Improving the Quality of Low-Fat Ice Cream Using Some Fat Replacers

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Abstract

Low-fat ice cream was made by partial replacement of buffaloes' milk fat with different fat replacers, Milk fat was standardized to 2% to meets consumers demand for low energy foods. Five treatments of low-fat ice cream ***i. e.*** (T1 inulin, T2 maltodextrin, T3 modified starch, T4 whey protein concentrate powder (WPCP) and T5 oat). However, control full-fat ice cream mix (C1) was standardized to 6% fat, 16% sugar, 11.0% MSNF, 0.4% stabilizer and 0.08% vanilla. Control low-fat made with the same mix of full-fat except fat was 2% (C2). The mixes and the resultant ice cream of different treatments and control were analyzed for chemical composition; rheological properties, overrun, microbiological quality as well as they were sensory evaluated. All the treatments were accepted by the panelists except the low-fat (C2) as it was a control without fat replacers. The best treatment was (C2) maltodextrin as it achieved the total panelist scores as the full fat (C1), followed by (T1). Caloric values of different recipes were calculated.

Keywords: Low-fat ice cream, Inulin, maltodextrin, modified starch, wpcp, oat.

Introduction

Consumers recently have directed their interest towards to reduced or low-fat products as they associated them with a reduced risk of obesity and coronary heart diseases. The consumption of low-fat foods has become a way of life for many health-conscious people. The Food and Drug Administration has approved the use of labeling names of reduced-fat, low-fat and non-fat ice creams for such products that containing low than 10% milk fat. So, Regular ice cream usually has a fat content of 10% while reduced fat and low-fat (light) ice cream contains at least 25 and 50% less total fat than regular ice cream, respectively (**Cavallo, 2017**). Nutritionists recommended that dietary fats should contribute less than 30% of energy intake.

Milk fat has been recognized as a critical constituent plays an important role in dairy products and ice cream. It descrete and partially coalesced fat globules present in the matr2ix, coat some parts of the air bubble surfaces as a binding agent and support the cells lined mainly by proteins. Moreover, interaction between milk fat and other ingredients in ice cream lead to an improvement in the texture, mouthfeel, creaminess, flavour and overall sensations of lipricity (**Adapa *et al* .,2000**).

Owing to the important and key role of the fat in improving the texture and flavour of ice cream, removal or reduction of its fat content causes many defects in the final quality of this product (**Berger, 1990; Marshall and Arbuckle, 1996**). One way to solve this health problem is by using fat replacers and flavour intensity which may be overcomed by addition of more flavouring agent.

Fat replacers continue to be a challenge and the availability of ingredients to assist in the development of reduced fat foods in recent years (**Kailasapathy and Songvanish, 1998**). In addition, the fat replacers should match the texture, mouthfeel and functionality of fat in the food products and should convey the desired flavour profile. (**Ohmes *et al.*, 1998).**

In this regard, the target numbers of fat replacers are hydrocolloids in which their functionalities allow them to mimic the properties of fat in food products (**Emadzadeh *et al.*, 2011**) and (**Razavi *et al.*, 2008**). Hydrocolloids are capable of interacting with water, develop the texture and viscosity of frozen dessert and increase the stability during storage by maintaining thickness and cryoprotection (**Soukoulis *et al.*, 2009**).

Dietary fibers are very important in the diet. They are found in different food sources such as inulin, oat and others. Several studies show the physiological and nutritional aspects of dietary fibers. Therefore, different studies try to incorporate dietary fibers in several food products to increase their health benefits (**Abdou *et al.*, 2018**). The physiologal effects of food products supplemented with dietary fibers include the improvement of gastrointestinal health, protection against colon cancer, reducing blood total and low-density cholesterol. Further-more, inulin is recommended for diabetics; since it is not absorbed, it does not affect the sugar blood level. Also, inulin and oat act as prebiotic as they stimulate the growth of ***Bifidobacteria*** which are regarded as beneficial strains in the colon. On the other hand, inulin is widely used in functional foods as it improves mouthfeel, stability and acceptability of low-fat foods as low caloric texturising agents **(Niness, 1999**; **Tungland and Meyer, 2002**). The characteristics of inulin as a fat replacer have been attributed to its ability to bind water molecules and form a particle gel network.

