

Improving Plasticity of Milk Fat for Use in Baking by Fractionation

S. Yella Reddy

Received: 25 May 2009 / Revised: 8 September 2009 / Accepted: 19 November 2009 / Published online: 13 December 2009
© AOCS 2009

Abstract Milk fat is soft with a low solids content at all temperatures up to 37 °C, which makes its usage limited. To extend its usage, the fat was fractionated to obtain stearin (St) with a 50–55% yield by dry fractionation. The stearin was found to contain an increased solids content at all temperatures and to have improved plasticity compared to its native fat. The physical properties of St were found to be similar to those of commercial bakery shortenings or vanaspati. The melting profiles and the solidification properties of milk fat St are similar to those of commercial bakery shortening. Also, St does not require extended stabilization or tempering, as it transferred to the most stable form quickly like commercial bakery fat. Milk fat St showed higher proportions of saturated fatty acids including those with short chains, compared to commercial vanaspati, the later having a high trans fatty acid content (15%). The olein obtained could also be used as a cooking medium or as a salad oil since it contains a lower solids content at ambient temperatures compared to its parent milk fat.

Keywords Milk fat · Fractionation · Plastic fat · Bakery shortening

Introduction

Milk fat is an important source of dietary fat, and imparts excellent flavour and superior mouth-feel to milk products.

However, the nutritional image and technical properties of milk fat make it unsuitable for many food applications. Milk fat is soft at all temperatures and, unlike commercial vanaspati, which normally exhibits a long plastic range with a higher solids content required for various applications such as baking, confectionery, etc. Due to the presence of a large quantity (6–30%) of trans fatty acids in different types of commercial vanaspati [1], the demand for plastic fats having natural fatty acids is increasing due to the health risks involved with trans fatty acids [2–4]. One of the diversified or extended usage of milk fat is to prepare plastic fats like vanaspati. Various means of improving the utilization of milk fat are under active development worldwide. Because the dairy industry is highly regulated, physical modification of milk fat composition through the application of fractionation processes, which could result in fat fractions with favorable technical and nutritional properties, appears to be the most promising option. The complex chemical nature of milk fat allows for diversity in the tailoring of the milk fat to meet the specific requirements of food applications. Fractionation is one of the modification processes to prepare fractions having diversified applications. Fractionation and applications of various fractions of milk fat and their blends in different foods have been reported and reviewed in the literature [5–16]. Hartel [5] suggested that the most common technique of milk fat fractionation is dry fractionation. He prepared several fractions from milk fat and utilized them in confectionery products like caramels, chocolate, etc. Kaylegian and Lindsay [6] have uniquely and elaborately described the different fractionation technologies of milk fat.

Reduction of cholesterol and milk fat fractionation technologies that have either developed or under development are reviewed [7]. The chemical composition and

S. Yella Reddy (✉)
Lipid Science and Traditional Foods Department,
Central Food Technological Research Institute
(Council of Scientific and Industrial Research),
Mysore 570020, India
e-mail: sy_reddy@yahoo.com

crystallization properties of milk fat and its primary fractions, obtained by dry fractionation were investigated and it was found that the stearin fraction was enriched with long-chain fatty acids, whereas the olein fraction was enriched with short-chain and unsaturated fatty acids. Crystallization properties of milk fat and its fractions were studied by differential scanning calorimetry and time-resolved synchrotron X-ray diffraction [8]. Krishna De et al. [9], studied solvent fractionation, blending of various fractions with other vegetable oils/fats and interesterification of blends to prepare plastic fats from milk fat. Recently, the amount of solid and liquid phases and the relative proportion of each of the crystalline structures within the solid phase in milk fat stearin and olein have been determined by synchrotron X-ray diffraction with differential scanning calorimetry [17].

The purpose of the present paper is to describe the improvement of plasticity by increasing solids content particularly at ambient temperature (25 °C), where milk fat has a low solids content by using a dry fractionation process. To prepare fractions similar to vanaspati in plasticity, so as to diversify and extend applications of milk fat in baking, confectionery and for culinary purposes to substitute vanaspati and also utilize other fractions for cooking or as salad oil.

Materials and Methods

Commercial Amul butter was procured from a local market.

The butter was heated to about 60 °C, kept at that temperature for 10 min to separate the aqueous phase. The supernatant clear oil was decanted and dried over anhydrous sodium sulphate. The clear liquid butter oil (milk fat) was used in the study.

