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Functional ice milk with Psyllium seed husk powder as a fat replacer

Wafaa, M. Salama[1], Nahed, A. ELwahsh[1] and Awad, R.A[2]

[1] Dairy Res. Dept., Food Technology Research Institute, Agriculture Research Center, Giza, Egypt.
[2]Food Sci. Dept., Faculty of Agric., Ain Shams Univ., Shoubra EL-Khaima, Cairo, Egypt.

Abstract

Performance of Psyllium seed husk powder (PSHP) as a fat replacer in ice milk formulas was investigated. All mixes, and resultant ice milk samples were evaluated for their chemical, physical and textural properties as well as sensory quality attributes. Total solids, protein, and ash contents were significantly increased by adding PSHP, whereas fat content decreased. Specific gravity was increased with adding PSHP in both mixes and resultant ice milk, while the overrun percent was significantly decreased. The addition of Psyllium seed husk powder in ice milk recipes led to slightly lower pH values by lowering the freezing point, and the product showed a lower ability to meltdown with the replacement of milk fat by PSHP compared to the full-fat treatment (control). Apparent viscosity, as well as flow time of mixes, were significantly increased ($P \leq 0.05$) with the prementioned replacement. Hardness and adhesiveness values increased with increasing PSHP percent in ice milk. The ice milk became smoother and highly acceptable by partial replacement of milk fat with PSHP. Therefore, ice milk can be produced with high quality using PSHP at a 1% level.

Key words: Psyllium seed husk powder, Ice milk, substitution, Textural properties, sensory evaluation.

INTRODUCTION

Obesity is a significant health problem in our world. It contributes to diseases such as diabetes mellitus type II, and certain types of cancers. Lowering fat content in the diet is the right approach to controlling fat intake and thus managing obesity. Accordingly, low fat products is continuously increasing (Ritvanen *et al.,* 2005).

Ice milk is a sweet dairy product including milk, sweetener, stabilizer, emulsifier, and flavoring. It that refers to a standardized frozen dessert class with a fat content between 2 and 8% (Tharp and Young, 2013). In Egypt and according to the Egyptian Standard 1185-3/2005, the fat content of ice milk must not be less than 3%.

Reduction of fat content in dairy products precedence to various defects such as hard and rubbery texture. Flavor, color, and mouth feel will also be adversely affected (Pereira *et al.*, 2009). Several approaches have been investigated for the possibility to improve the flavor and texture of low-fat dairy products, e.g., modification of conventional manufacturing process, use of enzymes, additives (stabilizers), and fat replacers (Rodriguez, 1998; Fenelon & Guinee, 2000 and Mistry, 2001). Using fat substitutes as food additives to replace fat in food while keeping the same functional and sensory properties of fat products has had great attention had great attention in the past few years. Available fat substitutes can be classified as carbohydrate-based; protein-based and fat-based fat replacers (Giese, 1996). Recent studies have focused on the effects of food additives-based fat replacers in ice cream such as Psyllium.

Psyllium's (Isabgol), the common name in India for *P. ovata*, comes from the Persian words "isap" and "ghol" which means horse ear, which is descriptive of the shape of the seed. India is the largest exporter of isabgol in the world. Psyllium has been used as a medicinal agent since ancient times worldwide. It is used for the treatment of constipation, diarrhea, hemorrhoids, and high blood pressure (Clark et al.,2020). Psyllium has been shown to reduce total cholesterol and low-density lipoprotein (LDL) in animals and in humans (Terpstra *et al.,* 2000). Psyllium may also affect appetite.

Dietary fibers from psyllium have been used extensively in processed food to aid weight reduction, for glucose control in diabetic patients, and it has been shown to improve insulin sensitivity (Anderson *et al.,*1999). The husk is about 10-25% of seed on a dry weight basis. The husk obtained after milling is white hydrophilic material forming clear and colorless mucilaginous gel after water absorption. Psyllium seed husk is composed of both soluble and insoluble fibers (Bijkerk*et al.*, 2004). Due to its high water-binding capacity and stability at various pH levels and temperatures, psyllium can be employed as a food additive, improving shelf life and consumer acceptance, and reducing stickiness (Ibuki 1989). Psyllium can be employed as an emulsifier, stabilizer, and fat replacer for wheat flour (Giuntini *et al.*, 2003; Zandonadi *et al.*, 2009). Limited studies mentioned adding psyllium seed husk in some dairy products. For example, Sakr (2019) used psyllium husk (PSH) or seeds (PSS) to develop functional non-fat stirred yoghurt. No studies have been published on the use of psyllium seed husk powder in ice milk. So, the objective of this study was to investigate the possibility of using psyllium seed husk powder as a natural fat replacer in the manufacture of ice milk.

