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Production of Functional Ice Cream Using Camel Milk Fat Fractions

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Abstract: This work aims to examine the quality features of functional camel ice cream (8% fat) prepared by replacing the cream with a solid milk fat fraction (SMF), a liquid milk fat fraction (LMF) and LMF: SMF (2:1 v/v) in the ice cream mixtures. All samples were assessed for their physiochemical and rheological characteristics and the sensory quality of the ice cream mixtures and resulting ice cream. The results clarified that the type of milk fat fraction affected the viscosity of the ice cream mixtures. Also, the whipping ability decreased gradually with the increasing slip melting point of the fraction used. The use of SMF in the ice cream mix decreased the adsorption of protein and fat destabilization, characterized by the slowest melting compared to ice cream with other milk fat sources. The highest and lowest hardness values were found in ice cream mixtures made with SMF and LMF, respectively. In conclusion, ice cream was successfully made by replacing the milk cream fat fractions. Cream substitution with SMF followed by LMF: SMF (2:1 v/v) is recommended in arid and semi-arid regions and improved the whipping ability, overrun, and flavor scores, which were lower when using SMF.

1 Introduction

Camel milk is a vital source of nutrients in desert regions and is mainly consumed in fresh or fermented form. Camel milk fat (CMF) could decrease risk factors related to cardiovascular diseases due to its high content of long-chain unsaturated fatty acids (Abrhaley and Leta 2018). Furthermore, it contains a double pound of linoleic acid, which is important for decreasing diabetes (Maqsood et al. 2019, Abrhaley and Leta 2018). Meanwhile, camel milk contains less short-chain fatty acids (SCFA) compared to the fat of goat and cow milk (Meena Sunita et al 2014, Awad et al 2008).

Milk fat has a pleasant flavor and unique crystallization and melting properties, which are highly desirable in food products like ice cream. However, milk fat has many attributes that reduce its use. This is because of its higher cholesterol content and saturated fatty acids (SFA) and its lower content of polyunsaturated fatty acids. Moreover, the high solid content in refrigerated CMF causes poor spreadability (Miciński et al 2012). A mixture of triacylglycerol with different molecular weights and a wide melting range has been identified in milk fat (Büyükbeşe et al 2014). This heterogeneity is used in many formulations by dividing these different melting components into fractions. Dividing milk fat into liquid and solid fractions improves fat characteristics and expands its uses in the food and dairy processing (Desouky 2021, Gandhi et al 2013).

The most common process for using milk in food and dairy products is multi-step dry fractionation. In this method, triacylglycerol separation occurs based on the melting points of the various constituents. This is more suitable for industrial applications due to the absence of solvent residues (Awad et al 2008). Also, the dry fractionation technique contributes to the concentration of short-chain unsaturated fatty acids in the fat fraction of the milk. This gradually decreases in the middle and high-temperature melting fractions (Awad et al 2008, Fatouh et al 2005).

The multi-phase process of producing ice cream includes factors such as fat globules, ice crystals, and air bubbles that infuence the physical and textural quality attributes of the end product (Marshall et al 2003). Milk fat plays a significant role in improving the ice cream structure. Also, it is responsible for the creaminess, mouth feel, and overall lubricity sensation of the ice cream (Crilly et al 2008). Furthermore, the ice cream fat content is provided by the milk fat, which is either whole cream, natural butter, anhydrous butter, or oil butter (Méndez-Velasco and Goff 2012). The ice cream quality depends on numerous factors, such as the percent of non-fat solids and the type of fat used, which have a prominent role in the features of the final ice cream (Syed et al 2018). Low-soluble portions of milk fat may be added to the ice cream formula to improve its nutritional value as they have attractive sensory properties and increase the concentration of short-chain and long-chain unsaturated fatty acids (Nadeem et al 2015). Due to the higher SFC, ice cream made with a high-temperature melting fraction shows better stand-up properties upon melting (Marshall et al 2003, Abd El-Rahman et al 1997). Ice cream mixtures with a high-melting fraction exhibited the highest viscosity and the lowest adsorbed protein levels. The low-melting fraction of ice cream has decreased melting resistance but an increased overrun and fat destabilization index (Bazmi and Relkin 2009, Fatouh et al 2005).

Many studies have evaluated the texture properties of ice cream using various types of milk, different sources of fat, and a variety of dairy and nondairy ingredients (Syed et al 2018, Karaman et al 2014). However, there are few studies on ice cream made from camel milk (Salem et al 2017, Flores and Goff 1999). Also, insufficient research exists on using different milk fat fractions (Gandhi et al 2013, Abd EL-Rahman et al 1997). Additionally, there is little research on CMF fractions in ice cream (Desouky 2021).