Starch is a common polysaccharide carbohydrate which consists of a very big number of glucose molecules. In order to enhance functional properties of starch, several studies have used different chemicals or enzymes to modify starch (malto-dextren). The resultant modified starch shows enhanced properties such as higher water holding capacity and improved thickening enabled modified starch to be used as fat replacer of different foods **(Abbas *et al.*, 2010; Abdou *et al.*, 2018)**.

Maltodextrin is produced as a result of starch fragmentation enzymes and acid. Maltodextrin gel easily combined with liquid and solid fats and form a stable emulsion gel and it gives the same taste as fat, since it helps foods to be broken easily into pieces in the mouth. Maltodextrin improves the taste, and the structure of foods; preventing re-crystallization and extending shelf life as a rise stuffing or carrier, it can be used in infant foods for improving their quality and health care function. Maltodextrin add consistence, improve shape structure and quality. It can help the maintenance of the original colour, luster and add some flavour.

Whey and whey products have been used successfully in ice cream making. Whey protein is a good source of essential amino acids and bio-active peptides. In addition, the positive relation established between protein content in whey and the emulsion stability of the continuous water phase as well as the quantity of protein absorbed at the surface of fat globules. The configuration and interaction of the molecules of whey protein eventually settled the appearance, texture and stability of such gels and tend to form of a three-dimensional network of aggregated proteins (**Eisen *et al.*, 2004**). Whey proteins improve overrun, creaminess, smoothness and flavour, also, it improve sensory properties besides increasing the protein content of the reduced fat ice cream. So, the aim of this study was to improve the quality of the low-fat ice cream using some fat replacers.

Materials and Methods

Materials:

Whole fresh buffaloes' milk was obtained from the herd of Fac., of Agric., Moshtohor, Benha Univ.,. The milk was separated in the Dairy pilot Unit in the Dairy Dept., using Alf Laval separator. The milk was standardized to 6% for the control full-fat and 2% for the low-fat ice cream. Skimmed milk powder grade A was imported from America with chemical composition of (lactose 53.3%, protein 34.0%, minerals 7.9%, fat 0.8% and moisture 3.8%) and parched from local Egyptian market, sugar cane was obtained from local market. Carboxy methyl cellulose (CMC) was obtained from Mifad Co Badr City, Egypt. Vanilla was imported from china (CH3O) (OH) (C6H3Cho). Inulin (I) (extracted from chicory root; frutofit ®HD, manufactured by sensus, netherlans) was obtained from premier specially ingredients, chennai, Tamil Nadu, India. Modified starch (MS) was obtained from Mifad Co., Badr city, Cairo, Egypt. Oat (OT) was obtained from local market, and grounded to fine powder. Maltodextrin (MD) was obtained from Aiochemica and Whey protein concentrate powder was supplied by Davisco foods international.

Preparation of ice cream mixs:

Ice cream mixes were prepared according to the method described by **Marshall and Arbuckle (1996).** Skimmed milk powder was first mixed with sugar and CMC to generate a "dry mix". Fresh skimmed milk was preheated to 40°C, fresh cream was added, temperature was raised to 65°C and the "dry mix" was slowly added with gentle stirring. The mixture was heated to 80°C/5 min., followed by cooling to 4-5°C. Vanilla powder was added during cooling and aging at 5°C to control 1 (6% fat, 11% MSNF, 16% sugar, 0.4% CMC, 0.08% vanilla)and to all low fat treatments (2% fat, 11% MSNF, 16% sugar, 0.4% CMC, and 0.08% vanilla). C2 was left as control, then fat replacers were added with a level of 2% as follows: T1 inulin, T2 maltodextrin, T3 modified starch, T4 whey protein concentrate and T5 oat. The different mixes were aged for 24hrs, freezed and whipped in the ice cream maker Promag DS 15/18, Italy. The ice cream was collected with an exit temperature of -5.5°C, packed in 100 ml plastic cups, covered, hardened at -25°C for one day and stored at -18°C until analyzed. All ice cream treatments were done in three replicates.

