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Composition and Functional Properties of Ice Cream Made From Two Barley Varieties

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ABSTRACT

The influence of complete replacement cow's skim milk either ivied or hydrolyzed and stabilizer/emulsifier with barley (Hordeum vulgare L.) milk either hulled Giza123 Var. or Hulless barley Giza130 Var. on the physico-chemical and organoleptic properties of ice cream mixes and their resultant frozen products was studied. Ice cream mixtures were standardized to contain 8% fat, 8.5% milk solid not fat (SNF) and 16% sugar. Results show that length and width of two barley varieties ranges of average 0.62-0.75mm long and 0.33-0.34mm width. Also, the density was 0.68 (g/ml) for Giza 123, while the mean weight and volume and density for Giza 130 were 40.2 (g), 60.5 (ml), 0.66 (g/ml), respectively. Results showed that, Giza123 var. was higher than Giza130 var. in crude protein, crud fat, Ash and crude fiber contents which were 11.25, 2.86, 2.93, and 3.14 % respectively. Main while Giza130 var. was higher in moisture, total carbohydrate, and *β-glucan* (10.22, 71.50, and 6.10% respectively). Barley ice cream mix was characterized by increased values of dry matter, protein, fiber, acidity and antioxidant activity were significant increased while the pH value and ash were reduced significantly. The specific gravity (sp.gr), weight per gallon and freezing point, viscosity as well as flow time of the barley mixes were higher than the control. In resultant ice cream, the sp. gr., weight per gallon and melting resistances were increased and consequently the overrun was decreased when barley milk was used in the mixes. All treatments were organoleptically acceptable and the hulless ice cream showed superior sensory properties compared to the other treatment. It could be recommended that ice cream of high quality and with low cost can be made by replacement cow milk with barley milk without the need of using stabilizer/emulsifier.

1. Introduction

Researchers and the food industry have to invest in the advancing the development of innovative and beneficial ice cream due to the increasing interest in foods that enhance human nutrition and health. As ice cream is the most popular frozen dairy product, it has an excellent chance of assisting individuals in improving their diets by reducing the intake of certain nutrients related to a greater chance of obesity and other related diseases. Furthermore, it provides essential as well as useful components. Therefore, the food possesses has constant challenges to maintain the attractiveness of ice cream since functional ice cream needs to be delectable in addition to being healthy. (Geovese et al., 2022). The ice cream market was valued at $68,052.20 million in 2020 and is expected to reach $122.1 billion by 2031, increasing at the compound annual growth rate (CAGR) of 5% from 2022 to 2031, according to a new report from (Allied Market Research, 2022). Barley (Hordeum vulgare L.) is a grain whose consumption has a significant nutritional benefit for human health as a very good source of dietary fiber, minerals, vitamins, and phenolic and phytic acids.

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Nowadays, it is more and more often used in the production of plant milk, which is used to replace cow milk in the diet by an increasing number of consumers. In Egypt, barley is the main cereal crop grown in the North West Coast, North Sinai and newly reclaimed lands. Development of barley cultivars having the ability to produce high yield is needed. An additional avenue is cultivation of the early-maturing barley cultivars before cotton and to support wheat production in Egypt for bread making to overcome the gap between wheat consumption and wheat production (Amer et al., 2017).

Lately, barley is becoming more popular as a food ingredient because of its high nutritional fiber content (Aly et al., 2021). Compared to other cereals, barley grains have about 20% dietary fiber and 3–7% beta-glucan, which is healthy due to its ability to minimize blood cholesterol and reduce the risk of developing chronic diseases (El basyoni et al., 2020).

Grain barley products are several such as barley milk. Whether is similar to cow milk in its gross chemical composition addition to their iron, zinc and dietary fiber contents. Additionally, it has a fluidity similar to cow milk but a higher viscosity and starchier flavor. Barley's milk is cheaper than cow's milk as protein sources with high nutritional value. Compared to cow's milk, barley milk is a more affordable source of protein with superior nutritional content. It also can be used as an appropriate, healthy substitute for cow's milk in the production of similar dairy products, particularly for those who are sensitive to milk protein or lactose intolerance and in situations where milk may be too expensive or unavailable, as they contain neither cholesterol nor casein (Ali, 2012 and Salama et al., 2017). Due to the high increasing prevalence of lactose intolerance and milk protein sensitive, the impact of lactose reduction on the quality of frozen foods, the potential for reduced sugar content, as well as lack of awareness on lactose hydrolysis's impact in fresh milk, the purpose of this study is to replacement cow milk either ivied or hydrolyzed and stabilizer/emulsifier with barley milk either hulled Giza123 Var. or Hulless barley Giza130 Var. on the physic chemical and organoleptic properties of ice cream as well as the cost of its production.