Materials and Methods

Materials

Cream consists of 65% fat, 30.64% moisture, 1.93% protein and 0.66% ash, whole milk (6.20% fat, 84.31% moisture, 3.64% protein and 0.79% ash) and skimmed (0.1% fat, 89.57% moisture, 3.70% protein and 0.85% ash), buffalo's milk was obtained from the herd of the Faculty of Agriculture, Cairo University and used for preparing the ice milk mixes. Skim milk powder (SMP) made in the USA (0.9% fat, 4.12% moisture, 33.93% protein and 7.99% ash) was obtained from Dairy American ™, USA. Commercial-grade cane sugar and vanilla were purchased from the local market. High viscosity carboxy methyl cellulose (CMC) produced by TIC gums, MD, USA was used as a stabilizer, whereas soy Lecithin was used as an emulsifier. Psyllium seed husk powder used in this study was obtained from the local market. The gross composition of Psyllium seed husk powder (PSHP) was 0.99% fat, 8.39% moisture, 3.95% protein, 3.04% ash, 80.80% carbohydrate and 2.83% Crude fiber. It contained 2469.80 ppm calcium, 91.50 ppm magnesium, 255.59 ppm phosphor, 62.417 ppm iron and 4.50 ppm zinc. The pH value of the PSHP was 5.50.

Separating the husk of psyllium seed

Local psyllium seed was purchased from the local market (Giza, Egypt), a laboratory mill (Tefal, Cairo, Egypt) was used to mill the psyllium seed for 2 min to separate the husk. Then the powder was sifted from a very narrow sieve of holes with mesh number 18 several times to get the smooth powder and kept in a glass bottle and stored in the refrigerator (Askari *et al.*, 2008).

Manufacture of ice milk

Ice milk batches were prepared from the a forementioned ingredients with quantities calculated as shown in Table (1). The control mix was standardized to contain 6% fat, 12% SNF, 15% sugar, 0.25% CMC, and 0.1% Lecithin. Psyllium seed husk powder (PSHP) was used to replace part or a whole-fat mixture of ice milk, as shown in Table (1). However, for treatments with PSHP, it was added into the blend at ratios of 0.5, 1, and 2 % as shown in Table (1). All prepared mixes were heat treated up to 85±1ºC for about 30 sec., then rapidly cooled to 5±1ºC and aged at the same temperature for 4hr. After aging, 0.01% vanilla powder was directly added to the mixes before freezing in a horizontal batch freezer (Taylor Co. USA). The ice milk was drawn in plastic cups (120 ml) and hardened at -26ºC for 24 hr. before analysis. All treatments were of three replicates.

Table (1): Formulation of ice milk containing different ratios of Psyllium seed husk powder (g/kg).

Ingredients	Treatments*			
	Control	$T_{0.5\%}$	$T_{1\%}$	$T_{2\%}$
Sugar	15	15	15	15
CMC	0.25	0.25	0.25	0.25
Lecithin	0.1	0.1	0.1	0.1
Psyllium seed husk powder	----	0.5	1.0	2.0
Cream	2.8	2.0	1.2	----
Skim milk powder	4.92	4.92	4.92	4.92
Fresh milk (whole 6%)	76.93	75.00	73.33	66.75
Fresh milk (skim)	----	2.23	4.20	10.98
Total	100	100	100	100

