	2.728^a	2.711^a	2.690^{ab}	2.678^{ab}	2.669^b
Overrun	50.15^c	52.58^{bc}	54.04^b	57.33^{ab}	59.52^a	61.05^a

C: control ice cream mix made without DRPC, containing 11% SNF from skim milk powder (SMP);T1, T2, T3, T4 and T5: the functional reduced lactose ice cream mixes made with substitution skim milk powder by DRPC at levels of 20, 40, 60, 80 and 100% respectively.
Means with same letter within the row are not significantly different at p ≥ 0.05.

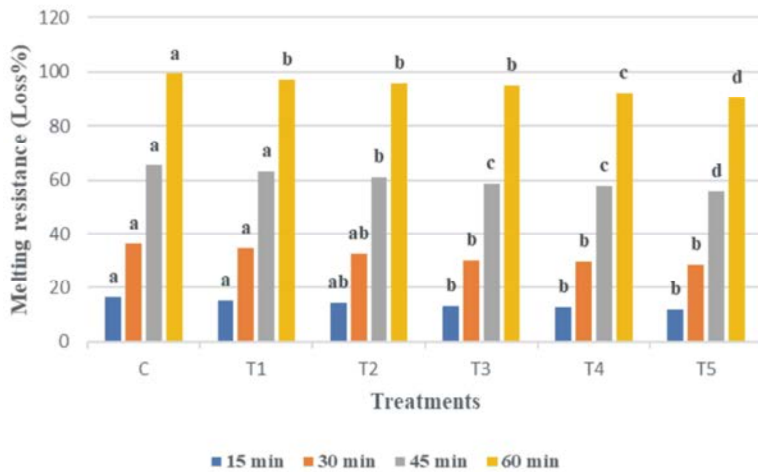

Fig. 3: Melting resistance percentages of the functional reduced lactose ice cream made with different levels of dried broken rice protein concentrate
C: control ice cream mix made without DRPC, containing 11% SNF from skim milk powder (SMP); T1, T2, T3, T4 and T5: the functional reduced lactose ice cream mixes made with substitution skim milk powder by DRPC at levels of 20, 40, 60, 80 and 100% respectively

DRPC reduced melting rates of ice cream samples. Kaya and Tekin [43] reported that the increase in viscosity values increased the resistance of the ice cream to melting.

Organoleptic Properties: Table (5) shows the sensory evaluation of ice cream product made with different levels of DRPC as SMP substitute. The results revealed significant differences among all functional ice cream treatments. The ice cream samples containing DRPC as a substitute of SMP had significantly less flavor scores than control treatment. Therefore, using DRPC at high levels to increase protein content and decrease lactose content, would need more vanilla flavor to be added to ice cream.

These results are in harmony with those obtained by Patel *et al.* [36] who stated that increased levels of whey protein concentrate in ice cream mix resulted in significant decrease in flavor scores of ice cream samples, which attributable to higher levels of whey protein concentrate that cover vanilla flavor. Addition of DRPC to ice cream formula up to 60% caused an improvement in body & texture properties of final product. This improvement could be due to the content of fiber and protein associated with adding different levels of DRPC and this may lead to improve body and texture score.

Fortification of functional ice cream blend with DRPC as a substitute of SMP improved the melting quality in resultant product. This could be due to the effect of DRPC on freezing point and melting resistance in the functional reduced lactose ice cream. Results showed that, fortification of ice cream blend with DRPC as a substitute of SMP caused a significant difference in color scores of ice cream samples. Addition of DRPC at levels of 80 and 100% in ice cream formula resulted in adverse effect on color and overall acceptability of functional reduced lactose ice cream.

Treatments 4 and 5 had lower scores for color and overall acceptability compared to the control and other treatments. This could be attributed to the color difference

Table 5: Properties of functional reduced lactose ice cream made with different levels of DRPC

		Treatments*				
Character assessed	Control	T1	T2	T3	T4	T5
Flavor (45)	43.7[a]	43.5[a]	42.4[a]	41.1[b]	38.2[b]	35.5[c]
Body & texture (30)	27.0[a]	27.6[a]	27.5[a]	27.0[a]	26.1[b]	25.2[c]
Melting quality (15)	14.5[a]	14.4[a]	14.2[a]	14.0[a]	13.6[b]	13.1[b]
Color (10)	9.5[a]	9.6[a]	9.4[a]	9.1[a]	8.6[b]	8.4[b]
Total score (100)	94.7[a]	95.1[a]	93.5[a]	91.2[b]	86.5[c]	82.2[d]

C: control ice cream mix made without DRPC, containing 11% SNF from skim milk powder (SMP)

T1, T2, T3, T4 and T5: functional reduced ice cream mixes made with substitution skim milk powder by DRPC at 20, 40, 60, 80 and 100% respectively