Fractionation of the Milk Fat

The milk fat was heated to about 60 °C, gradually (1 °C/min) cooled to 27 °C and held at this temperature for 1–2 h. The partially crystallized mass was filtered through a Buchner funnel under a vacuum to separate the stearin (St 50–55% yield) and olein fractions. The process was repeated five times for reproducibility and the variations in yield was 5%.

Differential Scanning Calorimetry (DSC)

A Mettler (Zurich, Switzerland) differential scanning calorimeter (DSC-30) was used to determine the melting and crystallization characteristics of the samples. The heat flow

of the instrument was calibrated using indium. The PT-100 sensor was calibrated using indium, zinc, and lead. To ensure the homogeneity and to destroy all crystal nuclei, the samples were heated to 60 °C, about 15 mg of molten sample was accurately weighed into a standard aluminum crucible and a cover crimped in place. An empty aluminum crucible with pierced lid was used as the reference. For melting characteristics, the samples were stabilized according to the IUPAC method [18], by keeping them at 0 °C for 90 min (in refrigerator), 26 °C for 40 h in a temperature-controlled incubator and 0 °C for 90 min prior to introduction into the DSC cell at 0 °C and cooled rapidly to –10 °C. Although, this tempering method applies to fats with extended stabilization like cocoa butter, it ensures complete transformation to the stable form and the results are comparable. Thermograms were recorded by heating at a rate of 2.0 °C/min from –10 to 60 °C. The peak temperatures, heat of fusion (ΔH) and percentage of liquid at various temperatures were recorded directly using a TC-10A data processor and the STARE program taking the entire melting endotherm (whole curve is taken as 100%). The solid fat content (SFC) was calculated from the percentage of liquid by subtracting the % liquid from 100 at each temperature and then melting profiles were drawn. The melting profile over a given temperature range is an important characteristic in fat functionality that can be used to predict how fat will behave at different stages of manufacture. For experimental samples, the averages of triplicates were reported. For crystallization studies, the samples were kept isothermally at 70 °C for 5 min to destroy all crystal nuclei, cooled immediately to –20 °C at 5 °C/min and the onset of crystallization and enthalpy were recorded. To find out the effect of stabilization on the transition to the most stable form, the samples were kept isothermally at 70 °C for 5 min, cooled to –20 °C at 5 °C/min and reheated at 5 °C/min to 60 °C. The melting endotherms and enthalpy were recorded and were compared with those obtained after a long stabilization period as described above.

Fatty Acid Composition

The fat samples were converted into corresponding fatty acid methyl esters (FAME) using KOH/MeOH by a AOCS procedure [19] and were analysed by GC (Fisons, 8000 series, CE Instruments, Rodano, Italy) with an FID and using a Supelco, SP-2340 (0.25 mm \times 30 m) capillary column, operating at a column temperature of 50–200 °C at 5 °C/min and maintained at 200 °C for 10 min, the injection temperature was 230 °C, the detector temperature 240 °C and the nitrogen flow was 0.9 mL/min. The fatty acids were identified by using authentic standards and presented as relative percentages.

Results and Discussion

Milk fat is soft having a low solids content at all temperatures and does not meet the specific requirements for bakery shortening because they normally require a long plastic range with a higher solids content like commercial vanaspati (Table 1). Milk fat stearin (50–55%) though showed two melting peaks like its parent fat, the proportions of these peaks are different and also the second peak is shifted towards a higher temperature (Table 2; Fig. 1). The proportion of the low melting peak is reduced and that of the higher melting peak is increased in St compared to its original fat due to the removal of the liquid fraction, which is reflected in SFC and melting profiles (Table 2; Fig. 2). The SFC at all temperatures is increased in St compared to the original fat and thus the plasticity is improved. It can be seen from Figs. 1 and 2 that the melting endotherms and the melting profiles of milk fat St and commercial bakery shortening are superimposable. Even the proportions of low and high melting peaks of both milk fat St and commercial bakery shortening are the same (Table 2).