2. Materials and Methods

Materials

-Barley (Hordeum vulgare L.) either hulled Giza123 Var. or Hulless barley Giza130 Var., varieties were obtained from Field Crops Research Institute, Agricultural Research Center (ARC), Giza - Egypt.

-Fresh cow's skim milk (91% moisture, 0.5% fat, 3.21% protein, 4.6% lactose and 0.69% ash) and fresh butter (29.4% moisture, 67% fat, 1.3% protein, 1.7% lactose and 0.6% ash) were obtained from Dairy Technology Unit, Faculty of Agriculture, Cairo University, (butter was traditionally converted to butter oil). Free lactose milk was obtained from Juhayna Co., Cairo, Egypt. Imported rennet casein Fonterra, (New Zealand) (10% moisture, 0.80% fat, 82.04% protein and 7.05% ash) was obtained from Al Garas Food Ingredients Bell foods, Alexandria, Egypt. Commercial grade of granulated sugar cane, sunflower oil and vanilla as flavour were purchased from the local market. A blend of stabilizer and emulsifiers (EXN 9080) was obtained from MIFAD (Misr Food Additives Giza- Egypt).

Methods

Preparation of barley milk

Preparation of barley milk (after trueing different methods) were as follow: 125g (Giza 123Var.) or 200g (Giza 130Var.) soaked enough water for 24 hr. ,then soaked barley grains (Giza 123 or 130Var.) cooked in water for 30 min, rinse and drain. After cooking, then, hot water were added in ratio 1:8 or 1:5 (Giza 123, 130Var.) respectively. Barley grains were grinding with hot water, blended and filtrated to get barley milk 5% T.S. Average chemical composition of barley milk (Giza123 or Giza130) were (95% moisture, 0.08% fat, 0.55% protein, 0.50% fiber, 3.43% carbohydrates and 0.44% ash), and (95% moisture, 0.08% fat, 0.50% protein, 0.41% fiber, 3.60% carbohydrates and 0.41% ash) respectively.

Manufacture of ice cream

The control mix was standardized to contain 8% fat, 8.5% milk solid not fat (SNF), 16% sugar and 0.3% stabilizer/emulsifier.

Rennet casein powder was added to raise the total solid in the barley mix without adding Stabilizer/

emulsifier as shown in Table 1. Mixes were homogenized and heat treated up to 85±I°C for about 5 min., then rapidly cooled to 5°C and aged at same temperature for 24 hr.. After aging, 0.01% vanilla powder was directly added before frozen in batch freezer system (Qutofrigor E.21.8, Co., Paris). The frozen ice cream was packed in plastic cups (100ml) and hardened at -20° C for 24 h before analyses.

Table 1. Formulations of different ice cream mixes (g/kg mix).

Ingredients	T_1	T_2	T_3	T_4
Sugar	160	160	160	160
Butter oil	76.6	76.6	-	-
Sunflower oil	-	-	80	80
Fresh skim milk	739.7	-	-	-
Free lactose milk	-	739.7	-	-
Rennet casein powder	20.7	20.7	55.2	55.2
Barley (Giza123 Var.)	-	-	704.8	-
Barley (Giza 130 Var.)	-	-	-	704.8
Stabilizer and emulsifier	3	3	-	-

T_1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.)

Physicochemical analysis

- One thousand grain weight, 1000 grain volume was determined according to (Williams et al., 1983). Grain weight was calculated as the mean weight of 1000 undamaged barley grains. For the determination of grain volume, grains were transferred to a 250 ml measuring cylinder, and 100 ml distilled water were added. Grain volume was determined as total volume minus 100. Density (g/mL) was then determined by dividing the weight of the barley by its volume, using the following formula: Density = grain weight / grain volume (g/ml).

-Moisture, fat, crude fiber, total nitrogen and ash were determined according to (AOAC, 2019). Total carbohydrates were calculated by differences.