* $T_{0.5}$, T_1, T_2: Treatments with 0.5,1 and 2% Psyllium seed husk powder

Analysis

Moisture, fat, ash, fiber and total protein percentages of mixes were determined according to AOAC (2007). Minerals (Zn, Ca, Mg, Na, Fe, and P) were determined by atomic absorption spectrophotometer (Varian Model Spectra AA 100 & 200) according to AOAC (2007). Titratable acidity of mixes was determined in duplicate according to Richardson (1986) by titration with NaOH 0.1N. Specific gravity was determined as described by Winton (1958) for mixes and resultant ice milk. The freezing point was tested for mixes as mentioned in the FAO Laboratory manual (1977). PH values were measured using a digital laboratory pH meter (HI 93 1400, Hanna instruments) with a glass electrode. The overrun in ice milk was calculated according to Marshall *et al.,* (2003) as the difference in volume between the resultant ice milk and the original mix. The melting rate for resultant ice milk samples was determined as mentioned by Segall and Goff (2002). Ice milk samples were allowed to melt at room temperature (23±1ºC), and the melted portion was weighed every 15 min. The percent mass loss/min in the linear region (slope) was used to compare the meltdown rate of different samples.

Physical properties

Viscosity and flow behaviour were determined in all mixes using a coaxial cylinder viscometer (Brookfield Engineering Labs.

DVIII Ultra Rheometer and COM1 or COM2 of our host computer) at rpm 5, 10, 15, 20, 25, and 40 as suggested by Arbuckle (1986). All samples were adjusted to 20±1ºC before loading in the viscometer device.

Textural properties

Texture profile analysis (TPA) of the resultant ice milk was done with an Instron Universal Testing Machine (Model 4302, Instron Corporation, Canton M.A, England) according to the procedure of Bourne (1978).

Sensory evaluation

Samples of ice milk after 24 h of hardening at -26ºC were judged by a panel of 10 judges from the Dairy Technology Research Department, Food Technology Research Institute, selected based on their consistency in scoring. The samples scored for flavor (45), body and texture (35), melting properties (10), and color (10), as suggested by Arbuckle (1986).

Statistical analysis: -

All data (mean of three replicates) were analyzed by the General Linear Models procedure of SAS (1990). The statistical analysis was performed using one-way analysis of variance (ANOVA). Means were compared by Duncan's test at the significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Properties of ice milk mixes

The chemical composition of ice milk mixed with Psyllium seed husk powder (PSHP) as a substitution of fat in the base formula is shown in Table (2). Total solid content in all treatments ranged from 32.12 to 34.15%. It is shown from the data that there were slight differences in the total solid contents of mixes. The total solid content of ice milk treatments increased with the addition of PSHP in the blend. The results recorded are similar to the findings of Mamun *et al.* (2020). Also, it can be observed from Table (2) that values for fat content decreased with the increase in the proportion of PSHP. On the other hand, the total protein of ice milk mixes was significantly affected by the addition of PSHP. However, the replacement of cream with PSHP resulted in higher protein content of treatments compared to the control. Also, ash content showed higher ratio in treated samples with PSHP than in the control. This is due to the higher ratio of protein and ash in PSHP (see Materials and Methods). The fiber content of ice milk treatments was higher than the control (free fiber) due to the addition of PSHP as a good source of dietary fiber. The fiber in food has been shown to reduce the risk of various medical conditions. The suggested benefits of fiber are to reduce breast cancer, type-2 diabetes, obesity, diverticular disease, hyperlipidemia, or high blood cholesterol (Franceschi *et al.,* 2001). Carbohydrate content in treatments ranged from 20.53- 22.18 % for different ice milk samples, including control. Among treatments, the highest carbohydrate content (22.18%) was found in T_2, and the lowest value (20.98%) was for $T_{0.5}$. The increasing trend in carbohydrate content was due to the addition of PSHP in the blend. These results are in agreement with Mamun *et al.* (2020).

Minerals content

From the obtained results in Table (2) it was noticed that the iron content of supplemented ice milk with PSHP varied between 5.917-8.583 ppm compared to 3.750 ppm in the control treatment. The addition of PSHP to the ice milk mix slightly increased the zinc content of the resultant ice milk. Adding PSHP to ice milk blends was also accompanied by a high calcium content level due to the high content of this element in the used powder (2469.80 ppm, see Materials and Methods). Also, the addition of PSHP to ice milk recipes increased contents of manganese and phosphorus in the resultant product which could be attributed to the high contents of these elements in PSHP (see Materials and Methods).