Analysis of ice cream mixes and ice cream:

Total solids, fat, protein, ash, and acidity % of ice cream mixes and ice cream were determined according to AOAC methods (**AOAC, 2016**). pH value was determined using pH meter JENCO model 1671, USA. The specific gravity and weight / gallon and freezing point by were estimated according to the methods described by **Marshall and Arbuckle (1996)**. The viscosity of the mix was measured using Brookfield at 5°C. The hardness was measured by Force measurement IMADA Texture Analyzer.

The overrun was determined according to **Marshall and Arbuckle (1996)**, melting rate by **Segall and Goff (2002)**. The sensory attributes of ice cream treatments were carried out after hardening. It was assessed by 12 panelists of the staff members of Dairy Dept., Fac., of Agric., Moshtohor, Benha Univ.,. The ice cream was tempered to -15°C to -12°C before sensory evaluation. Scoring was carried out according to the scheme of **Khalil and Blassy (2019)** for flavour (50 points), body and texture (30 points), melting rate (10 points) and colour (10 points). Caloric value of prepared ice cream mixes was calculated according to **Marshall and Arbuckle (1996)** as follows: fat 8.79, carbohydrate 3.87 and protein 4.27. Colour parameter of ice cream samples was measured using a colourimeter Model (Hanter lab colour Flex). The L^*, a^* and b^* values were recorded, with L^* denoting lightness on a 0-100 score from black to white; a^*, red (+) or green (-); and b^*, yellow (+) or blue (-) as described by **Francis (1983)**.

Statistical analysis:

All determinations were done in triplicates, and analysis of variance using the general linear models procedure of the Statistical Analysis System **(SAS, 2006).**

Table 1. Chemical composition of ingredients used in making different types of low-fat ice cream.

Ingredients	**Chemical composition%**			
	Moisture%	**Fat%**	**Protein%**	**Ash%**
Inulin	3.4	0.41	4.47	1.89
Maltodextrin	4.9	0.20	0.18	0.23
Modified starch	12.0	0.44	0.32	0.44
WPC	4.2	4.00	79.20	3.20
Oat	6.1	4.51	11.10	3.33

Table 2. Formulation of different low-fat ice cream mixes of different treatments (g/kg)

Ingredients	Treatments						
	C1	C2	T1	T2	T3	T4	T5
Cream	37	-	-	-	-	-	-
Buffalo's milk	751.8	333.3	333.3	333.3	333.3	333.3	333.3
Skimmed milk fresh	-	459.8	437.7	437.7	437.7	437.7	437.7
Skimmed milk powder	46.24	42.00	44.2	44.2	44.2	44.2	44.2
Sugar	160	160	160	160	160	160	160
CMC	4	4	4	4	4	4	4
Vanilla	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Inulin	-	-	20	-	-	-	-
Maltodextrin	-	-	-	20	-	-	-
Modified starch	-	-	-	-	20	-	-
WPC	-	-	-	-	-	20	-
Oat	-	-	-	-	-	-	20
Total	1000	1000	1000	1000	1000	1000	1000

Result and Discussion

Chemical composition of the mixes:

Chemical composition of different ice cream mixes are shown in table (3). The total solids was the highest in C1 (full-fat control) and the lowest in C2 (low-fat control). Thus, a highly significant difference (*P<0.05*) was observed between C1 (full-fat) and all other treatments due to the high fat content; while no significant difference (***P<0.05***) observed between all low-fat treatments either each to other and C1 and C2. The observed small differences between all low-fat treatments are attributed to the differences in the composition of the added fat replacers. The total solids of all treatments are within the normal level of ice cream given by **Arbuckle (1986)** and within the level that approved by the Egyptian Legal Standard (1993). C2 was the lowest in total solids as it is low-fat and in the same time without any fat replacer.

Fat content was standardized to 6% in C1, while it was standardized to 2% for the low-fat treatments. The differences in low fat treatments can be attributed to the fat content of the added fat replacers e.g. (oat, and whey protein contain 4.5 and 4.0% fat, respectively).

The protein content was almost the same in all recipes and the differences are referred to the protein content of the various fat replacers (*e.g.* the oat contained 11.1% protein and the whey protein concentrate 79.2%). The protein contents are consisted with **Awad *et al* (2012)**.

Non-significant differences were observed between all treatments in the ash content.

