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Using Psyllium Husk Powder as Fat Replacer and Stabilizer to Improve Low Fat Ice Cream Properties

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ABSTRACT

In the present study the effect of adding psyllium husk powder to low fat ice cream was investigated. For 45 days, the physicochemical, rheological, antioxidant scavenging activity, total phenolic compounds (TPC), and sensory qualities of all mixes and the resulting ice cream were assessed. Seven treatments were conducted. Control full fat(CFF)was made with 6.14% fat, control low fat (CLF) 1.2% fat. The other low fat treatments T1, T2, T3, T4 and T5 were made without using a stabilizer and by using 0.1, 0.3, 0.5, 0.7 and 0.9% psyllium husk respectively. As the psyllium husk ratios raised, there was a significant($p<0.05$)increase in both the specific gravity (SG)and weight per gallon (WPG) of the ice cream mix. During the aging process up to two hours, the rheological properties of the full fat ice cream (C1) tended to be higher than those of the control low fat ice cream mix and other low fat treatments. The SG and WPG of ice cream decreased as the psyllium husk content increased. Changes in the overrun were inversely correlated with specific gravity and weight per gallon. The melting rate of low fat treatments decreased significanttly($p<0.05$)by using psyllium husk as compared with CLF. There was an obvious notice to enhance in antioxidant scavenging activity, total phenolic compounds, flavor and overall acceptability of low fat treatments which contain psyllium husk powder. It can be concluded that adding psyllium husk powder to low fat ice cream up to 0.9% improved the physicochemical, rheological, antioxidant scavenging activity, TPC, sensory characteristics.

Keywords: Psyllium husk, low fat ice cream, fat replacer, stabilizer, antioxidant

INTRODUCTION

Ice cream is an extremely intricate food matrix and it is an aerated fat and water suspension in a concentrated solution of sugar that includes stabilizers, casein micelles, and proteins (Frøst *et al.*, 2005; Erkaya *et al.*, 2012). Ice cream is not only a high consuming product all over the world

(Sun-Waterhouse *et al.*, 2011), but also it is the most popular semi-solid dairy dessert (Cruz *et al.*, 2009; Soukoulis *et al.*, 2009; Di Criscio *et al.*, 2010; Isik *et al.*, 2011; Ferraz *et al.*, 2012).

Most of people realized the relation between low-fat products and avoiding obesity and coronary heart diseases. So, it has been a life style to consume low fat foods. Although ice cream has about 6–16% fat But recently consumers focused on the low-fat and fat –free dairy products to avoid the negative health impact related to consuming high milk fat in the diet. Dairy manufacturer has developed new varieties of low-fat and fat-free ice cream (Marshall *et al.*,2003). But these varieties have some defects in flavor and texture which reduce the acceptance of consumers. Decreasing milk fat content on ice cream led to several defects for body & texture with icier body and lack of flavour intensity(Marshall & Arbuckle, 1996 and Berger, 1990). Several strategies have been focused to overcome these defects such as using fat replacer. There are two types of dietary fibers: water-soluble and water-insoluble. It is one of the edible parts of plants. Dietary fibers that are insoluble in water are crucial for boosting feces' capacity and softening it. In the other hand, water-soluble dietary fibers increase the time of stomach emptying, reduce the levels of serum cholesterol and it make the process of absorbing glucose much lower (Cho &Dreher, 2001; Seçkin & Baladura, 2012).

Thus, it makes sense to anticipate a continuous rise in the intake of wholesome, high-fiber foods in the future. The majority of research has focused on adding fiber to various food products in order to improve texture. Emulsifiers and stabilizers including gelatin, xanthan gum, and pectin have been used in these studies. (Wittinger & Smith, 1986).

One of the richest sources of dietary fiber is Psyllium husk. Psyllium is a naturally occurring dietary fiber that is taken with water or milk in many countries to help with diarrhea and constipation. It contains mainly indigestable dietary fiber with a negligible amount of calories when it absorbs water; it characteristically swells several times and turns into a jelly like substance. Its principal ingredient is indigestible dietary fiber, and it has very little calories. This lubricates and stimulates the intestines, which causes the bowel movements to be activated (Leung & Foster, 1996).

This study aimed to study how adding psyllium husk powder affected the low-fat ice cream's physicochemical, rheological, antioxidant scavenging activity, and sensory properties.