The combination of globules with liquid and crystalline fats provides a suitable solid at refrigerated temperatures, which is important for the configuration of the ice cream structure (Deosarkar et al 2016). Therefore, our study aims to produce functional ice cream by adding CMF fractions as a substitute for milk cream. The physicochemical and rheological characteristics and the sensory quality attributes in the mixtures and ice cream were assessed.

2 Materials and Methods

Camel milk was collected from the herd belonging to the Animal Production Research Institute in the northwest coastal area of Egypt (EL-Kaser, Marsa Matrouh Governorate). Bulk milk samples contained 12.52% ± 0.14% total solids, 3.60% ± 0.23% fat, 3.60% ± 0.23% total protein, 4.45% ± 0.06% carbohydrates (by the difference), and 0.82% ± 0.001% ash, and had a pH value of 6.6 ± 0.04. Camel cream (52.60% total solids and 48% fat) and skim milk (8.85% total solids and 0.4% fat) were mechanically separated from the fresh milk. The cream is traditionally converted to butter oil and used as anhydrous milk fat.

Skim milk powder (97% total solids, produced by Dairy America TM). Carboxymethyl cellulose (CMC) as a stabilizer and lecithin as an emulsifier were obtained from TIC GUMS (Belcamp, MD, USA). Commercial-grade granulated cane sugar and vanillin were obtained from a local market in Cairo, Egypt.

2.1 Preparation of milk fat fractions

Camel butter oil was fractionated into solid and liquid fractions by the multi-step dry fractionation technique according to a previously described method of Awad et al (2008). The resultant SMF fraction (30°C) was separated from the LMF fraction (30°C) by centrifugation at 5000 × *g* for 5 min (O'Shea Marianne et al 2000). All fractions were frozen until use.

2.2 Ice cream processing

The manufacture of the camel ice cream mixture was achieved based on the results of a preliminary study that evaluated potential consumer preferences and was performed by panel of staff members at the Animal Production Division, Desert Research Center. The best ratio between the liquid to solid fat fraction was (2:1 V/V). The method used to prepare all ice cream mixtures was described by Schmidt (2004). Batches of the ice cream mixture were prepared with 8% fat from different sources (cream, LMF 30°C, SMF 30°C, LMF: SMF (2:1 v/v)). The formula was adjusted to contain 12% milk SNF (fresh skim camel milk and skim milk powder), 15% sucrose, 0.2% CMC, 0.1 % lecithin, and 0.1% vanillin.

Fresh skim milk and melted cream or their fractions were heated to 45°C ± 0.5°C in sanitized stainless steel milk cans placed in a water bath. The dry ingredients (skim milk powder, sucrose, stabilizer, and emulsifier) for each ice cream mix were added to the liquid ingredients at 45°C ± 0.5°C. All mixtures were homogenized at 27.59 MPa, heated at 80°C for about 15 sec, then cooled and aged overnight at 4.0°C ± 1°C. Before freezing in a batch freezer (Taylor, Model, 103), vanillin was added to each mixture. The resultant ice cream samples were packaged in plastic cups (80 ml) and hardened at -26°C for 24 h before analysis. For each treatment, three replicates were made.

2.3 Analysis of CMF and various fractions

Fatty acid methyl esters of camel butter oil and various fractions were prepared according to International Standard (ISO/IDF 2002). Gas-liquid chromatography (Hewlett Packard Model HP-6890 CA, USA) was used to identify it has on column injector and a flame-ionization detector. The injector temperatures were 250°C and 270°C, respectively. The temperature programming was as follows: column temperature 90°C–220°C; rate 2°C/min; injector temperature 220ºC; and detector temperature 240ºC. Gas flow rates were 300, 30, and 3 ml/min for air, nitrogen, and hydrogen, respectively.

The acid value, slip melting point (SMP), specific gravity (Sp gr), and free fatty acids were determined according to the method of AOAC (2012). The cholesterol content was determined with the method by Christian (2007).

2.4 Chemical and physicochemical analysis of functional ice cream mixtures

Fat content, pH values, and total solids of the ice cream mixtures were measured according to the method by AOAC (2012). Determination of the mixture's acidity was calculated as the lactic acid percentage by calibration with NaOH 0.1 N to a phenolphthalein indicator endpoint according to Arbuckle (1986). The mixtures' flow time was assessed in seconds according to the method by Arbuckle (1986). The apparent viscosity (expressed as centipoise (cP.s)) was measured at room temperature according to Awad and Metwally (2000) with a Brookfield digital viscometer (AMETEK, RV). All samples were placed in a small sample adapter, and an SC4-18 spindle was selected for sample measurement. The rheological parameters of the ice cream samples were studied at room temperature, with shear rates of 13.2–79.2 s^{-1}. The ice cream freezing points were also measured according to the method of Marshall and Arbuckle (1996). The Sp gr of the mix and the final product were measured according to the method described by Arbuckle (1986).