-Minerals content (Magnesium, sodium, zinc, iron, calcium, phosphorus, potassium and copper) for of two barely varieties grains (hulled Giza123 Var. or Hulless barley Giza130 var.) by using the flame photometer (Galienkamp, FGA 330, England) and Perkin Elmer Atomic Absorption Spectrophotometer. (Model 80, England) as described in AOAC (2019). Phosphorus content was calorimetrically determined by spectrophotometer at 650 nm according to the method described in AOAC (2019).

Determined of barley *β*-glucan

β-Glucan was extracted from grains (Giza123 or Giza130) were determined, using a hot water method as described by (Temelli, 1997) with few modifications. Giza123 or Giza130Var.barley flour (500 g) was added to distilled water (5 L) and the pH was adjusted to 8 with Na OH (1 M). Then the suspension was submitted to a water bath at 55 °C, under shaking (450 rpm), for 3 hr. solid to liquid separation was done by centrifugation at 5,500 rpm at 4° C for 10 min. The residue was discarded, and an equal volume of absolute ethyl alcohol (98%) was added to the supernatant to precipitate the *β*-glucan. The solution was kept for12 hr at 4 °C, and *β*-glucan gum was skimmed off and rinsed with ethanol. The yield (w/w) of *β*-glucan gum was calculated by the weighing of gum obtained from 100 g of (Giza123 or Giza130) barley flour.

Determination of acidity

Titratable acidity was determined according to (Richardson, 1986).

- Assessing pH Values

The pH value was measured using a pH meter using Lab. pH meter with a glass electrode, (Jenway Benchtop pH meter).

Antioxidant activity

Antioxidant activity of ice cream was assessment using stable radical, 1,1-diphenyl-2-picrylhydrazyl - (DPPH), as described by (Ali et al., 2014).

Summary, 5 ml of DPPH reagent (0.00039 gm in 1 liter methanol) was mixed to 0.1 ml of sample extract or standard and vortexes forcefully. The discoloration of DPPH was measured against a reagent blank at 517 nm after the reaction tubes had been incubated in the dark for 30 min at room temperature. The sample's percentage inhibition of DPPH's coloration was calculated using the following formula:

% Antioxidant activity = {(absorbance at blank) – (absorbance at test) / (absorbance at blank)} X 100

- Specific gravity and weight per gallon

Specific gravity of the ice cream mixes and the final frozen product were measured at 20 °C using pycnometer according to (Winton, 1958). The weight per gallon (kg) of ice milk mixes and the final frozen products were calculated according to (Kessler, 1981) by multiplying the specific gravity of the mix by the factor 3.793.

- Determination of viscosity

The viscosity of ice cream mixes was carried out as described by (Toledo, 1980) using Brookifield DV- E viscometer.

- Determination of flow time

Flow time of ice cream mixes was measured as the time in seconds required to discharging a 50 ml pipette at 5 °C under atmospheric pressure according to (Arbuckle, 1986).

- Determination of freezing point

Freezing point of ice cream mix was measured as described in FAO report (1977), using Digital thermometer (Digitemp D 200/20, Germany).

- Calculation of the overrun

The overrun percent was calculated as mentioned by (Goff and Hartel 2013) using the following equation:

$$Overrun\ \% = \frac{weight\ of\ mix - weight\ of\ ice\ cream}{weight\ of\ ice\ cream} \times 100$$

-Determination of melting rate of the resultant ice cream

Melting resistance of resultant ice cream was examined according to the method described by (Rolon et al., 2017).

-Texture analysis

The texture analysis was carried out using a Universal Testing Machine (TMS-Pro) and connected to a computer programmed with Texture Pro^{TM} texture analysis software (program, DEV TPA withhold) as mentioned by (El-Zeini et al., 2018). Sample surface was flattened to avoid early triggering of the test. A flat probe rod (37.75 mm diameter) was programmed to descend into the sample at a speed of 60 mm/sec to a depth of 40% of original sample high (60 mm) and then ascend back to its original position with a back-off distance of 20 mm. Distance of extrusion was set at 20 mm with a trigger force of 1N.

-Color measurement

Color parameters of the samples were analyzed in triplicate using a colorimeter (CR-10, Konica Minolta Sensing Inc., Japan) according to (McGurie, 1992). The color values were recorded as:

L* = lightness (0 = black, 100 = white), a* (-a* = greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness).