MATERIALS AND METHODS

Materials:

Fresh was cream (53% fat, and 4.23% MSNF) was acquired from the dairy department's pilot plant at Faculty of Agriculture- Suez Canal University- Ismailia- Egypt. powdered skim milk (97 %TS, and 1.4% fat) and sugar were bought from the local market, Ismailia, Egypt. Sodium carboxy methyl cellulose (CMC) was purchased from Misr

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Food Additives., MIFAD, Egypt. 1,1-diphenyl-2-pic-rylhydrazyl (DPPH) (Sigma Chemical Co., St. Louis, MO, USA) all chemical reagents were obtained from from El-Nasr pharmaceutical, and chemical Co., Egypt. Psyllium husk (PsH) was obtained from Imtenan Health Section, Food Additives Company, Egypt. Additional substances utilized in this study were of analytical quality.

Methods:

Manufacture of ice cream:

In accordance with Marshall and Arbuckle (1996), ice cream mixes were made by combining the ingredients listed in Table (1). The mixtures were heated to 80˚C for five minutes, cooled to 4˚C, and aged for two hours at that temperature. The mixture (three kilograms of mix for each treatment) was placed in an Italian Taylor- mate Model 156 ice cream freezer and frozen. The resulting ice cream was sealed in 100 ml cups and allowed to firm at -18˚C in a deep freezer. Seven treatments were carried out as following :

C1: CFF

C2: CLF

T1, T2, T3 and T4: Low fat ice cream made without using CMCand by adding 0.1, 0.3, 0.5, 0.7 and 0.9 % psyllium husk powder.

Table 1. Ice cream mixes ingredients.

Ingredients	The mix specification (kg/100 kg)						
	C1	C2	T1	T2	T3	T4	T5
Cream(53% fat, 4.23% SNF)	9.89	1.89	1.89	1.89	1.89	1.89	1.89
Skim milk powder (97.3% SNF, 1.4% fat)	10.67	12.16	12.16	12.16	12.16	12.16	12.16
CMC	0.2	0.2	-	-	-	-	-
Sugar	15	15	15	15	15	15	15
Psyllium husk powder	-	-	0.1	0.3	0.5	0.7	0.9
Water	63.59	70.65	70.85	70.65	70.45	70.25	70.05

The chemical analysis of psyllium husk:

The chemical analysis of psyllium husk in Table(2) was done according to AOAC, 2007.

Table 2. chemical composition of psyllium husk.

Constitutents	Quantity (%)
Moisture	6.35
Crude fat	0.15
Crude protein	2.12
Crude fiber	81.5
Ash	3.75
Total phenolic compounds (mg GAE/100gm)	87
Antioxidant activity %	28.6

Analysis of ice cream mix and ice cream:

The ice cream mix was analyzed for titratable acidity according to AOAC, 2007, specific gravity (SG), weight per gallon (WPG) and freezing point according to Marshall and Arbuckle (1996). The Brookfield viscometer (Brookfield Engineering Laboratories, Inc., MA, USA) with a Sc4-21 spindle operating at 50 rpm was used to measure rheological parameters. At a temperature of 10°C, measurements were conducted with a shear rate ranging from 23.3 to 232.5 S-1. Every rheological property test was conducted three times.

The ice cream samples were analysed for overrun, SG and WPG according to Marshal and Arbuckle (1996). Melting rate was measured as described by Bhanumurthi *et al.* (1972).

Determination of total phenolic compounds and antioxidant activity:

The TPC were determined in the ethanolic extract as described by Singleton and Ross i (1965). Using the 2, 2-diphenyl-1-picrylhydrazyl (DPPH) test, the antioxidant activity of psyllium husk powder was assessed (Cuendet and Pottera t, 1997; Burits and Bucar, 2000) using the following Equation:

DPPH radical - scavenging activity(%) = [(l – A_1/A_0) x 100]

A_0 is the absorbance of the control and A_1 is the absorbance of the sample.

With minor adjustments, the phenolic component extraction and antioxidant activity tests for the ice cream samples were carried out in line with Li et al. (2009) :

In 50 ml brown bottles, 10 g of ice cream and 20 ml of the solvent (15 ml 1N HCl and 85 ml 95% ethanol) were added. Next, the mixture was shaken in a rotary shaker (Julabo D-7633 Labortechmik, GMBIT, Jeelback / west Germany) set at 200 rpm for 90 minutes at 30°C. The mixture was then centrifuged (ICE PR-7000 centrifuge, International Equipment Company) for 45 minutes at 5°C and 2500 g. The supernatant fluids were Used to determine the TPC and DPPH scavenging activity, as was previously indicated.