The whipping ability of the ice milk mixture was measured according to the method by Baer et al (1999) using a hand mixer at speed setting no. 5 (Sonai, China). The mix (150 ml) was placed in a 1-L stainless steel bowl, with calibration volume, and placed inside a 2.5-L bowl. A mixture of salt and ice was placed between the bowls to cool the ice cream mix as it was whipped. The volume change was rotated at 5, 10, 15, and 20 min.

The protein adsorbed on the surface of the fat globules was measured as the protein content according to the method of AOAC (2012) in the aqueous phase of ice cream mix formulas before and after centrifugation.

$$\text{Protein load (\%)} = (\text{total protein} - \text{serum protein/total protein}) \times 100$$

2.5 Physicochemical analysis of the ice cream

The overrun was calculated according to Muse and Hartel (2004) as follows:

$$\text{Overrun} = (\text{weight of mix} - \text{weight of resultant ice cream})/\text{weight of resultant ice cream} \times 100$$

The ice cream melting index was calculated according to the equation described by Segall and Goff (2002). At room temperature (24°C ± 1°C), all ice cream samples were melted. Then, every 15 min, the weight of the melted part was measured. The meltdown rate of different treatments was compared using % mass loss as a function of time in the linear region (slope).

The fat-destabilization index was calculated according to the method by Goff and Jordan (1989), and the turbidity was measured (as absorbance) with a spectrophotometer at 540 nm.

An adapted method by Akalin et al (2007) was used to measure the frozen ice cream hardness using texture analysis (CT3, Texture Analyzer, Brookfield, USA). The hardness of the ice cream sample was calculated at -10°C ± 2°C. The texture analyzer was set to record the force (gm) used to penetrate the frozen sample to a depth of 15 mm at a speed of 3 mm/s.

A panel of 15 staff members scored sensory assessments of different ice cream treatments at the Food Science Department, Ain Shams University, according to the scale developed by Magdoub et al (1991), as follows: flavor (50 points), texture and body (30 points), melting quality (10 points), and appearance (10 points). All panel members were informed of all used ingredients and experimental details.

2.6 Statistical analyses

Statistical analyses were carried out using ANOVA post hoc tests. Tukey's HSD test was used to test for significant differences with the multcomp View package (Graves et al 2019). Statistical analysis was conducted in R v.4.0.3 (R Core Team 2020). The results are expressed as lower squares means with standard errors of the mean. Statistically different groups were determined by ANOVA post-hoc testing ($P \leq 0.05$).

3 Results and Discussion

3.1 Fatty acid composition of CMF and its various fractions

Table 1 represents the fatty acid profiles of various CMF fractions. The data indicated that there were significant differences ($P \leq 0.05$) in the fatty acid profiles of the various fractions. SFA was the most abundant among the fractions and in CMF. SMF had the highest long-chain saturated fatty acid (palmitic and stearic) contents, while the level of unsaturated fatty acids (USFA) was significantly lower. Also, the short-chain fatty acids and USFA (oleic and linoleic) migrated to LMF, characterized by the highest values. These findings are supported by previous studies (Desouky 2021, Büyükbeşe et al 2017, Awad et al 2008, Fatouh et al 2005). Among the fractions, the ratio of USFA/SFA was the highest in LMF, followed by CMF, while SMF had the lowest content (0.461 mg/100 mg fat).

3.2 Physicochemical characteristics of CMF and its fractions

The SMP of CMF and its various fractions are shown in **Table 2.** The highest SMP was observed for SMF (42.9°C) followed by butter oil (41.4°C), while the lowest melting point was observed for LMF (38.2°C). This is because the highest percentages of long-chain fatty acids are contained in SMF (**Table 1**). On the other hand, the SMP of LMF was the lowest owing to the decrease in both $C_{16:0}$ and $C_{18:0}$ accompanied by an increase in long-chain unsaturated fatty acids ($C_{18:1}$) and SCFA, which have the lowest melting points (**Table 1**). Changes in SMP are in the main changes happening in the ratio of ($C_{16:0}$), ($C_{18:0}$), and ($C_{18:1}$), having a lower melting point (Desouky 2021, Awad et al 2008, Fatouh et al 2005). Notably, major changes in melting properties are due to the fractionation process used, based on different melting points of the triacylglycerol in the mixture and the separate fatty acids. Our results are similar to those reported previously (Desouky 2021, Abbas et al 2019, Awad et al 2008).

Table 2 shows that the Sp gr decreased as the SMP of the fractions increased, reaching the lowest value for SMF (0.891), which has the highest SMP (42.9°C). This may be ascribed to the decrease in the USFA content (**Table 1**). Meanwhile, LMF had the highest Sp gr value (0.894). This result could be due to its low content of SFAs. Also, the Sp gr of CMF was close to that previously reported by Desouky (2021), and Awad et al (2008). Differences between fractions may be ascribed to the chain length of the fatty acids in the fraction and the content of saturated and unsaturated fatty acids (Abbas et al 2019, Awad et al 2008).