Table (2): Chemical composition (%) and Mineral contents (ppm) of functional ice milk mixes supplemented with Psyllium seed husk powder.

Treatments*	Total solids	Fat	Total protein	Ash	Cured fiber	Carbohydrate**
Control	32.12^{B}	6.12^{A}	4.43^{AB}	1.04^{AB}	0.00^{d}	20.53^{C}
$T_{0.5\%}$	32.54^{B}	5.52^{B}	4.46^{AB}	1.13^{AB}	0.45^{C}	20.98^{C}
$T_{1\%}$	33.31^{AB}	5.11^{B}	4.57^{AB}	1.16^{AB}	1.25^{B}	21.22^{B}
$T_{2\%}$	34.15^{A}	4.11^{C}	4.69^{A}	1.28^{A}	1.86^{A}	22.18^{A}
Mineral content (ppm)						
	Fe	Zn	Ca	Mg	P	
Control	3.750	5.417	2301.83	86.417	1302.33	
$T_{0.5\%}$	5.917	5.667	2361.58	88.917	1369.42	
$T_{1\%}$	6.333	6.916	2477.25	89.917	1374.92	
$T_{2\%}$	8.583	7.750	2491.58	90.00	1399.92	

*: -See table (1) for details; **: -Carbohydrate content was determined by difference. A B C: Means with the same letter among treatments are not significantly different.

The effect of PSHP on some physicochemical properties of ice milk mixes is shown in Table (3). Values of pH tended to decrease with adding PSHP in the ice milk formula. The difference in pH values of ice milk mixes could be due to the lower pH value of PSHP (5.5) compared to other ingredients in the formula. However, PSHP component contributed to the natural acidity of the ice milk mix and also a high content of protein in these mixtures, which led to a high acidity and thus a decrease in the pH value. Similar trends were obtained by Awad and Salama (2010).

The specific gravity (sp.gr.) of ice milk mixes was increased by adding PSHP (Table,3). The addition of the powder to the formula increased the specific gravity of mixes showing more increase with increasing the ratio added (Beikzadeh *et al. 2016*). Among all treatments, the control sample without adding PSHP had the lowest value of specific gravity. Values of specific gravity significantly increased with adding Psyllium seed husk powder in the formula being highest in treatment (T_2) with 2% powder. Specific gravity (sp.gr) of mixes varies with varying mix composition. The data in Table (3) indicated that weight per gallon values followed the same trend of specific gravity since its calculation was based on specific gravity value. From the same Table it could be noticed that the freezing points were significantly affected by adding PSHP to the mixes.

The mixes showed lower freezing points in treatments compared to the control. The control showed the highest freezing point among all treatments. Freezing points of ice milk mix are highly dependent directly on the soluble components like sweetener and indirectly, on the ratio of fat and protein in the mix. The freezing point is affected by the amount, type, and molecular weight of the solutes in the mix (Marshall *et al.* 2003). The data are in line with that obtained by Awad (2007).

Table (3): Effect of adding of Psyllium seed husk powder to ice milk recipes on some properties of ice milk mixes.

Treatments*	pH values	Specific gravity	Weight per gallon(pound)	Freezing point (°C)
Control	6.51	1.009	8.416	-2.0
$T_{0.5\%}$	6.42	1.036	8.642	-2.1
$T_{1\%}$	6.38	1.045	8.713	-2.3
$T_{2\%}$	6.31	1.049	8.750	-2.4

*: -See table (1) for details

Viscosity

It has appeared from the data given in Fig. (1, a) that the replacement of milk fat with PSHP had affected the apparent viscosity values. The data indicated that the control possessed the lowest viscosity value. Viscosity values were significantly increased, with adding the powder to the formula being highest in the treatment with 2% PSHP. The differences in viscosity values of ice milk treatments with the PSHP could be due to the differences in protein contents (Table 2).

The low viscosity of the control mix can be attributed to its low protein content compared to mixes from other treatments. Increasing the protein ratio in ice cream mixes was reported to increase the viscosity values, which could be attributed to proteins' high water binding capacity (Salem, 2000). Also, an increase in the absorption of water is caused by the interaction between the hydroxyl groups of water and those of polysaccharide macromolecules present in the husk (Dikeman & Fahey 2006). Similar results were reported by Awad (2007).