Sensory evaluation:

Ten staff members of the dairy department completed the sensory evaluation of the resulting ice cream in accordance with Marshall and Arbuckle (1996), scoring 45 points for flavor, 30 points for body and texture, and 25 points for appearance and color.

Cost of production

The cost of production of different mixes were calculated according to the available prices of raw materials used in ice cream making in the Egyptian market.

Raw material	Water	Sugar	Skim milk powder	Cream 55%	CMC	Psyllium husk
Price (L.E) / Kg	1	30	180	140	200	800

Statistical analysis:

CoStat (1998) and Windows software version 6.311 were used to perform statistical analysis and analysis of variance on all collected data. A significant difference was identified at ($p<0.05$) using the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Ice cream mix properties:

Table (3) presented the variations in WPG and SG, acidity and freezing point of ice cream mixes as influenced by substituting CMC by psyllium husk powder with different percentages.

All low fat treatments had higher SG and WPG than CFF. This result due to the higher solids not fat and the lower fat content of low fat treatments compared to full fat treatment. Khalil *et al.*, 2021 found same results.

Adding psyllium husk powder with different percentages increased SG and WPG of low fat treatments (T1, T2, T3, T4 and T5) compared to CLF. This may be due to the higher denisty of psyllium husk.

As shown at Table (3) CFF had the lowest titratable acidity compared to all low fat treatments this may be a result of the differences in the solids not fat content between full fat and low fat treatments.

Adding psyllium husk did not make significant differences between the acidity of treatments 1(T1) and 2 (T2) and control low fat (C2). But there were significant differences between control low fat (C2) and treatments T3, T4 and T5.

The freezing point depression (FDP), which affects the formation of ice crystals and their thermodynamic instability, is one of the most important aspects of ice cream. (Hartel, 2001). It can be observed from Table (3) that CFF ice cream had the highest freezing point as compared with other treatments. This may explained as a result of increasing the serum phase concentration or decreasing the solutes molecular weight (Hartel, 2001).

Using psyllium husk increased the freezing point depression than low fat control. This may be due to its content of fibers as Soukoulis *et al.,* (2009) reported that the freezing point of ice cream has been affected significantly by using fiber.

Table 3. Effect of substitution of CMC with psyllium husk on some properties of Ice cream mix

Properties	**Ice cream (mix)**						
	C1	**C2**	**T1**	**T2**	**T3**	**T4**	**T5**
Specific gravit y(gm/cm^3)	1.0850^f	1.1110^e	1.1182^d	1.1194^d	1.1245^c	1.1290^b	1.1320^a
Weight per gallon(Kg/gallon)	4.9325^g	5.0507^f	5.0834^e	5.0889^d	5.1120^c	5.1325^b	5.1462^a
Acidity%	0.19^d	0.23^a	0.23^a	0.22^{ab}	0.21^{bc}	0.21^{bc}	0.20^{cd}
Freezing point(C°)	-2.31^a	-2.35^b	-2.37^{bc}	-2.38^c	-2.39^{cd}	-2.41^d	-2.43^e

C1: control full fat, C2: control low fat, T1: 0.1% PsH, T2: 0.3% PsH, T3: 0.5% PsH, T4: 0.7% PsH, T5: 0.9% PsH.
***a, b, c, d, e , f & g : means with the same letter among the treatments are not significantly different (p<0.05).**

The rheological parameters:

Table (4) Presents the changes in apparent viscosity, plastic viscosity, yield stress consistency coefficient index and flow behavior index of different ice cream mixes during aging. It can be noticed that during aging process, as the aging time was extended, all treatments' viscosities has been increased. Up to two hours into the aging process, their impacts were impressive. This increase can be because of increasing water hydration and gel formation (Marshall and Arbuckle, 1996). C1 mix had higher apparent viscosity, plastic viscosity, yield stress consistency coefficient index than C2, T1, T2, T3 and T4 except T5.

Viscosity of low fat treatments was increased significantly by adding psyllium husk. These results Were confirmed by Hanaa (2019). Psyllium husk played an important role on ice cream mix viscosity because it hydrates slowly in water creating viscous solution due to soluble dietary fiber (Dikeman and Fahey, 2006). Flow behavior index had an opposite trend compared to other rheological parameters.