The crystallization curves recorded by DSC on cooling of the samples showed a different onset of crystallization

Table 1 Solids fat content of milk fat fractions

Sample	% Solids at °C						
	20	25	30	32.5	35	37.5	40
Milk fat	26.4	25	21	15	7.4	0.3	
Milk fat St	42	41	37	31	23	11	1
Milk fat olein	5.4	4	3	2	1	0	
Palm olein (Comm.)	7.7	6	1.2	0.6	0		
Comm. bakery fat	48.5	45	37	29	19	8	0.4
Comm. margarine	58.6	55	46.4	37.3	25	11	0.6

Comm. commercial, St stearin

Table 2 Melting peaks, their enthalpy and crystallization behaviour of milk fat fractions

	Melting		Crystallization	
	Pk1/ ΔH	Pk2/ ΔH	Onset (°C)	ΔH
Milk fat	15.5/31.1	35.1/10.5	18.80	33.0
Milk fat St	14.45/25.7	39.06/23.2	25.30	35.4
Milk fat Olein	16.4/40.5	35/2.0	12.25	27.0
Comm. Bak. fat	12.1/29.0	36.5/24.6	20.20	31.3
Margarine	12.5/28.0	36.3/27.0		
Palm olein (comm.)	9.36/43	26.9/2.7	10.25	22.0

ΔH in J/g, Pk peaks in °C, St stearin

for milk fat and its fractions, similar to those reported by Lopez et al. [8]. Milk fat St showed two exothermic peaks like the parent fat with the onset of crystallization of milk fat St being shifted to a higher temperature compared to its original fat as expected due to removal of liquid fraction and this onset is slightly higher than that of commercial bakery fat (Fig. 3; Table 2). The rate of transition of milk fat St and commercial shortening to the most stable form is studied by tempering under different conditions, one by long time stabilization and another by on line solidifying (quick tempering) and both by heating through DSC. Milk fat St, like commercial bakery fat solidified in the stable form rapidly and does not require extended stabilization. This could be seen from the DSC endotherms of milk fat St obtained after extended stabilization and on-line stabilization (Fig. 4). The melting peaks and the enthalpy of milk fat St obtained by on-line stabilization (rapid) and extended stabilization are similar to that observed with commercial

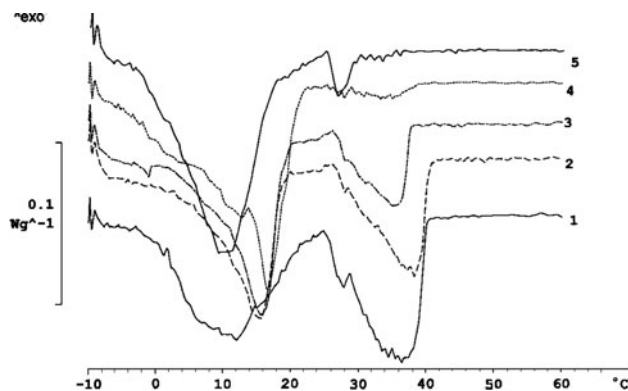


Fig. 1 DSC melting thermograms of 1 Bakery fat, 2 Milk fat Stearin, 3 Milk fat, 4 Milk fat olein, and 5 Palm olein, obtained by heating the stabilized samples from -10 to 60 °C at 2 °C/min