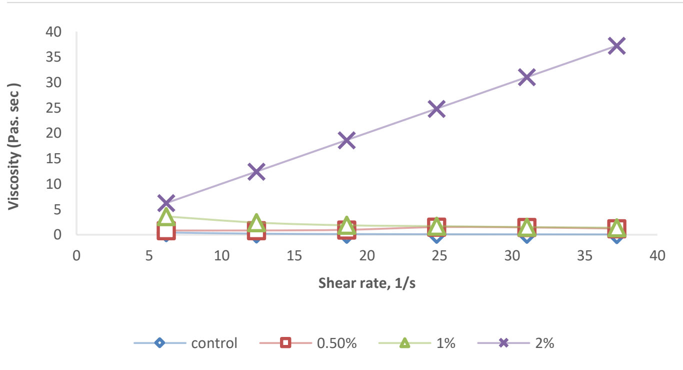

Fig.(1, a): Viscosity of functional ice milk mixes supplemented with different ratios of Psyllium seed husk powder.

Flow behavior

Flow behavior (shear stress/shear rate curve) for ice milk mix treatments is shown in Fig. (1, b). It could be noticed that pseudoplastic behavior was exhibited in all treatments with the existence of yield stress. The addition of PSHP to the ice milk mixes resulted in an upward shifting of the flow curve (building up of structure leading to an increase in the viscosity of the sample). Shear stress values for all treatments with the PSHP were higher than that of the control without addition.

This trend was independent of the shear rate. The shear stress increased in the treatments with an increasing ratio of PSHP. These results are in agreement with Awad (2007).

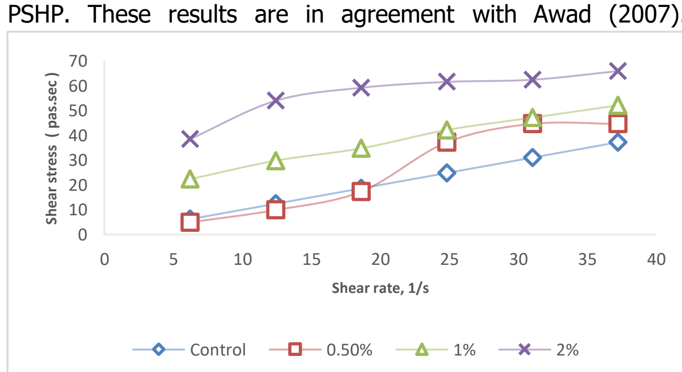

Fig.(1,b): Flow behavior of functional ice milk mixes supplemented with different ratios of Psyllium seed husk powder

Properties of resultant ice milk:

The effects of adding Psyllium seed husk powder on some properties of resultant ice milk are presented in Table (4). A slight increase in specific gravity and weight per gallon values was observed in ice milk treatments with PSHP compared to the control. Overrun percent in ice milk was significantly affected by adding PSHP being lowered with a higher addition ratio. The lower overrun percentage in ice milk treatments with PSHP could be related to the higher viscosity values since the viscosity value of the control was lower than that of any treatments with PSHP. Arbuckle (1986) and Marshall *et al.* (2003) reported similar results. Where the increase in viscosity values leads to a decrease in the volume of air incorporated into the mix. The data are in line with Beikzadeh *et al.* (*2016*).

Table (4): physiochemical properties of resultant ice milk supplemented with Psyllium seed husk powder.

Character assessed	Treatments*			
	Control	$T_{0.5\%}$	$T_{1\%}$	$T_{2\%}$
Specific gravity	0.742^{B}	0.776^{AB}	0.859^{A}	0.864^{A}
Weight per gallon	6.192^{B}	6.476^{AB}	7.168^{A}	7.210^{A}
Overrun (%)	63.28^{A}	59.71^{B}	56.83^{C}	54.14^{D}
Freezing Time (min.)	12.5^{A}	11.0^{B}	8.5^{C}	7.0^{D}
Melting resistance (loss % after)				
15 min.	6.39	1.48	----	----
30 min.	16.12	9.92	5.46	----
45 min.	60.12	28.48	20.31	10.08
60 min.	98.35	67.15	58.73	45.18
75 min.	melt	95.24	71.25	66.22
90 min.	melt	melt	96.78	81.14
105 min.	melt	melt	melt	93.29
120 min.	melt	melt	melt	melt

