Modifications of Butter Stearin by Blending and Interesterification for Better Utilization in Edible Fat Products

P.K. Pal, D.K. Bhattacharyya*, and S. Ghosh

Department of Chemical Technology, Oil Technology Division, University of Calcutta, Calcutta - 700 009, India

ABSTRACT: This work primarily aims to further modify the stearin fractions, obtained from anhydrous milk fat, after fractionation by dry process and by solvent process using isopropanol, for extending their scope of utilization in edible fat products. Butter stearin fractions, on blending with liquid oils like sunflower oil and soybean oil in different proportions, offer nutritionally important fat products with enriched content of essential fatty acids like $C_{18:2}$ and $C_{18:3}$. The butter stearin fraction from isopropanol fractionation, when interesterified with individual liquid oils by *Mucor miehei* lipase as a catalyst, yields fat products having desirable properties in making melange spread fat products with reasonable content of polyunsaturated fatty acids and almost zero *trans* fatty acid content.

Paper no. J9309 in *JAOCS 78,* 31–36 (January 2001).

KEY WORDS: Blending, butter stearin, fractionation, interesterification, melange product, milk fat, *Mucor miehei.*

Milk fat and its fractions receive a lot of attention even now as raw materials used to make edible fat products, and in spite of their high price and limited functionality compared to tailored vegetable fats and oils. Numerous modification techniques have been used to improve the functionality of milk fat. These modification techniques are fractionation, interesterification, and blending.

Milk fat has been fractionated through a variety of techniques, as summarized by Kaylegian and Lindsay (1), involving both dry and solvent fractionation. Modification of milk fat by enzymatic interesterification in the absence of organic solvents has been reported by several researchers (2–5). Interesterifications, when carried out in hydrocarbon solvents, require the reaction product to be bleached and deodorized for nutritional safety (2). It may be pointed out that the use of an *sn*-1,3-specific lipase confines the exchange of acyl moieties to the *sn*-1 and *sn*-3 positions, thus giving rise to a product with characteristics that cannot be obtained by chemical interesterification (6).

Milk fat fractions find increasing application in a variety of food products (7). According to this report, the high melting point stearins are useful in puff pastry while the mid-fractions are useful in Danish cookies. Stearins are also used in the reduction in blooming properties of chocolate (7).

Modification of high melting point butter stearins by blending and interesterification did not appear to have been studied previously. These modifications are worth investigating given the information available on the utilization of high-melting palm stearins obtained from palm oil after fractionation by interesterification and blending techniques. Chemical interesterification of mixtures of palm stearin with liquid oils was reported by Majumdar and Bhattacharyya (8) and by Petrauskaite *et al.* (9) to make zero-*trans* fats for margarines and shortenings. The nutritional aspects of interesterified fat products were reported by Majumdar and Bhattacharyya (10). Roy and Bhattacharyya (11) studied the nutritional quality of the fat products simulating hydrogenated fat product (vanaspati) made by blending palm stearins with liquid oils like sunflower, soybean, and rapeseed. Lipase-catalyzed interesterification of high-melting palm stearin with liquid oils from sunflower, soybean, and rice bran produced margarines and shortening fat bases that were free of *trans* and rich in polyunsaturated fatty acids (12). Butterfat was chemically modified by selective hydrolysis and lipase-catalyzed interesterification to engineer butterfat with improved nutritional properties (5).

The present work deals with the modification of butter stearins, obtained by dry and solvent techniques of fractionation by blending and lipase-catalyzed interesterification process techniques. Liquid oils rich in polyunsaturated fatty acids were chosen for making fats with desired physical properties and fatty acid compositions and therefore suitable for utilization in a variety of food products.