Carbohydrates were calculated by the differences and ranged from 24.31 to 26.33%. So, the differences between the treatments are due to the various composition of the ingredients of the recipes.

Acidity % and pH value: There were non-significant differences between the mixes in acidity and pH values as they were ranged from 0.17 to 0.18 % and 6.69 to 6.82 respectively. The natural acidity of the ice cream mix depends on the ice cream milk solids not fat (MSNF) percentage and it could be theoretically calculated through multiplication of the MSNF % by 0.17 **(Goff and Hartel, 2013)**. These results are in accordance with **Kasaca *et al* (2008)**. Also, **Salem *et al* (2016)** found that different fat replacers did not significantly affect the pH and acidity % of the ice cream mixes.

Properties of low-fat ice cream mixes:

Table (3) shows some properties of ice cream mixes. The freezing point depression (FPD) is a critical parameter in ice cream production as it influences the initial mean range and thermodynamic instability of the formed ice crystals which leads to their gradual growth **(Hartel, 2001)**. The results revealed that removal of fat did not affect the freezing point of the mixs. Addition of fat replacers decreased the freezing point of the mixes which may be due to the soluble constituents of these ingredients particularly the mineral contents **(Huiru *et al,* 2002)** as the freezing point of ice cream dependent on the soluble constituents in the mix **(Arbuckle, 1986).**

Specific gravity and weight / gallon of the mixes are recorded in table (3). It was observed that low-fat ice cream mixs had higher Specific gravity value than full-fat mix as a result of higher solids not fat and lower fat contents of these mixes as compared to full-fat mix. There is some differences between treatments which can be referred to the specific gravity of various fat replacers. Weight / gallon of the mixes were almost closely related to the specific gravity of the corresponding mixes.

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Table 3. Gross Chemical composition and some properties of different ice cream mixes

Properties	Treatments						
	C1	C2	T1	T2	T3	T4	T5
T.S%	36.55[a]	32.72[c]	34.00[b]	34.29[b]	33.89[b]	33.75[b]	33.86[b]
Fat %	6.00[a]	2.00[c]	2.10[c]	2.10[c]	2.10[c]	2.30[c]	3.00[b]
Protein%	4.63[b]	4.73[b]	4.75[b]	4.81[b]	4.58[b]	5.45[a]	5.00[ab]
Ash%	1.01[ab]	1.04[ab]	1.02[ab]	1.05[a]	1.04[a]	1.01[ab]	1.02[ab]
CHO%	24.92[bc]	24.95[bc]	26.19[b]	26.25[a]	26.18[a]	24.31[c]	24.83[bc]
Acidity%	0.17[a]	0.17[a]	0.17[a]	0.18[a]	0.17[a]	0.17[a]	0.18[a]
pH value	6.82[a]	6.69[a]	6.82[a]	6.79[a]	6.74[a]	6.73[a]	6.76[a]
Specific gravity(g/ml)	1.02[ab]	1.06[ab]	1.11[a]	1.06[ab]	1.00[b]	1.04[ab]	1.08[ab]
Weight/gallon (kg)	3.86[ab]	4.01[ab]	4.24[a]	4.01[ab]	3.79[b]	3.94[ab]	4.09[ab]
Freezing point (°c)	-2.9[a]	-2.8[a]	-2.9[a]	-3.1[ab]	-3.5[bc]	-3.8[c]	-3.3[ab]
Viscosity(CP)	1760[c]	960[e]	1520[d]	1520[d]	2800[a]	1760[c]	2320[b]

C1: control 1 (full fat 6 %) / C2: control 2 (low fat 2 %) / T1:2% inulin / T2: 2% maltodextrin , T3: 2% modified starch / T4: 2%whey protein concentrate / T5: 2% oats.

*Means with the same column with different superscript (a, b, c, ….) are significantly different (***P <0.05***).