-Sensory evaluation

Some staff members were selected from Dairy Technology and Field Crops Technology Department, Food Technology Research Institute, Giza, Egypt. The evaluation of the ice cream samples included the following sensory attributes; appearance, color, texture, aroma, taste and overall acceptability. The scale used was nine points hedonic scale, where represents dislike extremely, 5 for neither dislike or like, and 9 for extremely like as described by (Lim, 2011).

Statistical analysis

The data obtained (mean of three replicates) were statistically analyzed according to statistical analyses system user's guide (SAS, 2004). Analysis of variance (ANOVA) and Duncan's multiple comparison procedure were used to compare the means. A probability of $p<0.05$ was used to establish statistical significance.

3. RESULTS AND DISCUSSION

-Physicals properties and Color measurement of barley grains varieties

Physical properties such as (Length, width, the mean weight, volume, density and color) measurements of barley grains (Giza123 or Giza130) were determined, and the results obtained are presented in Table 2. The length and width of two barley varieties ranges of average, 0.62-0.75mm long and 0.33-0.34mm. Also, the density was 0.68 (g/ml) for Giza 123, while the mean weight and volume and density for Giza 130 were 40. 2 (g), 60.5 (ml), 0.66 (g/ml), respectively. Moreover, (Farooqui, et al., 2018), showed that the 1000 kernel weight of barley was 42.08 (g), density 0.62 (g/ml). The environmental factors, such as rainfall, temperature, soil conditions, fertilization and genetic factors, can contribute to variations in the chemical composition and physical characteristic of cereal grains (Rodehutscord, et al., 2016). Concerning the color measurement .the color values of presented in Table 2. Lightness (L*), redness (a*), and yellowness (b*) (there are significant differences between the two types of barley among all color measurement parameters ,where L* value (lightness) show a significant decrease 66.82 in Giza 123 verity (more darker than Giza 130 which recorded 72.01. The mean (a*) value, also Giza 123 verity showed a significant decrease in a negative Value (-2.9) due to the green color compared to Giza 130 var. concerning to (b*) values (indicated the yellow color), there is a significant increase in Giza130 (22.9) indicated that the yellowish color compared to Giza 123var.

Table 2. Physical properties and color measurement of barley grain varieties.

Properties	Giza123	Giza 130
	Physical properties	
Seed length (mm)	0.62 b	0.75 [a]
Seed Width (mm)	0.33 [a]	0.34 [a]
LlW (mm)	1.87 [b]	2.41 [a]
1000-kernel wt. (g)	41.3[a]	40. 2 [b]
Hectoliter (kg/hL)	60.2 [a]	60.5 [a]
Density (g/ml)	0.68 [a]	0.66 [a]
	Color measurement	
a	14.6 [b]	22.9 [a]
b	2.9 [b]	4.46 [a]
L	66.82 [b]	72.01 [a]

Each value represents the average of three determinations * a b c Means with different superscripts within rows are different ($P \leq 0.05$) -L (lightness with L = 100 for lightness, and L = zero for darkness), a [(chromaticity on a green (−) to red (+)], b [(chromaticity on a blue (−) to yellow(+)], c (color saturation), h [(hue angle where 0˚ = red to purple, 90˚ = yellow, 180˚ = bluish to green and 270˚ = blue scale. Values are mean of three replicates.

Chemical composition of barley grains.

Chemical compositions of barley grains (Giza123 or Giza130) were determined, and the results obtained are presented in Table 3. Results showed that, Giza123 var. was higher than Giza130 var. in crude protein, crud fat, Ash and crude fiber contents which were 11.25, 2.86, 2.93, and 3.14 % respectively. Main while Giza130 var. was higher in moisture, total carbohydrate, and *β-glucan* (10.22, 71.50, and 6.10%) respectively. This result agreement with obtained by (Elbasyoni et al., 2020; Jasmina and Marko 2022). Minerals content (mg/100g) in grains (Giza123 or Giza130 Var.) presented in Table 3. show that. Giza123 var. was higher than Giza130 var. in Na, Zn, Ca, P and Fe contents which were 44.0, 2.4, 52.0,275 and 6.1mg/100g .respectively. While Giza130 var. was higher than Giza123 var. in Mg and K contents which were (28 and 480 mg/100g .respectively). This result agreement with obtained by (Fahmy and Abd al-maksod, 2020).

Table 3. Chemical composition of barley grains varieties.