Table 4. Effect of substitution of CMC with psyllium husk on the rheological characteristics of Ice cream mixes

Aging time	**Treatments**							**Mean**
	C_1	**C_2**	**T_1**	**T_2**	**T_3**	**T_4**	**T5**	
	Apparent Viscosity (m Pas)							
0 hour	305	200	220	255	285	329	364	279.71^b
2 hours	357	230	245	280	330	380	429	321.57^a
Mean	331^c	215^g	232.5^f	267.5^e	307.5^d	354.5^b	396.5^a	
	Plastic viscosity (m Pas)							
0 hour	153	107	122	130	142	160	175	141.29^b
2 hours	185	140	155	163	174	195	213	175^a
Mean	169^c	123.5^g	138.5^f	146.5^e	158^d	177.5^b	194^a	
	Yield stress (N/m^2)							
0 hour	3.70	2.00	2.70	3.11	3.44	3.91	4.32	3.31^b
2 hours	4.66	3.05	3.6	3.91	4.20	4.81	5.6	4.30^a
Mean	4.18^b	2.675^f	3.15^e	3.51^d	3.82^c	4.36^b	4.96^a	
	Consistency coefficient index (m Pas)							
0 hour	100	50	62	77	89	108	123	87^b
2 hours	140	84	90	120	135	150	167	126.57^a
Mean	120^c	67^g	76^f	98.5^e	112^d	129^b	145^a	
	Flow behavior index							
0 hour	0.57	0.70	0.66	0.62	0.59	0.54	0.49	0.596^a
2 hours	0.54	0.67	0.62	0.58	0.55	0.51	0.46	0.561^b
Mean	0.555^{de}	0.685^a	0.64^b	0.6^c	0.57^{cd}	0.525^e	0.475^f	

Ice cream properties:

The specific gravity and weight per gallon of ice cream decreased during the pre-freezing process as a result of Incorporating air into the ice cream mix. In comparison to low fat ice cream treatments, CFF ice cream (C1) had lower weight per gallon and specific gravity values Table (5). This could be because fat has a significant role in maintaining the ice cream's air phase stability during freezing and whipping (Goff *et al.,* 1999).

Adding psyllium husk with different percentages caused a marked (p<0.05) decrease in SG and WPG of the resulting ice cream.

The addition of air causes the overrun, or the increase in ice cream volume over the volume of mix used. The results at Table (5) referes to that CFF (52.53), had significantly higher overrun % than that of CLF (C2) (40.00%) . This could be as a result of fat's significant contribution to the ice cream's air phase stability during pre-freezing and whipping (Goff *et al.,* 1999). Adding psyllium husk with different percentages caused a pronounced (p<0.05) increase in the overrun % of low fat ice cream. This may be due to the high viscosity of psyllium husk treatments which increase the availability of air into ice cream mix (Khalil *et al.,* 2021).

Table 5. Effect of substitution of CMC with psyllium husk powder on Ice cream properties

Properties	Ice cream						
	C1	C2	T1	T2	T3	T4	T5
Specific gravity(gm/cm^3)	0.7113^g	0.7936^a	0.7872^b	0.7757^c	0.7680^d	0.7494^e	0.7482^f
Weight per gallon (Kg/gallon)	3.2336^g	3.6078^a	3.5787^b	3.5264^c	3.4914^d	3.4068^e	3.4014^f
Overrun %	52.53^a	40.00^g	42.05^f	44.3^e	46.41^d	50.66^c	51.30^b

Melting rate of ice cream:

Ice crystals melt as heat slowly seeps through the ice cream's shell and into its interior. The resulting water diffuses into the concentrated frozen serum phase, the diluted solution passes through the intricate frothy structure of the ice cream, and eventually it drips (Muse and Hartel, 2004). The results at Table (6) cleared that CFF took longer time to melt than CLF.

Table 6. Effect of substitution of CMC with psyllium husk powder on melting rate (%) of ice cream within 60 min during storag e period at -18ºC.