MATERIALS AND METHODS

Butter oil (anhydrous milk fat) was purchased from Ghosh Dairy Co. Ltd. (Calcutta, India). Isopropanol (analyzed reagent grade) was supplied by S.D. Fine Chemicals Ltd. (Bombay, India). 1,3-Specific *Mucor miehei* lipase was a kind gift from Novo Industries A/S (Copenhagen, Denmark). Refined, bleached, and deodorized sunflower oil (Sundrop brand of ITC; Agrowtech Ltd., Hyderabad, India) and refined, bleached and deodorized soybean oil (vital brand of S.M. Deychem Ltd.,

*To whom correspondence should be addressed at Department of Chemical Technology, Oil Technology Division, University of Calcutta, 92, A.P.C. Road, Calcutta - 700 009, India. E-mail: dkb@cucc.ernet.in

Copyright © 2001 by AOCS Press

TABLE 1
Fatty Acid Composition and Triglyceride Composition of Sunflower Oil (SFO) and Soybean Oil (SBO)[a]

Oils	Fatty acid composition (% w/w)					Acyl carbon number (% w/w)		
	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	C_{50}	C_{52}	C_{54}
SFO	6.5 ± 0.32	3.5 ± 0.21	31.1 ± 0.57	58.9 ± 0.23	—	4.6 ± 0.12	17.2 ± 0.26	78.0 ± 0.54
SBO	11.2 ± 0.22	3.1 ± 0.31	24.2 ± 0.51	54.3 ± 0.12	7.2 ± 0.09	12.3 ± 0.34	41.5 ± 0.49	46.2 ± 0.36

[a]Values are mean ± SD.

Bombay, India) was purchased from a local market. The fatty acid composition and carbon number glyceride composition of sunflower and soybean oil are shown in Table 1.

Fractionation by dry method. Butter oil (250 g) was melted at 60°C in a round-bottomed flask then kept at 31 ± 1°C for 96 h. The solid part, known as butter stearin ($BOST_1$), and part by part were separated by centrifugation at 2,000 × *g* for 5 min. The liquid part was again kept at 28 ± 1°C for 24 h and separated by centrifugation to get a solid part as butter mid-fraction (BOMF) and a liquid part known as butter olein (BOO_1). The slip point, yield of the fractions, and fatty acid composition of the original butter oil and its fractions are shown in Table 2. Table 3 includes the carbon number, glyceride composition of butter oil, and its fractions.

Fractionation by solvent method (isopropanol). After it was completely melted in a water bath at 50°C, butter oil (250 g) was placed in a 2 L beaker (borosil glass). Isopropanol was added (4 mL/g butter oil), and the mixture was kept at this temperature for 10 min. The beaker was placed in a constant-temperature bath and stirred by a low-speed mechanical stirrer for 1 h. The crystallization process was done at different temperatures, *viz*., 15, 20, 25, and 30°C. The solid part and liquid part were separated by filtration under vacuum. The fractions were desolventized at 80°C for 1 h at 10 mm Hg pressure, weighed, and stored in a refrigerator.

Lipase-catalyzed interesterification reaction. About 50 g of total fat mixture containing butter stearin from isopropanol fractionation and liquid oils like sunflower oil and soybean oil was placed in a 100 mL round-bottomed flask. The blended oils for interesterification were 70:30, 50:50, and 30:70, respectively. Immobilized *M. miehei* lipase (5 g) was added to the flask and the mixture was stirred at 60 ± 2°C over a magnetic stirrer at <2 mm Hg for 5 h. After the reaction, the product mixture was isolated by filtration and the free fatty acids formed during reaction (about 1.4%) were then neutralized by standard mixed solvent refining process (13).

Analytical procedures. Slip points were determined by the method of the Indian Standard Institution (14). Solid fat content (SFC) was determined with a pulsed nuclear magnetic resonance (NMR) spectrophotometer (Minispec PC 120; Bruker, Karlsruhe, Germany). Before the analysis, the samples were heated to complete liquification for homogeneity, and then the samples were cooled and held at 0°C for 15 min, tempered at 27°C for 30 min, and cooled again and stabilized at 0°C for 24 h. The samples were then equilibrated at the lowest temperature in the temperature range of interest for at least 30 min, and the solid content was measured by pulsed NMR. Samples were then equilibrated at each of the next higher temperatures for SFC measurement. The SFC values for the original butter oil and the $BOST_{25}$ are shown in Table 4.