*: -See table (1) for details.
A B C: Means with the same letter among treatments are not significantly different

The time required for freezing ice milk mixes was lowed by adding PSHP to the mix formula. While control required 12.5 min. to be frozen, treatment with 2% PSHP took 7 min. The decrease in freezing time could be due to the addition of PSHP increased water absorption because of the hydrogen bonding interaction between the hydroxyl groups of water and those of polysaccharide macromolecules in the fiber (Dikeman & Fahey 2006).

Melting resistance given as loss in weight percent from the initial weight of the sample is also shown in Table (4). The melting resistance increased with increasing PSHP ratio in the ice milk and all functional ice milk formulations with PSHP showed lower melting than the control. The differences in melting resistance among all ice milk treatments are mainly due to the differences in added ratios of PSHP and their effects on mix properties. The melting resistance of resultant ice milk is mainly affected by the mix viscosity and freezing point values.

Generally, as the mix viscosity increased the resistance of ice milk to melt was increased. The results are in agreement with that reported by Arbuckle (1986) and Awad (2007).

Textural properties of resultant ice milk: -

From the obtained results (Table 5) it could be seen that the addition of PSHP into the blend increased significantly the hardness of ice milk for all treatments. Also, hardness increased with increasing added PSHP percent in ice milk. This could be related to a high content of protein (Table 2) and the stronger protein network which increased ice milk hardness. However, the different hardness values could be related to the freezing point, the amount of free water in the sample, the overrun percent, and the consistency of the treatment (Awad and Salama, 2010).

Table (5): Textural properties of resultant ice milk supplemented with Psyllium seed husk powder.

Character assessed		Treatments*			
		Control	$T_{0.5\%}$	$T_{1\%}$	$T_{2\%}$
Hardness	**(N)**	$\mathbf{1.2^{C}}$	$\mathbf{2.1^{B}}$	$\mathbf{2.4^{B}}$	$\mathbf{3.6^{A}}$
Adhesiveness	**(mj)**	$\mathbf{6.603^{C}}$	$\mathbf{6.853^{B}}$	$\mathbf{9.312^{A}}$	$\mathbf{9.649^{A}}$
Cohesiveness	**(ratio)**	$\mathbf{1.26^{B}}$	$\mathbf{1.83^{A}}$	$\mathbf{1.21^{B}}$	$\mathbf{0.61^{C}}$
Springiness	**(mm)**	$\mathbf{7.96^{D}}$	$\mathbf{10.62^{A}}$	$\mathbf{8.79^{C}}$	$\mathbf{9.30^{B}}$
Gumminess	**(N)**	$\mathbf{0.20^{B}}$	$\mathbf{0.50^{A}}$	$\mathbf{0.40^{AB}}$	$\mathbf{0.30^{B}}$
Chewiness	**(mj)**	$\mathbf{1.49^{D}}$	$\mathbf{5.79^{A}}$	$\mathbf{3.16^{B}}$	$\mathbf{2.53^{C}}$

*: -See table (1) for details.
A B C: Means with the same letter among treatments are not significantly different

The obtained values of Springiness (Table 5) for Psyllium seed husk powder ice milk of different treatments ranged from 10.62 to 8.79 mm. However, $T_{0.5}$ possessed the highest Springiness value compared to other ice milk treatments, including the control. Also, it can be seen from the obtained data (Table 5) that the average gumminess of control ice milk was low and increased in the treatments.

Among treatments, treatment with 2% PSHP (T_2) showed the highest gumminess and the lowest for that contained 0.5% PSHP ($T_{0.5}$). Cohesiveness values took the same trend as Gumminess. The chewiness is the number of chews required to swallow a certain amount of sample (from tender to tough). This property took the same trend of springiness, gumminess, and cohesiveness.

Sensory evaluation

Sensory panel evaluation is an important indicator of potential consumer preferences. The organoleptic evaluation of ice milk mixed with Psyllium seed husk powder is shown in Table (6). The results revealed that the addition of PSHP in the blend affected the sensory attributes of ice milk samples. Among treatments, $T_{0.5}$ exhibited a higher score of all organoleptic properties compared to other treatments.