Samples	Moisture	Crude protein	Crud fat	Ash	Crude fiber	Total Carbohydrate	*β-glucan*
Giza123	9.84 ^{b}	11.25 ^{a}	2.86 ^{a}	2.93 ^{a}	3.14 ^{a}	69.98 ^{b}	5.62 ^{b}
Giza130	10.22 ^{a}	10.41 ^{b}	2.40 ^{a}	2.65 ^{a}	2.82 ^{b}	71.50 ^{a}	6.10 ^{a}
Minerals content (mg/100g)							
	Na	Zn	Ca	P	Fe	Mg	K
Giza123	44.0 ^{a}	2.4 ^{a}	52 ^{a}	275 ^{a}	6.1 ^{a}	26 ^{b}	430 ^{b}
Giza130	43.4 ^{b}	2.3 ^{a}	41 ^{b}	255 ^{b}	4.7 ^{b}	28 ^{a}	480 ^{a}

Each value represents the average of three determinations. Means with different superscripts letters (a, b) in the same row are significantly different ($P \leq 0.05$)

Chemical properties of ice cream mix

Table 4. shows the chemical composition and antioxidant activity of ice cream mixes as affected by different kind of milk. The results indicate that, the fat content not influenced ($P>0.05$) by the kind of milk due to the previous adjustment of ice cream formulating. Moreover, there are significant increase ($p<0.05$) in the total solid, protein, fiber and antioxidant activity while the ash and carbohydrates decreased light significantly in barley ice cream mixes. This was mainly due to differences in chemical composition of cow and barley milk used material. Titratable acidity tended to slightly increase in barley ice cream mix. It could be due to lower acidity of rennet casein powder which added to increase the total solids in the formulated mixes to obtain a product acceptable quality.

Table 4. Chemical properties of ice cream mixes

Properties	T_1	T_2	T_3	T_4
Total solid	32.56 ^{b}	32.49 ^{b}	33.01 ^{a}	32.95 ^{a}
Fat	8.10 ^{a}	8.07 ^{a}	8.01 ^{a}	8.00 ^{a}
Protein	4.03 ^{b}	4.00 ^{b}	4.91 ^{a}	4.90 ^{a}
Ash	1.04 ^{a}	1.02 ^{a}	0.90 ^{b}	0.89 ^{b}
Carbohydrates	19.40 ^{a}	19.36 ^{a}	19.22 ^{b}	19.17 ^{b}
Fiber	-	-	0.19 ^{a}	0.16 ^{a}
Acidity (%)	0.21 ^{b}	0.22 ^{b}	0.24 ^{a}	0.25 ^{a}
Antioxidant activity (%)	22.44 ^{b}	22.61 ^{b}	30.81 ^{a}	30.43 ^{a}

T_1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.). Each value represents the average of three determinations. Means with different superscripts letters (a, b) in the same row are significantly different ($P \leq 0.05$)

Physical properties of ice cream mixes

The data in Table 5. shows the effect of barley milk replacement of cow's skim milk and stabilizer/emulsifier on some physical properties of ice cream mixes. The specific gravity, weight per gallon and freezing point were increased ($p<0.05$) in barley ice cream mix. It could be due to lower lactose and ash content in barley grains. Freezing point is affect by the amount, type and molecular weight of the solutes in the mix (Goff and Hartel, 2013). Moreover, Soleiman and Arman, 2015) pointed out a light reduction in freezing point of lactose hydrolyzed ice cream mixes from -2.18 of control to -2.48.

As appeared from the Table 5. replacement of cow's skim milk either ivied or hydrolyzed with barley milk either hulled or hulless significantly increase ($p<0.05$) the viscosity and flow time of the mixes. The differences in flow time and viscosity values of control and treatments could be due to differences in composition of materials. The high flow time and viscosity of barley ice cream mixes is due to the high content of starch and fiber in barley grain which able to gelatinize during the heat treatment and therefore, may increase the rheological properties of the ice milk mix whereas gelatinized starch has water holding capacity. These results are in agreement with the opinion of (Soukoulis et al., 2009 and Salama et al., 2017). They reported that, ice cream mixes with oat, wheat and barley fibers had significantly better viscosities and an enhanced shear thinning character, which were probably brought on by the presence of insoluble materials with a high capacity for retaining water as well as the increase in serum concentration brought on by the soluble fibers' ability to cling onto water.

Regarding pH value, data show that substitution barley milk in ice cream making led to decrease the pH value ($p<0.05$). The change is mainly attributed to high protein content and low pH value of rennet casein powder.