Means with same letter within the row are not significantly different at P ≥ 0.05

Table 6: Correlation among physical, chemical, sensory and rheological properties of different ice cream mixes and resultant ice cream products

Parameter	Protein	Ash	Lactose	S. G.	W./g.	F. P.	Overrun	Melt. Res.	Flavor	B. &T.	M. Qua.	Color	T. score	App. Vis.
Ash (%)	-1.000**													
Lactose (%)	-0.999**	0.999**												
Specific gravity	0.984**	-0.985**	-0.983**											
Weight per gallon in Kg	0.840**	-0.846**	-0.827**	0.853**										
Freezing point (°C)	0.991**	0.992**	0.993**	-0.978**	-.826**									
Overrun (%)	0.992**	-0.994**	-0.992**	0.992**	0.858**	-0.991**								
Melting resistance (Loss %)	-0.980**	0.981**	0.982**	-0.965**	-0.815**	0.966**	-0.968**							
Flavor	-0.945**	0.944**	0.948**	-0.964**	-0.750**	0.931**	-0.939**	0.954**						
Body & texture	-0.770**	0.767**	0.773**	-0.827**	-0.625**	0.766**	-0.770**	0.785**	0.912**					
Melting quality	-0.883**	0.879**	0.880**	-0.891**	-0.707**	0.862**	-0.867**	0.889**	0.922**	0.862**				
Color	-0.898**	0.900**	0.899**	-0.932**	-0.764**	0.890**	-0.905**	0.892**	0.938**	0.862**	0.782**			
Total score	-0.928**	0.926**	0.930**	-0.955**	-0.744**	0.915**	-0.923**	0.936**	0.996**	0.940**	0.930**	0.939**		
Apparent viscosity (cp)	0.994**	-0.994**	-0.994**	0.986**	0.830**	-0.984**	0.987**	-0.988**	-0.967**	-0.810**	-0.897**	-0.920**	-0.953**	

** Correlation is significant at the 0.01 level (2-tailed)

S.G.: Specific gravity; W./g.: Weight per gallon in Kg; F.P.: Freezing point (°C); Melt. Res.: Melting resistance (Loss % after 60 min); B. & T.: Body and Texture; M. Qua.: Melting Quality; T. score: Total score; App. Vis.: Apparent viscosity (cp) at 48.6 s^{-1}

between skimmed milk powder (white color) and DRPC (dark creamy color). To overcome this color defect, natural colors could be used in ice cream formula. The highest total score points were gained by control sample, T1 and T2 followed by T4 ice cream samples. While the lowest score was recorded for the T5 functional reduced ice cream sample. These results agreed with those obtained by Akesowan [20] who reported that increased levels of soy protein isolate substitution in ice cream resulted in more brownish green color of ice cream.

Correlation among physical, chemical, sensory and rheological properties of different ice cream mixes and resultant ice cream products were statistically analyzes and listed in Table (6). Total protein was negatively correlated with ash content (r = 1.000, P<0.01), lactose content (r = 0.999, P<0.01), melting resistance (r = 0.980, P<0.01), flavor (r = 0.945, P<0.01), body & texture (r = 0.770, P<0.01), color (r =0.898, P<0.01) and total score (r = 0.928, P<0.01).

Moreover, protein content was positively correlated with specific gravity (r = 0.984, P<0.01), weight per gallon (r = 0.840, P<0.01), freezing point (r = 0.991, P<0.01), overrun (r = 0.992, P < 0.01) and apparent viscosity (r = 0.994, P<0.01). These differences among all parameters are mainly due to the differences in the chemical composition and functional properties of dry rice protein concentrate and skim milk powder. Similar results were also obtained by Akesowan [20] and Tsuchiya *et al.* [22].

In addition to the aforementioned results, it is important to reduce production costs. Rationalization of these costs can be achieved by using cheaper substitutes of certain ingredients of the recipes. The relatively expensive component is milk powder which can be partially or completely replaced by low cost plant-based protein ingredients such as lupine, soy, rice, bean and pea proteins. In this study broken rice, a by-product of rice milling industry is a cheaper ingredient to prepare DRPC.

Thus, DRPC as a replacer of skim milk powder in manufacture of ice cream seems to be a rational solution in the case of functional reduced lactose ice cream for producers who want to reduce manufacturing costs without change desired characteristics of the final product. Furthermore, it is also considered very suitable and low-cost solution for individuals who suffering from lactose intolerance. On the other hand, the use of broken rice to prepare DRPC and use it in food industry is a good way to added value to the national income.