Table (6): Sensory evaluation of ice milk supplemented with different Psyllium seed husk powder ratios.

Character assessed		Treatments*			
		Control	$T_{0.5\%}$	$T_{1\%}$	$T_{2\%}$
Flavour	**(45)**	43.6^{A}	43.2^{A}	43.1^{AB}	39.7^{B}
Body&Texture	**(30)**	28.3^{A}	27.2^{B}	27.1^{B}	26.2^{C}
Appearance	**(15)**	14.4^{A}	14.3^{A}	14.1^{A}	12.3^{B}
Melting resistance	**(10)**	7.8^{B}	9.1^{AB}	9.2^{AB}	9.5^{A}
Total	**(100)**	94.1^{A}	93.8^{AB}	93.5^{AB}	87.7^{B}

*: -See Table (1) for details

A B C: Means with the same letter among treatments are not significantly different.

The flavor of resultant ice milk enhanced and became more preferable to panelists by adding PSHP into ice milk formula up to 1%. Also, the ice milk became smoother, less meltable, and more acceptable to panelists by incorporating PSHP into the formula up to 1%. Ice milk treatment T_2 scored the lowest points in all quality attributes. The appearance of the final product is affected by adding PSHP to the ice milk formula. The milky white color of the control ice milk changed to creamy in treated ice milk. This is due to the creamy color of PSHP.

Generally, resultant ice milk with PSHP was characterized by a creamy color and very good scores for acceptability, texture, and flavor up to 1 % of Psyllium seed husk powder.

Conclusion

From the obtained results, it could be concluded that ice milk can be produced as a functional food by adding Psyllium seed husk powder to the ice milk base blend. Ice milk can be successfully made with high acceptability by adding Psyllium seed husk powder up to 1 % into the mix as a source of natural fibers and fat replacer, improving the nutritional, health values and quality of a resultant product.

REFERENCES

1. Anderson JW, Allgood LD, Turner J, Oeltgen PR. and Daggy BP (1999) Effects of psyllium on glucose and serum lipid responses in men with type 2 diabetes and hypercholesterolemia. Am J Clin Nutr 70: 466-473.
2. AOAC (2007) Official Methods of Analysis18th.Ed., ch. 34. p.72-80. Dairy products, subchapter8: Ice Cream., Association of Official Analytical Chemists. Gaithersburg,M D,USA.
3. Arbuckle, W.S (1986). Ice cream (4th ed.) The AVI Publishing Company, Inc,Westport, USA.
4. Askari H., Farahnaky A., Aminlari M., Majzoobi M. and Mesbahi G.H. (2008) Extraction of mucilage gum (Plantago ovata L.) and the study of its rheological properties. In: Proceedings 18th National Congress on Food Technology. Mashhad. Iran.
5. Awad, R.A. (2007) Performance of rice flour in ice Cream manufacture. Proc.10th Egyptian Conf. Dairy Sci&Techn., 517-534.
6. Awad, R.A. and Wafaa M. Salama (2010) Production of low and free fat ice milk using sodium casinate and butter milk powder. Proc.11th Egyptian conf. for Dairy Sci.& Tech."Dokki, 1-3 November (2010),Cairo,Egypt.
7. Beikzadeh S., Peighambardoust S.H., Beikzadeh M., Asghari Javar-Abadi M. and Homayouni-Rad A. (2016). Effect of psyllium husk on physical, nutritional, sensory, and staling properties of dietary prebiotic sponge cake. Czech J. Food Sci., 34: 534–540.
8. Bijkerk C.J., Muris J.W.M., Knottnerus J.A., Hoes A.W. and De Wit N.J. (2004). Systematic review: the role of different types of fiber in the treatment of irritable bowel syndrome. Alimentary Pharmacology and Therapeutics, 19: 245–251.
9. Bourne, M.C. (1978). Food texture and viscosity. Academic press, NewYork.
10. Clark, C.C.; Salek, M.; Aghabagheri, E. and Jafarnejad, S. (2020). The effect of psyllium supplementation on blood pressure: a systematic review and meta-analysis of randomized controlled trials. Korean J Intern Med 35:1385-1399.
11. Dikeman C.L. and Fahey Jr G.C. (2006). Viscosity as related to dietary fiber: a review. Critical Reviews in