The acid value (AV) of CMF and its various liquid and solid fractions are illustrated in **Table 2**. The LMF characterized with the highest AV (0.39 mg KOH/g fat) were CMF (0.34 mg KOH/g fat) and SMF (0.23 mg KOH/g fat). This could be credited to the increase in USFA in the liquid fraction, which is evident from the fatty acid profile (**Table 1**). Desouky (2008) found that the AV of the CMF fraction L30 (0.52) was significantly higher than that of the original CMF (0.41), while the solid melting fraction showed the lowest AV (0.29 mg KOH/g fat).

Table 2 shows that LMF had a higher free fatty acid (such as oleic acid) content than the CMF (0.18 as oleic acid). In contrast, SMF had the lowest values of free fatty acids (0.14 as oleic acid). This could be because of the higher ratio of USFAs (38.13 mg/100 mg) in LMF compared to butter oil (34.4 mg/100 mg) and SMF (31.25 mg/100 mg) (**Table 1**).

Table 1. Fatty acid profile (%) of camel milk fat and its various fractions

Fatty acid	NO. of carbon	% Fatty acid*		
		CMF	L30	S30
Butyric	$C_{4:0}$	0.09ᵃ ± 0.01	0.21ᵇ ± 0.04	0.12ᵃ ± 0.02
Caproic	$C_{6:0}$	0.14ᵃ ± 0.02	0.26ᵇ± 0.02	0.19ᵃ ± 0.03
Caprylic	$C_{8:0}$	0.12ᵃ ± 0.04	0.49ᶜ± 0.04	0.25ᵇ± 0.04
Capric	$C_{10:0}$	0.17ᵇ ± 0.02	0.09ᵃ± 0.02	0.12ᵃ± 0.01
Lauric	$C_{12:0}$	1.11ᵃ ± 0.05	1.45ᵇ± 0.09	1.43ᵇ± 0.11
Myristic	$C_{14:0}$	15.32ᵇ ±0.11	13.25ᵃ±0.61	14.8ᵃᵇ± 1.00
Myristoleic	$C_{14:1}$	0.58ᵃ ± 0.07	0.54ᵃ± 0.05	0.50ᵃ± 0.05
Pentadecancoic	$C_{15:0}$	0.96ᵃ ± 0.15	0.91ᵃ± 0.05	0.98ᵃ± 0.03
Palmitic	$C_{16:0}$	30.78aᵇ ± 0.14	29.45ᵃ± 0.75	31.93ᵇ± 0.55
Palmitoleic	$C_{16:1}$	3.33ᵃ ± 0.10	3.68ᵇ± 0.06	3.59ᵇ± 0.03
Heptadeconoic	$C_{17:0}$	0.96ᵃ ± 0.08	0.86ᵃ± 0.08	1.05ᵃ± 0.09
Stearic	$C_{18:0}$	13.58ᵃᵇ ± 0.63	12.78ᵃ±0.52	14.81ᵇ± 0.37
Oleic	$C_{18:1}$	26.93ᵇ ± 0.86	30.47ᶜ± 0.68	24.64ᵃ± 0.05
linoleic	$C_{18:2}$	2.7ᵃ ± 0.18	2.65ᵃ± 0.02	2.52ᵃ± 0.04
Linolenic	$C_{18:3}$	0.86ᵃ ± 0.11	0.79ᵃ± 0.04	0.76ᵃ± 0.01
nonadecanoic	$C_{19:0}$	0.98ᵃ ± 0.04	0.93ᵃ± 0.01	0.95ᵃ± 0.02
Arachedonic	$C_{20:0}$	1.38ᵇ ± 0.1	1.2ᵃ ± 0.03	1.35ᵇ ± 0.03
Total	-	99.99	99.99	99.99
TSC	$C_{4:0}$ -$C_{8:0}$	0.35ᵃ ± 0.06	0.94ᵇ ± 0.05	0.91ᵇ ± 0.09
TLC	$C_{10:0}$ –$C_{20:0}$	99.64ᶜ ± 0.06	99.05ᵃ ± 0.09	99.43ᵇ ± 0.05
TSC/TLC	-	0.0035ᵃ±0.002	0.009ᶜ± 0.008	0.006ᵇ±0.007
USFA	$C_{14:1}$ –$C_{18:3}$	34.4ᵇ ± 0.65	38.13ᶜ ± 0.58	31.25ᵃ ± 0.11
SFA	$C_{4:0}$ –$C_{20:0}$	65.59ᵇ ± 0.91	60.92ᵃ ± 0.53	67.73ᶜ ± 0.1
USFA/SFA		0.5245ᵇ ± 0.02	0.626ᶜ ± 0.01	0.461ᵃ ±0.004

*CMF: Camel milk fat; L: liquid fractions; S: solid fractions at the temperature at which the fraction separated (30ºC). TSC: Total short chains; TLC: Total long chains; USFA: Unsaturated fatty acids; SFA: Saturated fatty acids. A small letter denotes within raw the statistically different groups as identified by ANOVA post-hoc ($P \leq 0.05$) significant differences between butter oil and milk fat fractions.