Fatty acid composition (15) and carbon number glyceride composition (16) of the fats and oils were determined by gas–liquid chromatography. The fatty acid composition of the original butterfat and the $BOST_{25}$ is shown in Table 4.

RESULTS AND DISCUSSION

$BOST_1$ from dry process can be a very useful source of a hard fat component, in limited amount, for use in fat-based edible products such as spreads and chocolate, shortenings, and vanaspati due to its high slip point (46.3°C). In order to increase the use of butter stearin, it has been modified by blending it with liquid oils like sunflower oil (SFO) and soybean oil (SBO) in different proportions to decrease the slip points of the blended products (Table 5) within the specified limits of certain edible fat products. With the increase in proportion of SFO and SBO, the slip points of the butter stearin decreased gradually and reached the range of 37–42°C. Blends of palm stearin and liquid oils, in the natural state (12) and following interesterification (8), followed the same trend. The blended products can be utilized as polyunsaturated fatty acid rich-cum-zero-*trans* fat bases for incorporation in margarines or in spread fats (melange products).

Tables 6 and 7 show the fatty acid composition and carbon number glyceride composition, respectively, of the blended products. The $BOST_1$ fraction is rich in saturated fatty acids and is deficient in essential fatty acids like $C_{18:2}$ and $C_{18:3}$. By blending with SFO and SBO, the content of essential fatty acids increased substantially with the increased proportion of the liquid oils. Therefore, these blended products will be rich in essential fatty acids along with the saturated, short-, and medium-chain fatty acids.

Anhydrous milk fat, when fractionated at 25°C using isopropanol, yields a stearin fraction ($BOST_{25}$) with a slip point of 40.1°C, which can be used as a shortening agent. This fraction has been blended with individual oils, like SFO and SBO, at 30, 50, and 70% levels to obtain products with even lower slip points. The slip points and the SFC of the blends are shown in Table 8.

The SFC values of the blends at 10, 20, and 30°C are in the range of 45–36, 30–16, and 19–6, respectively. The SFC values were not lowered by adding as much as 70% oil to a butter stearin. This could be due to the fact that butter stearin

TABLE 2
Yield, Slip Point, and Fatty Acid Composition of Butter Oil (anhydrous milk fat) and Its Fractions Obtained by Dry Fractions[a]

Butter oil/ fractions	Yield (% w/w)	Slip point (°C)	Fatty acid composition (% w/w)										
			$C_{4:0}$	$C_{6:0}$	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$
Butter oil (original)	—	31.9 ± 0.16	2.8 ± 0.06	2.1 ± 0.08	1.3 ± 0.13	2.0 ± 0.05	1.7 ± 0.0	49.1 ± 0.23	31.7 ± 0.24	2.2 ± 0.12	14.0 ± 0.12	32.4 ± 0.52	0.7 ± 0.01
Butter stearin ($BOST_1$)	7.4 ± 0.98	46.3 ± 0.22	2.1 ± 0.03	2.9 ± 0.04	1.0 ± 0.06	2.2 ± 0.07	2.5 ± 0.12	11.3 ± 0.15	41.6 ± 0.22	1.4 ± 0.24	16.0 ± 0.26	19.0 ± 0.32	—
Butter mid (BOMF)	9.3 ± 1.1	42.2 ± 0.31	1.6 ± 0.04	1.8 ± 0.03	1.5 ± 0.01	3.2 ± 0.09	2.4 ± 0.23	12.7 ± 0.21	40.0 ± 0.53	1.9 ± 0.32	13.0 ± 0.11	21.9 ± 0.43	—
Butter olein (BOO_1)	83.3 ± 0.34	22.5 ± 0.03	3.0 ± 0.09	2.1 ± 0.02	1.8 ± 0.08	1.9 ± 0.12	1.6 ± 0.21	8.5 ± 0.31	29.9 ± 0.52	2.3 ± 0.02	13.9 ± 0.13	34.8 ± 0.23	0.6 ± 0.06

[a]Values are mean ± SD.