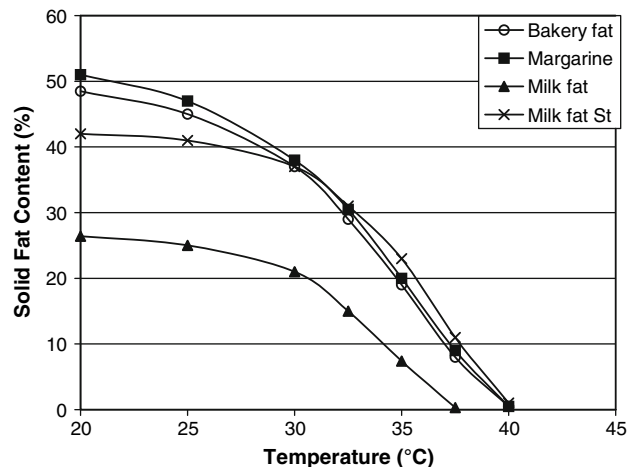


Fig. 2 Melting profiles of milk fat, its fraction and commercial bakery fat

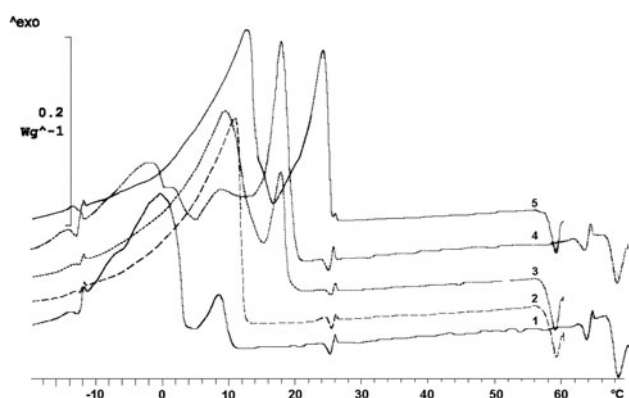


Fig. 3 DSC crystallization curves obtained by cooling from 70 to -20 °C at 5 °C/min. 1 Palm olein, 2 Milk fat olein, 3 Milk fat, 4 Bakery fat, 5 Milk fat St

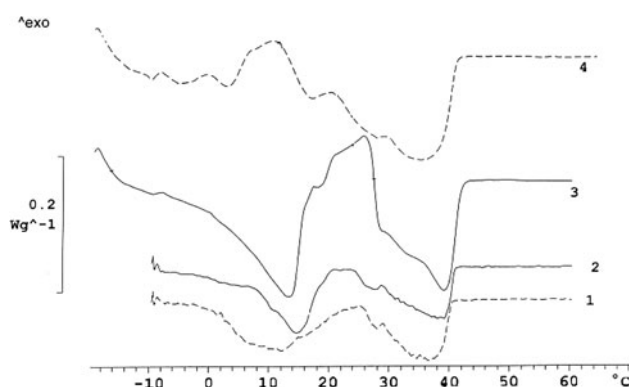


Fig. 4 DSC melting thermograms. 1 Milk fat St, 2 Bakery fat: obtained by heating at 5 °C/min after a long period of stabilization, 3 Milk fat St, 4 Bakery fat: obtained by heating at 5 °C/min after cooling from 70 to -20 °C (on-line stabilization)

Table 3 Melting peaks and their enthalpy obtained after extended stabilization and on-line stabilization

Sample	On-line stabilized ^a		Stabilized for a long period ^b	
	Pk1/ ΔH	Pk2/ ΔH	Pk1/ ΔH	Pk2/ ΔH
Milk fat St	13.3/48	38.75/25	14.45/25.7	39.06/23.2
Comm. bak. fat	-5, 2/16	34.8/36.4	12.1/29.0	36.5/24.6

Pk peaks in °C, ΔH in J/g

^a Cooled from 60 °C to -20 °C at 5 °C/min and heated at 5 °C/min through DSC

^b Stabilized as per IUPAC (14) and heated at 5 °C/min by DSC

bakery shortening (Fig. 4; Table 3) indicating rapid stabilization (transition) to the most stable form.

The olein obtained after removal of 50% stearin showed only one exothermic peak with a lower onset of crystallization compared to its original fat or St, due to removal of

Table 4 Fatty acid (%) composition of milk fat fraction and commercial shortening

Sample	4–12	14:0	16:0	18:0	18:1t	18:1c	18:2	Satd.
Milk fat	10.3	10.6	33.0	13.0	ND	24.3	2.0	67
Milk fat St	5.0	10.5	35.0	15.8	ND	23.9	1.7	66
Comm. bakery fat	0	0	39.6	4.9	14.7	33.2	4.9	45
Milk fat olein	5.0	11.2	33.9	12.6	ND	28.5	2.0	63
Comm. palm olein	0	0	40.4	3.7	ND	38.3	9.5	44

t, trans; c, cis; Comm, Commercial; Satd, Saturated; ND, not detected

the higher melting fraction (Fig. 3; Table 2). The olein showed very small high melting peak unlike parent fat or St (Fig. 1) and the solids present at ambient temperature (25 °C) are reduced (only 4%) compared to parent milk fat (about 25%) (Table 1). Both melting endotherms and crystallization exotherms of milk fat olein are closer to those of palm olein showing the removal of high melting fraction (Figs. 1, 3). Thus milk fat olein is more suitable as a cooking medium like liquid oils, having lower solids at ambient temperatures. The SFC of milk fat olein is similar to that of commercial palm olein (Table 1) and finds application as a cooking medium or as a salad oil.