Treatment	Storage period (days)				Mean
	Fresh	15	30	45	
15 min					
C1	5.97	3.00	2.49	2.00	3.37^g
C2	9.50	7.82	4.30	3.61	6.31^a
T1	9.43	7.51	3.90	3.45	6.07^b
T2	9.36	6.72	3.57	3.19	5.71^c
T3	9.17	5.93	3.48	3.05	5.41^d
T4	7.17	4.11	3.33	2.48	4.27^e
T5	6.16	3.40	3.10	2.42	3.77^f
Mean	8.11^a	5.49^b	3.45^c	2.89^d	
30 min					
C1	15.58	10.50	5.63	4.52	9.06^g
C2	26.97	14.86	10.5	9.11	15.36^a
T1	26.86	13.72	9.21	7.96	14.41^b
T2	23.07	12.53	8.54	7.13	12.82^c
T3	21.08	11.98	8.00	6.87	11.98^d
T4	20.36	11.51	7.11	5.98	11.24^e
T5	19.14	11.12	6.67	5.44	10.59^f
Mean	21.87^a	12.32^b	7.95^c	6.70^d	
45 min					
C1	28.93	19.00	10.00	7.54	16.37^g
C2	45.93	33.58	29.24	23.00	32.94^a
T1	44.6	30.00	28.10	20.32	30.76^b
T2	42.52	28.00	27.46	19.88	29.47^c
T3	39	26.98	26.01	18.70	27.67^d
T4	35.77	25.11	24.31	17.33	25.63^e
T5	32.08	24.12	23.50	16.65	24.09^f
Mean	38.40^a	26.68^b	24.09^c	17.63^d	
60 min					
C1	44.04	25.34	20.11	17.00	26.54^g
C2	70.76	40.55	36.55	32.00	44.97^a
T1	58	38.23	35.40	30.32	40.49^b
T2	57.82	37.00	34.13	29.14	39.52^c
T3	55	36.12	33.97	28.20	38.32^d
T4	51	35.22	32.56	27.77	36.64^e
T5	47.4	34.66	31.45	26.12	34.91^f
Mean	54.86^a	35.30^b	32.02^c	27.17^d	

This could be explained by the fat's role in giving ice cream its structural qualities and by the fat's lower heat conductivity (Soukouli s *et al.*, 2009).

The melting rate of psyllium husk-containing ice cream was significantly lower than that of CLF. The latent heat of the ice cream may have diminished with extended frozen storage, causing the melting rate to gradually drop. So, the ice cream takes longer to melt which enhances the melting quality.

TPC and antioxidant activity of ice cream:

Fig.1 (A) and (B) show the changes in TPC and antioxidant activity of ice cream as affected by using psyllium husk. It can be seen from the figures that full fat ice cream had lower values than low fat treatments may be due to high solids not fat in low fat treatments. The increase in solids not fat means that there is an increase in proteins and non protein antioxidant. The protein group includes a wide range of peptides and enzymes with antioxidant and phenolic compound properties (Lindmark -Mansson and Akesson, 2000).

The results shows that adding psyllium husk to low fat ice cream increased significantly the TPC and antioxidant activity this may be as a result of the TPC content and antioxidant activity of psyllium husk (Table 2).

Cost of production:

Table (7) shows the production cost of different ice cream treatments as affected by using psyllium husk powder and decreasing the fat content calculated as its common prices in the local market. Full fat ice cream had the highest cost of production. Reduction of fat specification to 1.2 % decreased the used cream in the mix causing a 21.89 % reduction of the production cost. Using substantial psyllium husk powder at ratio 0.1, 0.3, 0.5 and 0.7% in low fat ice cream decreased the production cost with 16.44, 12.30, 8.16 and 4.02% as compared with C_1 respectively. But increasing the additive ratio to 0.9% psyllium husk powder in low fat ice cream had equal cost production of C_1 because of the higher price of psyllium husk powder. So, it can be said that it is available to produce good quality low fat ice cream with higher healthier characteristics without an addition cost for the product.