Table 2. Physicochemical characteristics of camel milk fat and its various fractions

Character assessed	Fractions*		
	CMF	L30	S30
Slip melting point (°C)	41.4ᵇ± 0.2	38.2ᵃ ± 0.1	42.9ᶜ± 0.1
Specific gravity	0.905ᵇ± 0.002	0.894ᵇ± 0.004	0.891ᵃ± 0.003
Acid value (mg KOH/g fat)	0.34ᵇ± 0.03	0.39ᶜ± 0.01	0.23ᵃ± 0.01
Free fatty acids (% oleic acid)	0.18ᵇ± 0.004	0.25ᶜ± 0.002	0.14ᵃ± 0.003
Cholesterol (mg/100g)	324.70ᵇ± 0.01	370.14ᶜ± 0.91	256.66ᵃ± 1.54

*See footnote Table 1 Small letters denote within raw the statistically different groups as identified by ANOVA post-hoc ($P \leq 0.05$) significant differences between butter oil and Milk fat fractions

LMF showed a higher cholesterol content (370.14 mg/100 g) than the CMF (324.7) and SMF (256.66 mg/100 g). LMF provided a higher cholesterol concentration due to the high affinity of cholesterol for USFAs and SCFAs, which predominate in LMF. Awad et al (2008) reported that LMF showed a higher cholesterol content than CMF, with a cholesterol content of 321.97 and 343.5 mg/100 g fat for butter oil and a low melting fraction L30, respectively.

3.3 Physicochemical properties of functional ice cream mixtures

The effect of various CMF forms used in the ice cream mixtures on the physicochemical properties of these ice creams are presented in **Table 3**. No significant differences ($P \leq 0.05$) were observed for the mean total solids content, pH values, and acidity among various mixtures as affected by the fat source used, as shown in **Table 3**. All treatments are within the normal range reported by Marshall et al (2003).

The weight per gallon (kg) and the Sp gr of the mixtures made with LMF were slightly increased compared with the other treatments (**Table 3**). The Sp gr is based on the constituents of the formula, the mix's ability to integrate air, and the overrun percent of the ice cream (Marshall et al 2003). Also, the Sp gr of the ice cream mixtures decreased with increasing SMP of the fraction used, which may be ascribed to the decrease in USFA content with increasing fractionation temperature. The same observation was seen in previous studies (Desouky 2021, Awad et al 2008).

The flow time of the ice cream mixtures decreased as the melting point of the fat source used in the formula decreased, with the lowest being TL treatment (**Table 3**). This may be attributed to its lower solid fat content and higher USFA content compared to TS treatment, with a flow time of 94.30 s. Gonzalez et al (2003) stated that a higher content of USFAs decreased the viscosity of the resultant ice cream mix.

The freezing points of the ice cream mixtures were significantly ($P \leq 0.05$) affected by the fat fraction used in the formula (**Table 3**). The mixtures showed higher freezing points with SMF in the ice cream formula. Meanwhile, the low freezing point for the control compared to TLS treatment may be due to the high unsaturated fatty acid ratio in this fraction (**Table 1**). These results are in agreement with those of Marshall et al (2003).

The data in **Table 3** shows significant differences within the adsorbed protein (%) of the ice cream mixtures prepared with various fat sources. The lower the melting point of the fraction used, the higher the adsorbed protein on the fat globules. The hydrophobic protein segment affinity to lipids in the liquid state was much stronger than that of crystallized lipids, which cannot dissolve protein, with similar results obtained by Fatouh et al (2005).

Among the treatments, the solid (SMF 30ºC) and liquid (LMF 30ºC) fat fractions used in the ice cream mixtures had the highest and lowest viscosity values, respectively (**Fig 1**). The ice cream mix became less viscous by increasing the liquid fat in the mixtures than those formulated with a solid fraction. The higher saturated fat content of the SMF may contribute to the higher dynamic viscosity of the ice cream, which could be due to the higher amount of solidified fat in the SMF. Higher levels of saturated fatty acids make the ice cream structure more compact compared to ice cream made with a liquid fraction. These results align with those of previous reports by Desouky (2021), Scott et al (2003). The mix made with SMF is characterized by higher viscosity values than that with LMF. Also, the viscosity of the mix made with LMF: SMF (2:1) was lower than that made with cream, possibly because LMF: SMF (2:1) contains a higher amount of liquid fat, which causes the fat globules to agglutinate during aging (Abd El-Rahman et al 1997).