Viscosity (Cp):

Viscosity results revealed that the lowest viscosity was for C2. Addition of fat replacers increased the viscosity of low-fat mixes with various degrees (significant ***P<0.05***) according to the properties of the fat replacers. The highest viscosity was for T3 then T5 mixes. This agrees with the results of **Salem *et al* (2016)** who found that the addition of modified starch to the low fat ice cream mix showed the highest viscosity followed by oat. These high values of viscosity could be attributed to the ability of starch and oat to improve network of the mix which contain the serum area and, thus, leads to increase of viscosity. Also, **Soukoulis *et al* (2009)** reported that the addition of oat and wheat fibers to ice cream mixes was characterized by significant improvement of the resultant ice cream viscosity. This improvement of viscosity could be likely induced by the presence of insoluble materials and high-water retention ability of oat and wheat fibers. In addition, the lowering effect of maltodextrin (T2) on viscosity may be due to the lowering ability of maltodextrin for formation of gelling net and viscosity progress. These results are in agreement with **Soukoulis *et al*. (2009)**. The same results were reported by **Emara *et al*. (2015)**. Moreover, it was observed that the viscosity of ice cream mix was low by incorporation of inulin (T1); suggesting that any interaction between inulin microcrystals was less than that between fat globules. Similar trend was reported by **Akalin *et al*. (2008)**. Also the low viscosity of the mix containing inulin may be due to the interaction between inulin and microcrystals was less than that between fat globules which suggesting changes in the product matrix. A similar trend was recorded by **Akalin *et al* (2008)** when using inulin and whey protein concentrate as fat replacers. It was detected that the modified starch (T3) caused the highest viscosity followed by oat (T5) treatments. These results are in line with that obtained by **Salem *et al* (2016).**

Properties of the resultant ice cream:

Overrun:

Data of table (4) reveal that the overrun of low-fat (C2) ice cream was higher than that of full-fat (C1). This was in accordance with **Surapat and Rugthavon (2003)**. The reason of this is that fat provides a barrier to the whipping properties of ice cream **(Marshall and Arbuckle, 1996)**. Addition of fat replacers significantly affect the percentage of overrun according to its nature and composition. It was observed that addition of modified starch as a fat replacer in ice cream mix caused a reduction of air incorporation because of its higher viscosity (citric acid treated starch), which could have prevented air incorporation resulting in the lower overrun **(Stanley *et al.*, 1996)** . These results are consisted with **Babu *et al.* (2018)**. The differences between other used fat replacers were small except T5 (oat) as it caused higher viscosity of the mix.

Specific gravity and weight / gallon:

Specific gravity and weight / gallon results clear that the full-fat ice cream (C1) had significantly higher value than low-fat (C2) ice cream which agreed with **Khalil and Blassy (2015)**. Incorporating fat replacers to the low-fat mixes gave different results of specific gravity according to its type and composition. The highest specific gravity was for (T3) as its viscosity was the highest of all treatments, and its overrun was the lowest of all treatments. These results are in harmony with those given by **Mahran *et al.* (1984)** who stated that the specific gravity of ice cream is inversely related to changes in the overrun, in agreement with the present results. The weight / gallon of ice cream was closely related to the specific gravity of the ice cream.

Table 4. Some Physical Properties of Different Low-fat Resultant Ice Cream

Properties		Treatments						
		C1	C2	T1	T2	T3	T4	T5
Overrun%		38.64^{d}	47.62^{b}	46.46^{b}	47.26^{b}	24.00^{e}	49.72^{a}	43.82^{c}
Specific gravity(g/ml)		0.79^{a}	0.68^{b}	0.76^{ab}	0.75^{ab}	0.83^{a}	0.68^{b}	0.77^{ab}
Weight/gallon(kg)		2.99^{a}	2.57^{a}	2.88^{ab}	2.84^{ab}	3.14^{a}	2.57^{b}	2.92^{ab}
Hardness		5.40^{d}	7.30^{b}	5.30^{d}	5.20^{d}	9.10^{a}	6.20^{c}	8.60^{a}
Colour	*L**	87.13	84.84	85.05	87.00	84.18	82.60	82.25
	*a**	-2.66	-2.77	-2.92	-2.75	-2.93	-1.78	-2.08
	*b**	12.22	11.89	11.67	10.43	13.87	12.88	11.72
Melting resistance	15min	0.10	0.78	0.60	0.34	0.33	-	-
	30min	1.25	7.75	5.20	2.54	0.79	2.58	2.50
	45min	10.46	15.65	12.23	7.81	6.90	8.45	8.50
	60min	19.20	23.96	21.00	18.50	12.67	17.45	11.50
Microbiology x10^3CFU/gm		3.20^{a}	3.10^{a}	3.10^{a}	3.26^{a}	3.20^{a}	3.20^{a}	3.36^{a}

See footnote table (3)

*Means with the same column with the same superscript are non-significantly different (***$P<0.05$***).