CONCLUSION

In the present study, substitution of skim milk powder (SMP) with dry rice protein concentrate (DRPC) prepared from broken rice, as a by-product of milling industry has significant effects on viscosity, overrun, freezing point, specific gravity, fiber, protein, lactose, melting resistance and sensory attributes of ice cream samples. An increase in DRPC levels lead to produce less lactose, viscous, more protein and resistance to meltdown ice cream samples. For practical application, 60% DRPC substitution seems to produce a functional reduced lactose ice cream product, demonstrating sensory attributes comparable to the control ice cream. The production of functional reduced lactose ice cream is a good way to introduce low cost, low fat, low lactose and rich ice cream product especially for individuals who suffering from lactose intolerance.

REFRENCECS

1. Hasler, C.M., 1998. Functional foods: their role in disease prevention and health promotion. J. Food Technology, 52(1): 63-70.
2. Ross, S., 2000. Functional foods: the food and Drug administration perspective, Am. J. Clin. Nutr., 71: 1735-1738.
3. Varnam, A.H. and J.P. Sutherland, 1994. Milk and Milk Products: Technology, Chemistry and Microbiology, 1st ed. Chapman and Hall, London, U.K, pp: 387-428.
4. Karaman, S., S. Toker, F. Yüksel, M. Çam, A. Kayacier and M. Dogan, 2014. Physicochemical, bioactive and sensory properties of persimmon-based ice cream: technique for order preference by similarity to ideal solution to determine optimum concentration. J. Dairy Sci., 97(1): 97-110.
5. Sormoli, Mona, E., D. Das and T.A.G. Langrish, 2013. Crystallization behavior of lactose/sucrose mixtures during water-induced crystallization. J. Food Eng., 116: 873-880.
6. Abbasi, S. and A. Saeedabadian, 2015. Influences of lactose hydrolysis of milk and sugar reduction on some physical properties of ice cream. J. Food Sci. Technol., 52(1): 367-374.
7. Swagerty, D.L., A.D. Walling and R.M. Klein, 2002. Lactose intolerance. Am. Fam. Physician, 65(9): 1845-1850.
8. Shaukat, A., M.D. Levitt, B.C. Taylor, R. Mac Donald, T.A. Shamliyan, I. Robert, R.I. Kane and T.J. Wilt, 2010. Systematic review: effective management strategies for lactose intolerance. Ann. Intern. Med., 152: 797-803.
9. Prado, F.C., J.L. Parada, A. Pandey and C.R. Soccol, 2008. Trends in non-dairy probiotic beverages. Food Research International., 41: 111-123.
10. Chrastil, J., 1992. Correlation between the physicochemical and functional properties of rice. J. Agric. Food Chem., 40: 2152-2155.
11. Phongthai, S., W. Homthawornchoo and S. Rawdkuen, 2017. Preparation, properties and application of rice bran protein: A review. Intern. Food Res. J., 24(1): 25-34.
12. Arbuckle, W.S., 1986. *Ice Cream*, 4th ed. Springer Science Business Media New York: AVI, pp: 145-152.
13. AOAC, 2012. Official Methods of Analysis, 19th ed. Association of Official Analytical Chemists. Washington DC, USA.
14. Winton, A.L., 1958. Analysis of Foods. 3rd printing. John Wiley and Sons Inc., New York.
15. Pearson, D., 1973. Laboratory Techniques in Food Analysis. Butterworth & Co. Ltd, London, England.
16. Akin, M.B., M.S. Akin and Z. Kirmaci, 2007. Effects of inulin and sugar levels on the viability of yogurt and probiotic bacteria and the physical and sensory characteristics in probiotic ice-cream. Food Chem., 104(1): 93-99.
17. Toledo, R.T., 2007. Fundamentals of Food Process Engineering, 3rd edn. Springer Publisher, New York, pp: 153-155.
18. SAS, 1999. SAS User' Guide: Statistics, Version 8.0. SAS Inst., Inc., Cary, NC. USA.
19. El-Zeini, Hoda, M., M.M. El-Abd, Metwaly, Fatma, M.A. Zeidan and Y.F. Hassan, 2016. Using whey protein isolate as a substitute of milk solid not fat on chemical and physico-chemical properties of ice cream. J. Food &Dairy Sci., 7(2): 133-137.
20. Akesowan, A., 2009. Influence of soy protein isolate on physical and sensory properties of ice cream. Thai Journal of Agricultural Science, 42(1): 1-6.
21. Jian, V.K. and D.C. Rai, 2018. Physicochemical properties of reduced fat, low calorie and protein rich ice cream. J. Pharmacog. Phytochem., 7(6): 2631-2636.
22. Tsuchiya, Ana, C., M.S. Da Graça, Ana, D. Brandt, D.L. Kalschne, D.A. Drunkler and E. Colla, 2017. Lactose-reduced ice cream enriched with whey powder. Ciências Agrárias, Londrina, 38(2): 749-758.