TABLE 3
Carbon Number Triglyceride Composition of Butter Oil (anhydrous milk fat) and Its Fractions Obtained by Dry Fractions[a]

Butter oil/ fractions	Acyl carbon number (% w/w)														
	C_{26}	C_{28}	C_{30}	C_{32}	C_{34}	C_{36}	C_{38}	C_{40}	C_{42}	C_{44}	C_{46}	C_{48}	C_{50}	C_{52}	C_{54}
Butter oil original	0.1 ± 0.01	0.3 ± 0.02	0.5 ± 0.06	1.0 ± 0.02	2.1 ± 0.03	6.5 ± 0.23	11.3 ± 0.21	9.5 ± 0.26	5.9 ± 0.24	6.5 ± 0.12	8.8 ± 0.06	12.5 ±0.14	16.3 ± 0.27	13.8 ± 0.36	4.9 ± 0.13
$BOST_1$	—	0.2 ± 0.03	0.4 ± 0.04	0.5 ± 0.02	1.4 ± 0.19	5.4 ± 0.12	7.4 ± 0.34	6.3 ± 0.42	4.8 ± 0.26	7.3 ± 0.09	13.2 ± 0.41	16.0 ± 0.13	19.5 ± 0.28	15.2 ± 0.62	2.4 ± 0.10
BOMF	—	0.2 ± 0.01	0.4 ± 0.01	0.6 ± 0.05	1.6 ± 0.10	4.7 ± 0.21	8.9 ± 0.43	7.8 ± 0.22	5.7 ± 0.31	6.5 ± 0.02	11.3 ± 0.08	13.8 ± 0.42	18.4 ± 0.62	16.4 ± 1.0	3.7 ± 0.62
BOO_1	0.1 ±0.08	0.3 ± 0.10	0.6 ± 0.13	1.1 ± 0.21	3.3 ± 0.33	1.8 ± 0.23	12.9 ± 0.41	11.2 ± 0.32	6.3 ± 0.62	6.8 ± 0.31	8.7 ± 0.26	12.0 ± 0.18	15.6 ± 0.56	13.6 ± 0.52	5.7 ± 0.62

[a]Values are mean ± SD. See Table 2 for abbreviations.

TABLE 4
Fatty Acid Composition and Solid Fat Content of Original Butter Oil and the Fractions Obtained by Isopropanol Fractionation[a]

Butter oil/ fractions	Fatty acid composition (% w/w)										
	$C_{4:0}$	$C_{6:0}$	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$
Butter oil (original)	2.8 ± 0.06	2.1 ± 0.12	1.3 ± 0.12	2.0 ± 0.04	1.7 ± 0.21	9.1 ± 0.11	31.7 ± 0.23	2.2 ± 0.22	14.0 ± 0.10	32.4 ± 0.24	0.7 ± 0.03
$BOST_{25}$	3.2 ± 0.14	3.1 ± 0.16	2.2 ± 0.21	2.8 ± 0.05	2.2 ± 0.20	11.6 ± 0.32	43.4 ± 0.73	1.1 ± 0.32	16.4 ± 0.25	13.5 ± 0.29	0.5 ± 0.01
BOO_{25}	2.5 ± 0.21	1.7 ± 0.32	1.0 ± 0.06	2.0 ± 0.09	1.2 ± 0.09	7.8 ± 0.22	22.2 ± 0.34	2.8 ± 0.32	12.5 ± 0.34	44.5 ± 0.54	1.8 ± 0.62

Fat/fractions	Solid fat content by NMR at		
	10°C	20°C	30°C
Butter oil (original)	32.8 ± 0.23	19.7 ± 0.35	7.6 ± 0.54
$BOST_{25}$	66.9 ± 0.78	50.1 ± 0.62	33.7 ± 0.59

[a]Values are mean ± SD. NMR; nuclear magnetic resonance; $BOST_{25}$, stearin fraction yielded when anhydrous milk fat is fractionated at 25°C; see Table 2 for other abbreviations.