Hardness:

The hardness of low-fat ice cream (C2) was (significantly ***$P<0.05$***) higher than the full-fat (C1) ice cream. This is consistent with the results acquired by **Guinard *et al.* (1997)** and **Akbari *et al.* (2016)** who reported that the hardness of the ice cream texture is inversely correlated with the fat content and increase of the fat content reduces the ice crystals volume, the increases of the ice crystals could probably lead to a harder texture. The addition of fat replacers affects the hardness according to the type and characterization of them. Incorporation of inulin and maltodextrin (T1 and T2) mixes, respectively decreased the hardness of the resultant ice cream than (C2). This decrease in hardness may be due to that the excess of carbohydrate material which interfere with structure development and partly prevents strand formation and protein- protein interaction, thereby reducing the strengthen of the resulting product. This suggests that it is the protein network, which is more important to structure **(Rawson and Marshall, 1997).** The results are in accordance with **Abd El-Aty and El-Nagar (2004)**. The low hardness may also be negatively correlated with viscosity; the increase in viscosity might inhibit the development of iciness in frozen dairy desserts. This owing to the concentration of the unfrozen phase in the lamellae may increase sufficiently to decrease water molecules movement and thus, limit ice cream crystal growth **(Schmidt and Smith, 1992)**. T3 and T5 treatments had high viscosity than other treatments which lead to higher hardness. The increase of viscosity by incorporation oat was stated by **Salem *et al.* (2003)** and lead to higher hardness, that was attributed to the nature dietary fibers found in oat (glucan) which had exceptional water binding capacity and ability to enhance viscosity **(Wang *et al.*, 1996).**

Melting resistance:

Melting rate is influenced by many factors. The ability of heat to penetrate into the ice cream (thermal diffusivity) is a factor that affects meltdown rate and there is a direct relation between both of them. Milk fat one of the reasons to reduce the heat transfer rate through the ice cream, then as the fat content of an ice cream increases, its melting rate decreases. Moreover, it has been suggested that fat globule clusters and agglomerates can stabilize air bubbles in ice cream structure and consequently decrease the melting rate. Therefore, less fat content was probably the main reason for the higher melting rate of the low-fat ice cream compared to that of the control ice cream (full-fat). The overrun also influence the melting resistance of ice cream. Addition of different fat replacers had various effects on the low-fat ice cream according to its types and properties. Incorporating of modified starch (T3) showed the highest resistance to melting. Citric acid treated modified starch could form H-bonds with water which increased the viscosity of the ice cream mix, thus, increasing its resistance to melting. This is in line with finding of **Salem *et al.* (2016)** and **Babu *et al.* (2018)**. Moreover, using oat as a fat replacer cause a high melting resistance. This can be attributed to the addition of dietary fibers which lead to increase the viscosity which would increase the melting resistance. The results consist with **Arbuckle (1986)**. The obtained results indicated that all fat replacers used increased the melting resistance significantly than the low-fat control (C2), but with different rates.

Colour:

The colour values (*L*, a*, b*)* of different samples are summarized in table (4). The *" L*"* values are determining the black (0) to white (100) colour. The *"L*"* value was 87.13 for C1 (full-fat) control. Removal of fat decreased the *"L*"* value to be 84.84 for C2. Addition of fat replacers, gave almost the same value of *"L*"* ranging from 82.25 to 85.05 except T2 which was similar to C1. For maltodextrin, the result was consisted with **Roland *et al.* (1999)**. Fat reduction caused a decreased value of yellowness of the low-fat ice cream since the yellowness of ice cream is proportional to its fat content. These observations were recorded by **Akalin *et al.* (2008) and Akabari *et al.* (2016)**.

The *"a*"* value is an indicator of red colour (positive value) to green (negative value). It was ranged from -2.88 to -2.93. This indicates that all treatments showed more green than red colour. It was reported that addition of whey protein powder T4 resulted in a reduction in "a" value compared to control. Similar results were reported by **Salem *et al.* (2016).**

Looking to the results of *"b*"* values are comparing yellow (positive values) to blue (negative values) colour. Incorporation of fat replacers into the ice cream blends caused some differences in *"b*"* values according to the type of these materials as it was ranged from 11.72 to 13.87.