The whipping ability of ice cream mixtures made with different fat fractions is illustrated in **Fig 2**. A comparison of the volume of the ice cream mixtures to varying whipping times revealed significant differences ($P \leq 0.05$) among treatments. A substantial increase of 46.67%, 53.3%, 40.0%, and 33.33% in the initial volume (150 mL) of cream, LMF: SMF (2:1), LMF, and SMF ice cream mixtures were observed after whipping for 5 min, respectively. These results can be explained by differences in the viscosity of the mixtures (**Fig 1**). The viscosity of the mixtures increased with increasing melting point of the fractions used. The mix prepared with LMF: SMF (2:1) had the lowest viscosity, followed by the control and LMF, whereas the highest viscosity was seen in the SMF treatment. Similar results were obtained by Desouky (2021). The whipping rate also depends on the whipping mechanism's efficiency and mixture processing. Proper homogenization and resting of the mixture improves its whipping ability (Marshall et al 2003). Additionally, the absorbed protein and whipping ability of ice cream mixtures decreased gradually with increasing SMP of the fraction used (Fatouh et al 2006).

3.4 Physicochemical properties of the ice creams

The ice cream treatment properties are presented in **Table 4**. The Sp gr and weight per gallon of the ice cream were significantly affected by the fat source used. The Sp gr and weight per gallon decreased when adding LMF to the mixture rather than SMF. This mainly depends on the ingredients used, the ability of the mixture to incorporate air bubbles, and therefore the overrun percent in the resultant ice cream (Marshall et al 2003).

The overrun percent was significantly ($P \leq 0.05$) affected by the addition of different fat sources into the mixtures **Table 4**, which was also increased by adding LMF as a substitute for cream in the mixture and decreased ($P \leq 0.05$) in the treatment with SMF. However, the treatments with cream and LMF were characterized by the highest overrun values. The differences in the viscosity of the ice cream mixtures may result in differences in the percentages of overrun among samples. Furthermore, the mixture should have

Table 3. Physicochemical characteristics of functional ice cream mixtures made using camel milk fat and its various fractions

Characteristics assessed	Treatments*			
	CMF	TL	TS	TLS
Total solid%	35.40^{a}± 0.1	35.40^{a}± 0.1	35.43^{a}± 0.21	35.43^{a}± 0.31
Fat%	8.0^{a}± 0.17	8.0^{a}± 0.2	8.1^{a}± 0.1	8.03^{a}± 0.06
Acidity%	0.41^{a}± 0.01	0.49^{b}± 0.03	0.46^{b}± 0.01	0.47^{b}± 0.01
pH value	6.36^{a}± 0.05	6.22^{a}± 0.18	6.34^{a}± 0.05	6.23^{a}± 0.21
Specific gravity	1.139^{a}± 0.01	1.154^{a}± 0.02	1.138^{a}± 0.01	1.149^{a}± 0.03
W.Gallon (kg)	4.31^{a}± 0.3	4.39^{a}± 0.12	4.31^{a}± 0.17	4.35^{a}± 0.10
Flowe time (s)	81.31^{a}± 0.6	77.30^{a}± 1.94	94.30^{b}± 1.76	93.97^{b}± 1.14
Freezing point(-c)	−2.27^{b}± 0.06	−2.5^{a}± 0.10	−2.6^{a}± 0.004	−2.33^{b}± 0.06
Adsorbed protein (%)	52.54^{a}± 0.06	77.62^{d}± 0.04	69.99^{c}± 0.5	68.41^{b}± 0.04

*CMF: camels' milk cream, TL: liquid melting fraction (30 °C), TS: solid melting fraction (30 °C), TLS: LMF:SMF, 2:1. Small letters denote the mean with the different superscript letters within the same raw indicate (P≤0.05 significant) differences between treatments.