Food Science and Nutrition, 46: 649–663.
12. FAO Regional Dairy Development and Training Center for the Near East. (1977). Laboratory Manual, FAO, Rome, Italy.
13. Fenelon M.A. and Guinee T.P. (2000). The Effect of Fat Content on the Microbiology and Proteolysis in Cheddar Cheese During Ripening. J. Dairy Sci. 83(10), 2173-2183.
14. Franceschi, S., Masco, L.D., Augustin, L., Negri, E., Parpinel, M., Boyle, P., Jenkins, D. and Vecchia, C.L. (2001). Dietary glycemic load and colorectal cancer risk. Annals of Oncology,12, 173-178. https://doi.org/10.1023/A:1008304128577
15. Giese, J. (1996). Fats, oils and fat replacers. Food Technol., 50(4): 78-89.
16. Giuntini E.B., Lajolo F.M. and Menezes E.W. (2003). Potencial de fibra alimentar em países ibero-americanos: alimentos, produtos e resíduos. Archivos Latinoamericanos de Nutrición, 53: 14–19.
17. Ibuki, M. (1989). Moist pellet type feeds containing psyllium gum for culturing fishes. Japanese Kokai Tokkyo Koho, Japan Patent 01, 202, 262 (89, 202, 262). (Chemical Abstracts, 112, 7626y).
18. Mamun, A.A., Matin, A. and Badsha, M.R. (2020). Proximate composition, sensory evaluation and microbial quality of a dairy product (Special Kheersa) formulated with psyllium husk and malta peel powder. Food Research 4 (6): 1871 – 1877.
19. Marshall, R.T., Goff, H.D. and Hartel, R.W. (2003). Ice cream 6th ed. Kluwer Academic/Plenum Publishers, London, USA.
20. Mistry V.V. (2001). Low fat cheese technology. International Dairy J., 11, 413-422.
21. Pereira C.I.P., Gomes A.M.P. and Malcata F.X. (2009) Microstructure of cheese: processing, technological and microbiological considerations. Trends in Food Sci. and Technology, 20, 213-219.
22. Richardson, H. G. (1986). Standard Methods for the Examination of Dairy Products. (15 th ed.) Amrican Public Health Association, Washington. USA.
23. Ritvanen T., Lampolahti S., Lilleberg L., Tupasela T., Isoniemi M. and Appelbye U. (2005). Sensory evaluation, chemical composition and consumer acceptance of full fat and reduced fat cheeses in the Finnish market. Food Quality and Preference, 16, 479-492.
24. Rodriguez J. (1998). Recent advances in the development of low-fat cheeses. Trends in Food Sci. and Technology, 9, 249-254.
25. Sakr,H.S. (2019). A Study on Supplementation of Non-Fat Yoghurt with Psyllium. J. of Food and Dairy Sci., Mansoura Univ., Vol 10 (9) 303-308.
26. Salem,A.S. (2000). Ice cream modified with some sorts of milk proteins.Egypt.J.Appl.Sci.,15:141.
27. SAS institute (1990). SAS User's Guide/ STAT ver.6.04th Ed. SAS Inst, Inc., Cary, NC.
28. Segall, K. I. and Goff, H.D. (2002) A modified ice cream processing routine that promotes fat destabilization in the absence of added emulsifier. Inter. Dairy J. 12(12)1013-1018.
29. Terpstra, A.H.M., J.A. Lapre, H.T.De Veries and A.C.Beynen,(2000). Hypocholesterolemic effect of dietary psyllium in female rats. Ann.Nutr. Metabol.,44:223-228.
30. Tharp, B.W. and Young, L.S. (2013) An encyclopedic guide to ice cream science and technology. 183. DES tech Publications, Inc.
31. Winton A.L., (1958). Analysis of foods. 3 rd Ed. J. Wiley and Sons Inc., New York, USA p.6.
32. Zandonadi R.P., Botelho R.B.A. and Araújo W.M.C. (2009) Psyllium as a substitute for gluten in bread. research and professional briefs. Journal of the American Dietetic Association, 109: 1781–1784.