Thus, both fractions from milk fat could be used for different applications, the higher melting fraction for baking or confectionery as a plastic fat like vanaspati and the lower melting fraction as a cooking medium or as a salad oil.

Milk fat fractions showed higher proportions of saturated fatty acids compared to commercial vanaspati or cooking oil (Table 4) though the consistency or melting profiles are similar. This is mainly due to the presence of short chain fatty acids in milk fat fractions and the presence of trans acids in vanaspati. Milk fat has been reported to contain small quantities of vaccenic and conjugated linoleic acids (0.25–1.14%).

Conclusions

The applications of milk fat are extended by fractionation. The solid fraction had extended and improved plasticity like commercial vanaspati and could find application in baking, confectionery, culinary purposes, etc. The liquid fraction had a lower solids fat content at ambient temperature and could be used as a cooking oil or a salad oil.

Acknowledgments The author thanks Dr. Lokesh B R, Head of Department and Dr. Prakash V, Director of the Institute for their keen interest in the work.

References

1. Jeyarani T, Reddy SY (2005) Physicochemical evaluation of vanaspati marketed in India. *J Food Lipids* 12:232–242
2. Etherton PK (1995) Trans fatty acid and coronary heart diseases risk. *Am J Clin Nutr* 62:655S–708S
3. Mensink RP, Katan MB (1990) Effect of trans fatty acids on high density and low density lipoprotein cholesterol levels in healthy subjects. *N Engl J Med* 323:439–445
4. Mensink RP, Zock PL, Katan MB, Hornstra G (1992) Effect of dietary cis trans fatty acids on serum lipoprotein [a] levels in humans. *J Lipid Res* 33:1493–1501
5. Hartel W (1996) Applications of milk-fat fractions in confectionery products. *J Am Oil Chem Soc* 73:945–953
6. Kaylegian K, Lindsay RC (1995) Handbook of milk fat fractionation technology. AOCS Press, Champaign, pp 39–508
7. Boudreau A, Arul J (1993) Cholesterol reduction and fat fractionation technologies for milk fat: an overview. *J Dairy Sci* 76:1772–1781
8. Lopez C, Bourgaux C, Lesieur P, Riaublanc A, Ollivon M (2006) Milk fat and primary fractions obtained by dry fractionation 1. Chemical composition and crystallization properties. *Chem Phys Lipids* 144:17–33
9. De Krishna B, Hakimji M, Patel A, Sharma D, Desai H, Kumar T (2007) Plastic fats and margarines through fractionation, blending and interesterification of milk fat. *Eur J Lipid Sci Technol* 109:32–37
10. Dimick PS, Reddy SY, Ziegler GR (1996) Chemical and thermal characteristics of milk fat fractions isolated by melt crystallization. *J Am Oil Chem Soc* 73:1647–1651
11. Van Aken GA, Ten Grotenhuis E, Van Ingevelde AJ, Schenk H (1999) Composition and crystallization of milk fat fractions. *J Am Oil Chem Soc* 76:1323–1331
12. Amer MA, Kupranycz DB, Baker BE (1985) Physical and chemical characteristics of butterfat fractions obtained by crystallization from molten fat. *J Am Oil Chem Soc* 62:1551–1557
13. Bhaskar R, Rizvi SSH, Bertoli C, Fay LB, Hug B (1998) A comparison of physical and chemical properties of milk fat fractions obtained by two processing technologies. *J Am Oil Chem Soc* 75:1249–1264
14. Kaylegian KE, Hartel RW, Lindsay RC (1993) Applications of modified milk fat in food products. *J Dairy Sci* 76:1782–1796
15. Deffense E (1993) Milk fat fractionation today: a review. *J Am Oil Chem Soc* 70:1193–1201
16. Kaylegian KE (1999) The production of speciality milk fat ingredients. *J Dairy Sci* 82:1433–1439
17. Lopez C, Ollivon M (2009) Triglycerides obtained by dry fractionation of milk fat 2. Thermal properties and polymorphic evolutions on heating. *Chem Phys Lipids* 159:1–12
18. International Union of Pure Applied Chemistry (IUPAC) (1987) In: Paquot C, Hautfenne A (eds) Standard methods for the analysis of oils, fats and derivatives. 7th edn. Blackwell, London
19. AOCS (2002–2003) Official methods and recommended practices of the American Oil Chemists' Society, 5th edn. AOCS Press, Champaign method no. Cc 4–25