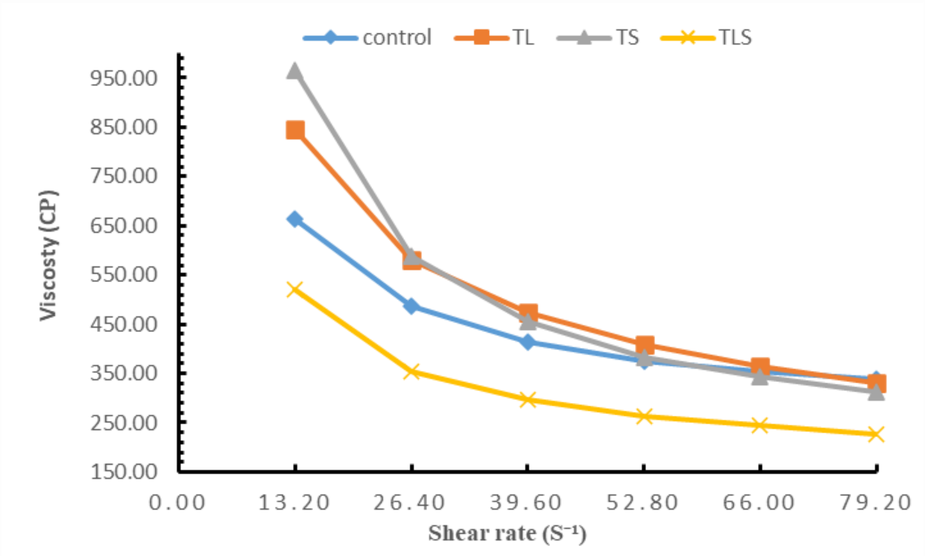

Fig 1. Viscosity of functional ice cream mixtures made with camel milk fat and its various fractions

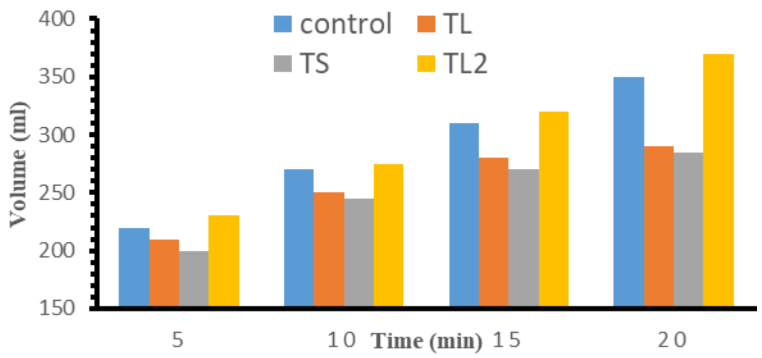

Fig 2. Whipping ability (ml) of functional camel ice cream mixtures as affected by various milk fat fractions

a certain viscosity for the suitable retention of air cells and proper whipping. Additionally, the overrun was affected by the lowest or highest viscosity values, which result in lower whipping ability and maintenance of air bubbles (Pinto Suneeta and Dharaiya 2014). Air cells cannot be easily integrated into SMF and LMF ice cream mixtures during the freezing process because a high amount of saturated fat leads to very high viscosity. Thus, dropping the saturated fat level in the treatments made by cream and LMF: SMF (2:1) may reduce the viscosity to an appropriate level. Also, this will increase the value of the overrun. These results agree with those of Tekin et al (2017). **Table 4** shows that the required freezing time for the mixture was increased in the LMF sample and because of the reduction in the freezing point (**Table 3**). Meanwhile, the time needed to freeze the mixtures decreased with an increasing ratio of saturated fatty acids as in SMF (**Table 1**). The decrease in freezing time was because of the increase in the freezing point. Our results are in line with the previous reports of Abdel-Haleem and Awad (2015), and Marshall et al (2003).

The hardness of ice cream was affected ($P \leq 0.05$) by adding different fat sources to the ice cream mixtures, as shown in **Table 4.** The hardness values of the ice creams were in the range of 2405–3331 g and tended to decrease with increasing USFA content. The same findings were reported previously (Desouky 2021, Gonzalez et al 2003, Abd El-Rahman et al 1997). The ice cream made with SMF was harder than that with LMF: SMF 2:1 (v/v) and had a smoother body and texture. This could be because of changes in the distribution of fatty acids, especially SFA (**Table 1**). The same findings were previously reported (Desouky 2021, Fatouh et al 2006).

The differences in the fat destabilization index among ice cream treatments were significant ($P \leq 0.05$), as shown in **Table 4**. The ice cream treatment with cream showed the highest fat destabilization index (1.43%), while the SMF treatment gave the lowest (0.360%). This may be due to the higher solid fat content in fat globules, which reduces shear sensitivity by increasing the rigidity of the globule and thus results in less fat destabilization. Conversely, decreased solid fat content increases the susceptibility of the fat globule to be broken by the shear forces throughout freezing (Adleman and Hartel 2002).

The melting rates of the ice cream samples were affected by the addition of different fat forms, as depicted in **Table 4**. The data reveal a substantial impact of the fat thermal properties on the melting characteristics of the ice cream. As the melting point of the fraction used decreased (LMF), the melting resistance of the ice cream decreased. The differences in the melting rates of the ice cream treatments were significant ($P \leq 0.05$). Ice cream made with SMF had the lowest melting rate (88.97%), while that with LMF had the highest (94.84%). The current data confirms the pattern reported previously by Desouky (2021), and Abd El-Rahman et al (1997).