Table 5. Physical properties of ice cream mixes

Property	T_1	T_2	T_3	T_4
Specific gravity	1.0988^{b}	1.1016^{ab}	1.1477^{a}	1.1472^{a}
Weight (Kg)/gallon	4.1677^{b}	4.1783^{ab}	4.3532^{a}	4.3513^{a}
Freezing point ˚C	-2.23^{b}	-2.46^{c}	-1.99^{a}	-2.03^{a}
Flow time (sec.)	90.63^{d}	91.54^{c}	114.50^{a}	110.86^{b}
Viscosity (CP)	810^{c}	840^{b}	1500^{a}	1450^{ab}
PH	6.63^{a}	6.63^{a}	6.51^{b}	6.45^{b}

T_1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.). Each value represents the average of three determinations. Means with different superscripts letters (a, b) in the same row are significantly different ($P \leq 0.05$)

Physical properties of resultant ice cream

The results presented in Table 6. revealed that the physical properties of resultant ice cream affected by replacing cow's skim milk with barley milk. Both specific gravity and weight per gallon of resultant ice cream were increased, which could be explained the basis of the decreased overrun percent gained ($p<0.05$) in the resultant ice cream. Also, the melting resistance increased significantly ($p<0.05$) as replacement of cow milk with barley milk, and hulled barley milk exhibited the highest melting resistance. It is noteworthy to mention that, there is a positive relationship between the melting resistance and freezing point of ice cream. On the other hand, the latter has a reverse correlation to the lactose and ash contents of the mix. These results are in agreement with (Salama et al., 2017).

Table 6. Physical properties of resultant ice cream

Property	T_1	T_2	T_3	T_4
Specific gravity	0.6904^{b}	0.6917^{b}	0.8336^{a}	0.8325^{a}
Weight (Kg)/gallon	2.6186^{b}	2.6236^{b}	3.1618^{a}	3.1576^{a}
Overrun %	47.72^{a}	46.81^{a}	28.79^{b}	28.40^{b}
Freezing time (min)	17.3^{a}	17.0^{a}	13.1^{b}	13.0^{b}
		Melting % after		
10 min	15.60^{a}	15.23^{a}	11.86^{b}	12.04^{b}
20 min	32.56	31.94	20.30	20.87
30 min	60.13	58.67	40.25	41.97
40 min	80.19	79.95	62.61	70.54
50 min	91.20	90.4	77.62	80.78
60 min	100	100	86.29	87.12

T_1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.). Each value represents the average of three determinations. Means with different superscripts letters (a, b) in the same row are significantly different ($P \leq 0.05$)

Texture and color parameters of resultant ice cream.

The textural parameters viz., hardness, adhesive energy, adhesive force and resilience of the control and all treatments of ice cream were presented in Table 7.

Hardness is determined by the greatest force that the probe can exert while penetrating the substance during a back extrusion test. It indicates the amount of energy needed to chew the ice cream until it is ready to be chewed on. It was observed that the use of barley milk increased the maximum penetration force, which means that the ice creams became harder.

Resilience is a gauge of how quickly the sample bounces back energy intake to energy output ratio. It indicates work that cannot be recovered from the complete distortion. The resiliency revealed a declining percentage. As indicated in Table 7. resilience not influenced (P>0.05) in all sample. The adhesiveness values were significantly (P<0.05) higher in all treatments than control. These results are in agreement with results reported by (El-Zeini et al., 2018).

As observed in Table 7. the different color parameters of ice cream. It was revealed that the lightness (L*) value of the free lactose ice cream was significantly higher than other treatments whereas the redness (+a*) and yellowness (+b*) values were significantly lower. The white color of milk results from the presence of colloidal particles, such as milk fat globules and casein micelles, capable of scattering light in the visible spectrum (García-Pérez et al., 2005), which explains the high L* value of the milk ice cream in comparison to that of barley ice cream. This trend is in accordance with that in the study by (Zayan et al., 2014) for function frozen yoghurt fortified with carob powder.