Sensory Evaluation:

Data presented in table (5) show the differences in organoleptic properties of ice cream treatments compared with controls. Data reveal that all ice cream treatments gained higher organoleptic scores than the low-fat control (C2).

Flavour scores influenced by the percentage of fat samples containing fresh milk and cream flavours were higher than other treatments. Milk fat interacts with other ingredients to develop the texture, mouthfeel, creaminess, and overall acceptability (**Akoh, 1998)**. A harsh flavour was received in reduced fat ice cream which may be partly due to the missing of fat in the form of emulsion and some water soluble flavours . This is one of the problems with reduced fat products because the fat is the carrier of fat soluble flavour **(Leland, 1997)**. The results showed that low-fat control (C2) scored the lowest flavour. Addition of fat replacers improved the flavour and showed no significant effect on the flavour scores of ice cream. Similar results, **Babu *et al*. (2018)** was observed non- Significant

Table 5. Sensory evaluation of different low-fat ice cream

Treatments	Flavour	Body& Texture	Melting Resistance	Colour	Total acceptability
C1	47.00[ab]	28.00[a]	8.00[a]	9.00[a]	92.00 [a]
C2	44.33[bc]	25.00[b]	7.00[b]	8.00[ab]	84.33 [d]
T1	46.00[b]	27.00[a]	8.00[a]	8.66[ab]	89.66 [ab]
T2	47.33[a]	27.00[a]	8.00[a]	9.00[a]	91.33 [a]
T3	45.33[abc]	27.00[a]	8.00[a]	8.33[ab]	88.66 [bc]
T4	44.00[bc]	27.00[a]	8.00[a]	7.66[ab]	86.66 [c]
T5	43.33[c]	27.00[a]	8.00[a]	7.33[b]	85.66 [c]

See footnote table (3)

*Means with the same column with different superscript (a, b, c, ….) are significantly Different (P <0.05).

in flavour score of fat free dairy desserts with added fat replacers. The MD (T2) scored the same as control (C1) ice cream for cream flavours. Cooked milk flavour in ice cream containing WP (T4) was observed by some panelists, which agreed with **Ohmes *et al.* (1998) and Aykan *et al.* (2008)**.

Texture is an important factor as it influences how a sample of ice cream reacts within a person's mouth. The texture attributes iciness, meltability, airholes and coldness showed similar results for the order in which the samples were noted (***i.e.*** from not very to very). The results are in harmony with those reported by **Specter and Setser (1994)** who found non-significant differences were recorded between the mouth coating properties of the regular fat ice cream and their reduce fat ice creams containing fat replacers. Fat replacers could bind water available to change ice characteristics **(Miller- Livney and Hartel, 1997)**. The results revealed that MD and inulin samples scored closest to the full-fat control (C1), then generally in order T3, T4, T5 and at last the low-fat ice cream control (C2).

It was found that the melt rate of the low-fat ice cream were almost the same with the standard formula because the fat replacers could form H-bonds with water which increase the viscosity of the ice cream mix, thus, increasing its resistance to melting. Thus, the sensory scores for each set of samples had sensory characteristics close to the ideal.

There was no observed effect of all ice cream treatments on the colour except replacement of fat with WP and OT (T4 and T5) which showed a slight lowered score for colour. Only the MD treatment (T2) was as white as full-fat control (C1). The same observation was reported by **Roland *et al.* (1999)**.

The overall scores and acceptability response to the ice cream samples were affected by the variation of fat content as mentioned by the judges. Thus, the low-fat control (C2) gained the lowest scores. Addition of fat replacers to the blends improved the flavour & aroma, body & texture as well as the melting rate of the resultant products which lead to improvement of total scores to be almost close to the full-fat ice cream (C1), but it was sometimes the same (***i.e.*** T2) . The results demonstrated no marked differences for all samples containing fat replacers.