The sensory properties reported of the functional ice creams as illustrated in **Table 5** indicate that the fat source used in the mixtures significantly ($P \leq 0.05$) affects their sensory attributes. Ice cream made with cream was characterized by smoothness, creaminess, and slightly pale color. Meanwhile, treatments with camel fat fractions were characterized by creaminess and sourness. The flavor score was the highest when cream was used as the fat source. Among the treatments with fat fractions, the flavor score for ice cream made with LMF was significantly higher than that made with LMF: SMF (2:1) and SMF. The decrease in acceptability was more pronounced in ice cream made with SMF, which had a higher saturated fatty acid content. Slight differences in texture scores between ice cream made with cream and other treatments were observed. The differences in texture scores among treatments with LMF, SMF, and LMF: SMF (2:1) were not significant. The substitution of cream with LMF significantly lowered the body and texture quality of the resulting ice cream. Among the treatments, the mean overall acceptability scores for ice cream made with cream were higher than those for the other treatments.

The overall acceptability of the ice cream made with cream was higher than that with LMF. The substitution of cream with SMF promoted the melting characteristics of the ice cream, while a significantly lower melting quality occurred when LMF was used. The results showed that SMF and LMF can be used as substitutes for cream in ice cream mixtures. Furthermore, the ice cream became harder when SMF was used rather than cream, which may be due to the excess saturated fatty acids (**Table 1**).

Table 4. Properties of functional ice cream made using camel milk fat and its various fraction

Characteristics assessed	Treatments*			
	CMF	TL	TS	TLS
Specific gravity	0.701^{a} ± 0.002	0.786^{c} ± 0.002	0.801^{c} ±0.003	0.731^{b} ±0.004
Weight per gallon (Kg)	2.65^{a} ± 0.06	2.97^{b} ± 0.01	3.03^{b} ± 0.04	2.77^{a} ± 0.01
Overrun (%)	62.48^{bc} ± 0.24	46.18^{a} ± 0.04	41.60^{a} ± 0.07	57.87^{b} ±0.43
Freezing time (min)	26.50^{c} ± 0.1	24.09^{b} ±0.01	24.15^{b} ± 0.01	22.05^{a} ± 0.01
Hardness (g)	2750^{b} ±1	2405^{a} ± 1	3331^{d} ± 1	2807^{c} ± 1
Fat destabilization index	1.43^{d} ± 0.02	1.290^{c} ± 0.02	0.360^{a} ±0.003	0.640^{b} ±0.004
Meltdown rate (% mass loss/min)	1.00^{b} ± 0.001	1.05^{d} ±0.004	0.99^{a} ± 0.003	1.02^{c} ± 0.002
Melting resistance (Loss % after)				
15min	2.92^{b} ±0.03	0^{a} ± 0.00	0^{a} ± 0.00	0^{a} ± 0.00
30min	8.43^{d} ±0.04	3.44^{a} ±0.01	4.95^{b} ±0.01	5.21^{c} ±0.01
45min	21.83^{d} ±0.01	13.33^{a} ±0.03	16.73^{c} ±0.04	15.63^{b} ±0.05
60min	50.15^{b} ±0.12	66.74^{d} ±0.01	46.5^{a} ±0.02	56.6^{c} ±0.03
75min	78.21^{b} ±0.1	89.02^{d} ±0.02	72.16^{a} ±0.99	80.59^{c} ±0.02
90 min	90.12^{b} ±0.08	94.84^{d} ±0.10	88.97^{a} ±0.01	91.90^{c} ±0.08

*See footnote to Table 3. Small letters denote means, with the different superscript letters within the same raw indicating significant ($P \leq 0.05$) differences between treatments.

Table 5. Sensory evaluation of functional ice cream made using camel milk fat and its various fraction

Characteristics assessed	Points	Treatments*			
		CMF	TL	TS	TLS
Flavor	50	49.18^{c}±0.01	47.6^{bc}± 0.89	42.5^{a}± 0.34	45.3^{b}± 1.07
Body & texture	30	29.18^{a}± 0.01	28.0^{a}± 0.05	28.0^{a}± 0.66	28.56^{a}± 0.87
Melting quality	10	9.4^{a}± 0.55	8.6^{a}± 0.14	9.7^{a}± 0.20	8.9^{a}± 0.65
Appearances	10	9.8^{a}± 0.2	9.6^{a}± 0.35	9.6^{a}± 0.28	9.0^{a}± 0.35
Total scores	100	97.56^{d}± 0.86	93.8^{c}± 4.5	89.8^{a}± 1.67	92.76^{b}± 1.45

*See foot not Table 3. Small letters denote means, with different superscript letters within the same raw indicating significant ($P \leq 0.05$) differences between treatments

4 Conclusion

In general, ice cream can be prepared successfully from different CMF fractions with a high acceptability and sensory quality. The substitution of cream with SMF enhanced the melting properties of ice cream, whereas the melting quality decreased when LMF was used. LMF produces lower fat destabilization than a solid melting fraction, which is a desirable feature for the ice cream structure. Substitution with camel butter oil and its fractions is highly recommended in ice cream processing, especially for use in arid and semi-arid regions.

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