Table 7. Texture analysis and color parameters of resultant ice cream

Property	T_1	T_2	T_3	T_4
Hardness (N)	9.5 ^{d}	10.5 ^{c}	16.1 ^{a}	14.6 ^{b}
Resiliance	0.01 ^{a}	0.01 ^{a}	0.02 ^{a}	0.01 ^{a}
Adhesive Energy (mj)	-0.1 ^{d}	-0.3 ^{c}	-1.2 ^{a}	-0.7 ^{b}
Adhesive Force (N)	0.171 ^{d}	0.545 ^{c}	6.18 ^{a}	3.053 ^{b}
Color parameters				
L	84.96 ^{a}	86.79 ^{a}	66.25 ^{b}	66.07 ^{b}
a	0.62 ^{b}	0.48 ^{b}	2.23 ^{a}	2.11 ^{a}
b	3.57 ^{b}	3.35 ^{b}	8.80 ^{a}	8.68 ^{a}

T_1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.). Each value represents the average of three determinations. Means with different superscripts letters (a, b) in the same row are significantly different (P ≤ 0.05)

Sensory score of resultant ice cream

The sensory attributes of ice cream samples are shown in Table 8. Generally, replacement of cow's skim milk either ivied or hydrolyzed with barley milk either hulled or hulless enhanced the sensory attributes of ice cream. Ice cream appearance and color affected by substitute barley milk, while the texture and taste were improved. It is noteworthy that, the sensory properties and overall acceptability of free lactose ice cream (T_1) was similar to control. Hulless barley milk (T_4) gained the highest sensory scores compared to other treatments including the control. It was described as good flavor, a rich taste with good melting resistance. These results agree with the trends reported by (Salama et al., 2017).

Production cost of different ice cream recipes

The production cost of different ice cream recipes were calculated and showed in Table 9. Results revealed that, the cost reduction (%) remarkably increased as replacement barley milk in the blend, while, using free-lactose milk in the blend led to an increase in the cost about +48.32 %. As shown the approximately ice cream treatment can be manufactured with up to 36.73% reduction in the cost by replacement of cow's skim milk with barley milk without adding Stabilizer/emulsifier. It could be recommended that ice cream of high quality and with low cost can be made by replacement cow milk with barley milk without the need of using stabilizer/ emulsifier.

Table 8. Sensory score of resultant ice cream

Property	T_1	T_2	T_3	T_4
Appearance and Color	8.10 ^{a}	8.24 ^{a}	7.73 ^{b}	7.80 ^{b}
Texture	7.89 ^{b}	7.66 ^{b}	8.00 ^{a}	8.11 ^{a}
Taste and Aroma	8.21 ^{a}	8.01^{ab}	7.99 ^{b}	8.27 ^{a}
Overall acceptability	8.23 ^{a}	7.95 ^{b}	8.01^{ab}	8.21 ^{a}

T_1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.). Each value represents the average of three determinations. Means with different superscripts letters (a, b) in the same row are significantly different ($P \leq 0.05$)

Table 9. Total cost of different ice cream recipes with the use of barley milk as replacement cow's skim milk and stabilizer/emulsifier (L.E/ kg mix)

Ingredients	Cost (LE)	T_1	T_2	T_3	T_4
Sugar	18	2.88	2.88	2.88	2.88
Butter oil	200	15.32	15.32	-	-
Sunflower oil	60	-	-	4.80	4.80
Fresh skim milk	20	14.79	-	-	-
Free lactose milk	50	-	39.49	-	-
Rennet casein powder	300	6.21	6.21	16.56	16.56
Barley (Giza123)	15	-	-	1.32	-
Barley (Giza 130)	20	-	-	-	2.82
Stabilizer	400	1.20	1.20	-	-
Total Cost (LE/ kg mix)	-	40.40	59.92	25.56	27.06
Cost reduction %		---	+48.32	-36.73	-33.02

T1: control, T_2: free lactose; T_3: Hulled barley (Giza123 Var.) and T_4: Hulless barley (Giza130 Var.).

4. Conclusions

Complete replacement cow's skim milk either ivied or hydrolyzed and stabilizer/emulsifier with barley (Hordeum vulgare L.) milk either hulled Giza123 var. or Hulless barley Giza130 var. were characterized by increased values of dry matter, protein, fiber, acidity and antioxidant activity. In resultant ice cream, the sp. gr., weight per gallon and melting resistances were increased and consequently the overrun was decreased when barley milk was used in the mixes. All treatments were organoleptically acceptable and the hulless ice cream showed superior sensory properties compared to the other treatment.It could be recommended to use barley milk as an appropriate, healthy substitute for cow's milk in the production of ice cream without the need of using stabilizer/ emulsifier, particularly for those who are sensitive to milk protein or lactose intolerance and in situations where milk may be too expensive or unavailable, as they contain cholesterol.

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