In conclusion all the treatments were accepted by the panelists and they gained almost more than 90 degree. The best treatment was that containing MD (T2) as it achieved the same scores as full-fat control (C1) then that containing inulin (T1). **Roland *et al* (1999)** demonstrated that the MD sample scored closest to the 10% fat sample.

Microbiological quality:

Ice cream is a good media for microbial growth due to high nutrient value, almost neutral pH value (pH 6-7) and long storage duration of ice cream. However, pasteurization, freezing and hardening steps in the production can eliminate most of the microbiological hazards. Pasteurization can destroy almost all pathogenic bacteria in the milk. The subsequent process that subjects the mixtures to freezing temperature can also inhibit the growth of any remaining flora. Also, heat treatments of the blends can destroy most of the specific pathogens that pose risk to public healthier. The total bacterial count of all treatments ranged from (3.10 – 3.36 x 10^3 cfu/g)

The coliform bacteria was absent in all treatments, also psychrophilic bacteria was not detected in all treatments of ice cream. The results are in accordance with **Sonwane and Hembade (2014)** and **Babu *et al.* (2018)**. Moreover, the report of microbial analysis conveys that ice cream products were processed, packed and stored under strict hygienic condition without any contamination.

Caloric value:

Table (6) shows the caloric values of various recipes. From a conceptional point of view, fat replacement is the reduction in fat- constituted calories by using food ingredients with less calories than conventional fat. Therefore, one of the strategies to develop fat replacers is to explore reduced calories compounds from non-lipid-based sources such as (carbohydrate and proteins). Since most of fat replacers either carbohydrate or protein base have less energy (***i.e.*** generally 4 kcal/g), the energy density of the foods can be readily reduced. The diet high in fat leads to undesirable health problems such as obesity, high blood pressure, and heart diseases. Therefore, the world health organization recommends that the total fat intake should be less than 30% of the calories and that the intake of saturated fat should not exceed 10% of total calories (WHO, 2003)

The highest caloric value of the ice cream was observed in (C1) (168.95 kcal/100g), while (C2) the reduced fat ice cream was (134.33 kcal/100g) with a reduction of 20.49% in the caloric value. There was no much differences in the caloric value among treatments containing fat replacers, but when compared to control (C1), there were a significant reduction.

Table 6. Caloric value of different type of low-fat ice cream

Properties	Treatments						
	C1	C2	T1	T2	T3	T4	T5
Caloric value Kcal/100g	168.95	134.33	140. 14	140.89	139.89	137.57	143.69
% Reduction	-	20.49	17.05	16.60	17.20	18.57	14.95

See footnote table (3)

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تحسين خواص الآيس كريم منخفض الدهن باستخدام بدائل دهن مختلفة

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تم تصنيع آيس كريم منخفض الدهن باستخدام بدائل دهن مختلفة (إينولين– مالتودكسترين– نشا معدل– مركزبروتينات الشرش– الشوفان). لذلك تم تعديل نسبة الدهن في اللبن الجاموسي المستعمل إلي 2% لإنتاج آيس كريم منخفض الطاقة ليلبي إحتياجات المستهلك– كما تم تصنيع آيس كريم كامل الدسم (6% دهن) كعينة مقارنة– وأجريت الإختبارات الفيزوكيميائية والريولوجية والحسية والميكروبيولوجية وتكلفة الإنتاج علي حسب مكونات الخلطة والآيس كريم الناتج. ولقد أوضحت النتائج أن جميع الإختبارات كانت في الحدود المطلوبة للآيس كريم منخفض الدهن. وأظهرت نتائج التقييم الحسي لعينات الآيس كريم أن إضافة 2% من بدائل الدهن المستخدمة قد حسنت من درجة قبول الآيس كريم منخفض الدهن بالمقارنة مع عينة الكنترول بدون إضافة بدائل الدهن (C2) التي حصلت علي أقل الدرجات وكانت جميع المعاملات مقبولة حسيا. وكانت أفضل العينات قبولا هي (T2) التي حازت علي أعلي الدرجات والتي تماثل عينة المقارنة كاملة الدسم (C1) ويأتي بعدها بالترتيب T5-T4-T3-T1. وقد وجد أن معدل إنخفاض الطاقة في الآيس كريم منخفض الدهن تتراوح بين 25.45 عن الكنترول C1 إلي 34.62.