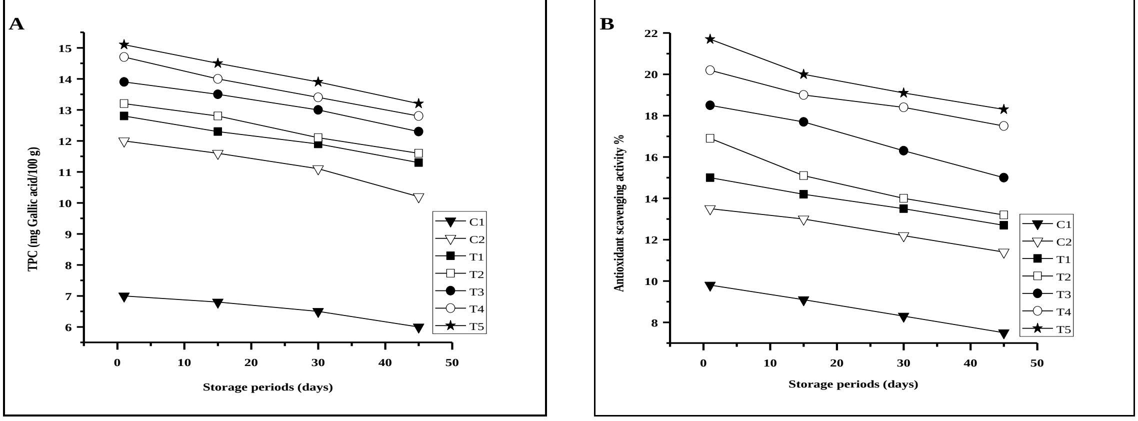

Fig. 1. Effect of psyllium husk powder on TPC (A), and antioxidant scavenging activity % (B) of ice cream treatments

Table 7. Effect of substitution of CMC with psyllium husk powder on cost of production of ice cream treatments

Properties	C_1	C_2	T_1	T_2	T_3	T_4	T_5
Cost of production	3858.8	3014.1	3224.4	3384.2	3544.0	3703.8	3863.6
% reduction of cost as compared to full fat one	-----	21.89	16.44	12.30	8.16	4.02	-0.12

Sensory properties of ice cream:

Fig.2 shows the sensory properties of ice cream treatments. It can be observed from the results that CFF had the highest scores for flavor, body& texture, appearance and colour and Overall acceptability. This might be because milk fat is known to be an important factor in the development and maintenance of the structural qualities of ice cream (Turgut and Cakmacki,2009). This has been linked to the functioning of milk fat, such as fat destabilization, enhanced air incorporation and stabilization of air cells, lubrication of oral tissue, and enhancement of mouth feeling (Dresselhuis *et al.*, 2008).