23. Hagiwara, T. and R.W. Hartel, 1996. Effect of sweetener, stabilizer and storage temperature on ice recrystallization in ice cream. J. Dairy Sci., 79: 735-744.
24. Muse, M.R. and W.R. Hartel, 2004. Ice cream structural elements that affect rate and hardness. J. Dairy Sci., 87(1): 1-10.
25. Soukoulis, C., D. Lebesi and C. Tzia, 2009. Enrichment of ice cream with dietary fibre: effects on rheological properties, ice crystallization and glass transition phenomena. Food Chem., 115: 665-671.
26. Attalla Neamah, R. and A. El-Hussieny Enas, 2017.Characteristics of Nutraceutical Yoghurt Mousse Fortified with Chia Seeds. International Journal of Environment, Agriculture and Biotechnology, 2(4): 2033-2046.
27. Zaky, W.M., H.M. Abbas, W.I.A. Nasr and W.I. El-Desoki , 2019. Chia Seeds as Natural Stabilizer and Healthy Ingredient in Ice Milk Preparation. World Journal of Dairy & Food Sciences, 14(1): 52-58.
28. Zhang, H.J., H. Zhang, I. Wang and X.N. Guo, 2012. Preparation and functional properties of rice bran proteins from heat-stabilized defatted rice bran. Food Res. Intern., 47: 359-363.
29. Friedeck, K.G.Y. Karagul - Yuceer and M.A. Drkae, 2003. Soy Protein Fortification of a Low-fat Dairy-based Ice Cream. J. Food Sci., 68(9): 2651-2657.
30. El-Nagar, G.F. and V. Kuri, 2001. Rheological quality and stability of yoghurt ice cream with added fibers. Proc. 8th Egyptian Conf. for Dairy Sci. & Tech., 3-5 November, Cairo, pp: 525.
31. Cody, T.L., A. Olabi, A.C. Pettingell, P.S. Tong and J.H. Walker, 2007. Evaluation of rice flour for use in vanilla ice cream. J. Dairy Sci., 90: 4575-4585.
32. Das Graças Pereira, G., J.V. De Resende, I.R. De Abreu, T.M. De Oliveira Giarola and L.T. Perrone, 2011. Influence of the partial substitution of skim milk powder for soy extract on ice cream structure and quality. Eur. Food Res. Technol., 232: 1093-1102.
33. Chang, Y. and R.W. Hartel, 2002. Stability of air cells in ice cream during hardening and storage. J. Food Eng., 55: 59-70.
34. Goff, H.D. and R.W. Hartel, 2004. Ice cream and frozen desserts. In: Handbook of Frozen Foods. Hui, Y.H.; Cornillon, P., Legarretta, I.G.; Lim, M.H.; Murrell, K.D. and Nip, W.K. (eds), Marcel Dekker Inc., New York, pp: 499-570.
35. Sofjan, R.P. and R.W. Hartel, 2004. Effects of overrun on structural and physical characteristics of ice cream. Intern. Dairy J., 14(3): 255-262.
36. Patel, M.R., R.J. Baer and M.R. Acharya, 2006. Increasing the protein content of ice cream. J. Dairy Sci., 89: 1400-1406.
37. Moussa, M.E.S., A. Fathi, Fatma and R.A. Awad, 2005. Production of probiotic ice cream. Pol. J. Food Nutr. Sci., 14/55(3): 267-271.
38. Yadav, R.B., B.S. Khatkar and B.S. Yadav, 2013. Electrophoretic characterization and functional properties of rice proteins from Indian rice cultivars. Inter. J. Food Prop., 16: 1776-1788.
39. Marshall, R.T., H.D. Goff. and R.W. Hartel, 2003. *Ice Cream*, 6th ed., Springer Science Business Media New York, pp: 304-317.
40. Patel, I.J., C.N. Dharaiya and S.V. Pinto, 2015. Development of technology for manufacture of ragi ice cream. J. Food Sci. Technol., 52(7): 4015-4028.
41. Mohan, B.H., A. Gopal, N.G. Malleshi and R.N. Tharanathan, 2005. Characteristics of native and enzymatically hydrolyzed ragi (*Eleusine coracana*) and rice (*Oryza sativa*) starches. Carbohydrate Polym., 59: 43-50.
42. Sakuri, K., S. Kokubo, K. Hakamata, M. Tomita and S. Yoshida, 1996. Effect of production conditions on ice cream melting resistance and hardness. Milchwissenschaft, 51: 45-454.
43. Kaya, S. and A.R. Tekin, 2001. The effect of salep content on the rheological characteristics of a typical ice cream mix. J. Food Eng., 47(1): 59-62.