TABLE 5
Slip Point of the Blends of Stearin Fraction ($BOST_1$) with Liquid Oils Like SFO and SBO[a]

Blend no.	Composition of the blend (% w/w)	Slip point (°C)
BL-1	$BOST_1$ + SFO (70:30)	42.1 ± 0.08
BL-2	$BOST_1$ + SFO (50:50)	40.8 ± 0.16
BL-3	$BOST_1$ + SFO (30:70)	38.3 ± 0.16
BL-4	$BOST_1$ + SBO (70:30)	41.0 ± 0.32
BL-5	$BOST_1$ + SBO (50:50)	38.3 ± 0.20
BL-6	$BOST_1$ + SBO (30:70)	37.0 ± 0.12

[a]Values are mean ± SD. See Tables 1 and 2 for abbreviations.

is very rich in the saturated glycerides. On the basis of the slip points and SFC values, the blended products can also be utilized as a vanaspati (hydrogenated fat products) substitute having zero-*trans* fatty acids and a substantial content of essential fatty acids ($C_{18:2}$ and $C_{18:3}$).

The fatty acid compositions of the blended products are tabulated in Table 9. The presence of SFO and SBO at various levels make the blended products rich in essential fatty acids. The products will be desirable in spreadable fat formulations after incorporating appropriate antioxidants.

The blends of butter stearin ($BOST_{25}$) with SFO or SBO at the 30% level have been enzymatically interesterified with the help of *M. miehei* lipase. The slip points of the interesterified products were lower than the corresponding blends (Table 10). The interesterification reaction of butter stearin ($BOST_{25}$) with soybean or sunflower oil in presence of a regiospecific lipase as a catalyst will result in the incorporation of the unsaturated fatty acids, *viz.*, 18:2 (linoleic) and 18:3 (linolenic) in the 1- and 3-positions of the butter stearin glycerides. The saturated fatty acids, mostly palmitic and myristic acids, will be displaced during interesterification. This kind of specific interchange of fatty acids will form glyceride molecules of relatively lower slip melting points in the interesterified products.

There may not be much alteration in the overall acyl carbon number profiles after interesterification, but one would expect a distinct change in the content of the high-melting glycerides belonging to the C_{46}, C_{48}, and C_{50} acyl carbon number profiles. The acyl carbon number profiles from C_{20} to C_{44} will also decrease due to the exchange of fatty acids from SBO or SFO. These trends are corroborated by our earlier work on the glyceride compositions of some enzymatically interesterified fat products (17). The overall effect of the alterations of the acyl carbon number profiles as indicated will reduce the slip points of the blends of butter stearin and SBO or SFO after the specific lipase-catalyzed interesterification reaction.

On the basis of slip point and SFC data, it can be stated that the interesterified products are suitable in formulating melange products and spread fats with almost zero *trans* fatty acid content and with reasonable content of polyunsaturated fatty acids. The modification by blending or interesterification of butter stearins is an interesting and important approach for utilization of milk fat stearins in a number of edible fat products.