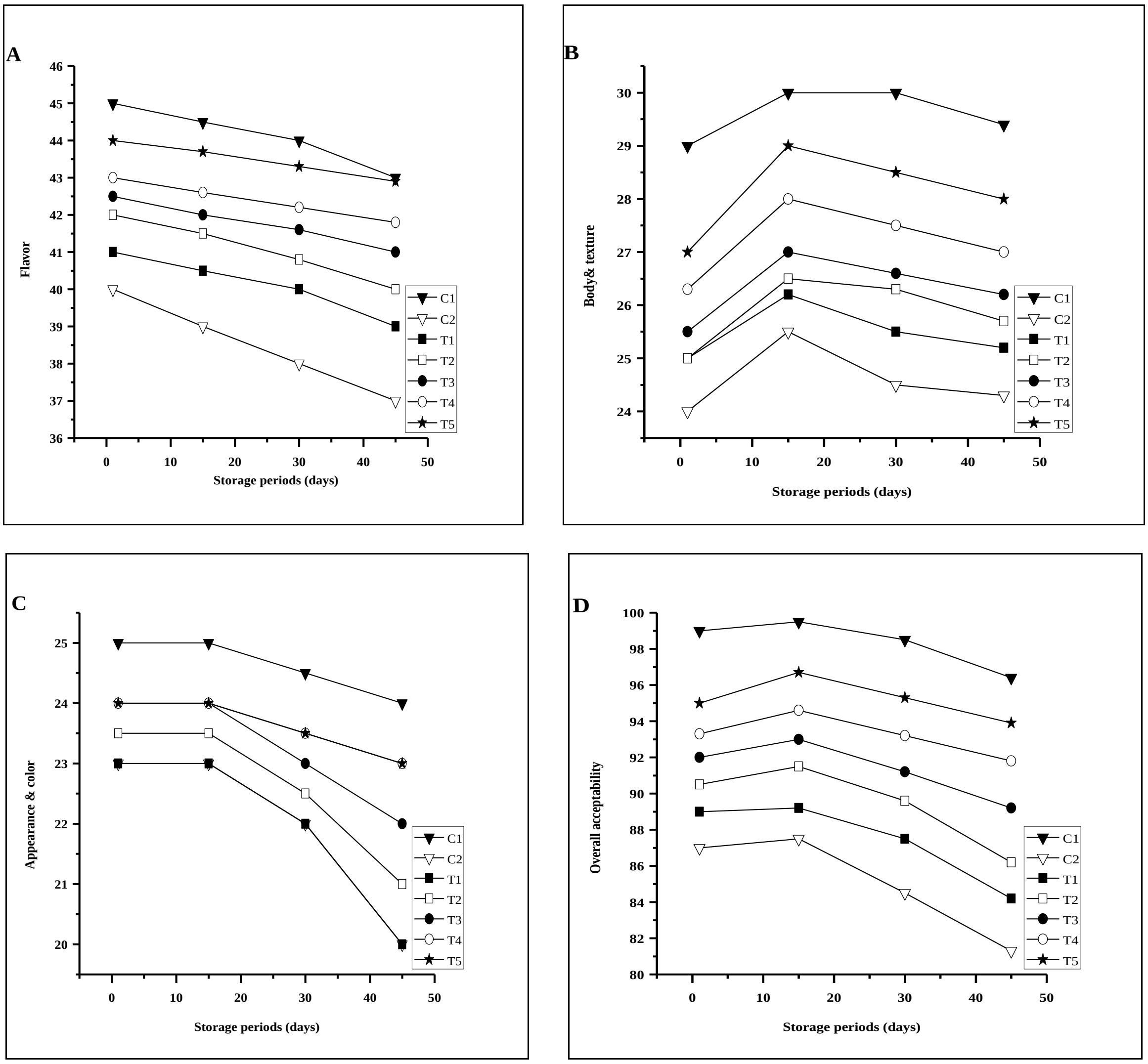

Fig. 2. Effect psyllium husk powder on the flavor (A), body & texture (B), appearance & color (C), and overall acceptability (D) of ice cream during storag e period at –18ºC

From the same figure, it was observed that as psyllium husk ratio used in ice cream making increased as flavour and body & texture scores were enhanced during all freeze storage period. Resultant ice cream became more smoother and had creamy appearance with improving flavor intensity. This may be due to the higher viscosity of the treated ice cream

It can be concluded that adding psyllium husk powder with different percentages to low fat ice cream improved the rheological characteristics, melting rate and sensory properties of low fat ice cream. Treatment (5) which contain 0.9% psyllium husk powder was the best treatment among all low fat treatments.

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إستخدام مسحوق قشور السيليوم كمثبت وبديل للدهن لتحسين خواص الايس كريم منخفض الدهن

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الملخص

فى هذا البحث تمت دراسة تأثير إضافة مسحوق قشور السيليوم للايس كريم منخفض الدهن. تم تقييم الخواص الفيزيوكيميائية ، الريولوجية ، النشاط المضاد للأكسدة ، المركبات الفينولية الكلية والخواص الحسية لكل المخاليط والايس كريم الناتج وذلك لمدة 45 يوم. تم عمل 7 معاملات عينة المقارنة كاملة الدسم صنعت بإستخدام 6،1% دهن وعينة المقارنة منخفضة الدهن صنعت بإستخدام 2،1% دهن. كما تم عمل المعاملات منخفضة الدهن الاخرى T1 ، T2 ، T3 ، T4 و T5 بدون إضافة مثبت وبإضافة قشور السيليوم بنسب 0،1 ، 0،3 ، 0،5 ، 0،7 و 0،9% على الترتيب . زادت الكثافة النوعية والوزن بالجالون لمخاليط الايس كريم بشكل معنوى بزيادة نسب قشور السيليوم. وجد أن الخواص الريولوجية لمخلوط عينة المقارنة منخفضة الدهن وللمعاملات منخفضة الدهن الاخرى كانت أقل من عينة المقارنة كاملة الدسم خلال فترة التعتيق لمدة ساعتين. وجد أنه كلما زادت نسبة قشور السيليوم كلما قلت الكثافة النوعية والوزن بالجالون للايس كريم. كانت الكثافة النوعية والوزن بالجالون متناسبا بشكل عكسى مع التغيرات التى تحدث فى الريع. انخفض معامل إنصهار المعاملات منخفضة الدهن بإستخدام قشور السيليوم. كان هناك تحسن واضح فى النشاط المضاد للاكسدة ، المركبات الفينولية الكلية ، النكهة والقبول العام للمعاملات منخفضة الدهن التى تحتوى على السيليوم. يمكن الإنتهاء إلى أن إضافة مسحوق قشور السيليوم للايس كريم منخفض الدهن حتى نسبة 0،9 % أدى إلى تحسن الخواص الفيزيوكيميائية ، الريولوجية ، النشاط المضاد للأكسدة ، المركبات الفينولية الكلية والخواص الحسية.