REFERENCES

1. Kaylegian, K.E., and R.C. Lindsay, *Handbook of Milk Fat Fractionation Technology,* AOCS Press, Champaign, 1995, pp. 39–508.
2. Kalo. P., H. Huotari, and M. Antila, *Pseudomonas fluorescens* Lipase-Catalyzed Interesterification of Butterfat in the Absence of a Solvent, *Milchwissenschaft 45*:282–285 (1990).
3. Kalo, P., P. Parviainen, K. Vaara, S. Ali-Yrrko, and M. Antila, Changes in the Triglyceride Composition of Butter Fat Induced by Lipase and Sodium Methoxide Catalyzed Interesterification Reactions, *Ibid. 41*:82–85 (1986).
4. Posorske, L.H., G.K. LeFebvre, C.A. Miller, T.T. Hansen, and B.L. Glenvig, Process Considerations of Continuous Fat Modification with an Immobilized Lipase, *J. Am. Oil Chem. Soc. 65*: 922–926 (1988).
5. Balcao, V.M., A. Kemppinen, F.X. Malcata, and P.J. Kalo, Modification of Butter Fat by Selective Hydrolysis and Interesterification by Lipase: Process and Product Characterization, *Ibid. 75*:1347–1358 (1998).
6. Macrae, A.R., Microbial Lipases as Catalysts for the Interesterification of Oils and Fats, in *Biotechnology for the Fats and Oils Industry,* American Oil Chemists' Society, Champaign, 1984, pp. 189–198.
7. Kellens, M., Developments in Fractionation Techniques, in *Treatise in Fats, Fatty Acids and Oleochemicals,* edited by O.P. Narula, Industrial Consultants (India) Section B1, Chapter 7, 1997, p. 15.
8. Majumdar, S., and D.K. Bhattacharyya, *trans*-Free Vanaspati from Palm Stearin and Vegetable Oils by Interesterification Process, *Oleagineux 41*:235–240 (1986).
9. Petrauskaite, V., W.D. Greyt, M. Kellens, and A. Huyghebaert, Physical and Chemical Properties of *trans*-Free Fats Produced by Chemical Interesterification of Vegetable Oil Blends, *J. Am Oil Chem. Soc. 75*:489–493 (1998).
10. Majumdar, S., and D.K. Bhattacharyya, Nutrition of Hydrogenated Vanaspati and Interesterified Vanaspati Made from Palm Stearin and Selective Oils, *Oleagineux 41*:393–399 (1986).
11. Roy, S., and D.K. Bhattacharyya, Comparative Nutritional Quality of Palm Stearin Liquid Oil Blends and Hydrogenated Fat (vanaspati), *J. Am. Oil Chem. Soc. 73*:617–622 (1996).
12. Ghosh, S., and D.K. Bhattacharyya, Utilization of High Melting Palm Stearin by Lipase-Catalyzed Interesterification with Other Liquid Oils, *Ibid. 74*:589–592 (1997).
13. Bhattacharyya, A.C., and D.K. Bhattacharyya, Refining of High FFA Rice Bran Oil by Mixed Solvent Neutralization Process, *J. Oil Tech. Assoc. India 17*:31–32 (1985).
14. Indian Standard Methods of Sampling and Tests for Oils and Fats (revised), Fourth Reprint, May 1975, *Indian Standard Institution* IS:548 (Part I) pp. 33 (1964).
15. Chaudhuri, S., S. Ghosh, D.K. Bhattacharyya, and S. Bandyopadhyay, Effect of Mustard Meal on the Production of Arachidonic Acid by *Mortierella elongata* SC-208, *J. Am. Oil Chem. Soc. 75*:1053–1055 (1998).
16. Rossel, J.B., Differential Scanning Calorimetry of Palm Kernel Oil Products, *Ibid. 52*:505–511 (1975).
17. Bhattacharyya, S., and D.K. Bhattacharyya, Glyceride Composition of Enzymatically Interesterified Fats, *Oleagineux 44*:489–491(1989).

[Received July 9, 1999; accepted August 27, 2000]

TABLE 6
Fatty Acid Composition of the Blended Products[a]

Blend no.	Fatty acid composition (% w/w)											
	$C_{4:0}$	$C_{6:0}$	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
BL-1	1.4 ± 0.06	2.0 ± 0.08	0.6 ± 0.01	1.5 ± 0.12	1.7 ± 0.11	7.9 ± 0.12	30.7 ± 0.54	0.8 ± 0.30	12.3 ± 0.21	22.0 ± 042	19.1 ± 0.32	—
BL-2	1.5 ± 0.09	1.9 ± 0.06	0.4 ± 0.03	1.0 ± 0.14	1.4 ± 0.12	5.7 ± 0.23	23.5 ± 0.42	0.6 ± 0.21	10.0 ± 0.22	24.1 ± 0.28	29.9 ± 0.24	—
BL-3	0.6 ± 0.12	0.8 ± 0.02	0.3 ± 0.06	0.8 ± 0.04	0.7 ± 0.04	3.5 ± 0.26	13.4 ± 0.32	0.4 ± 0.23	7.5 ± 0.23	23.1 ± 0.30	48.8 ± 0.25	—
BL-4	1.3 ± 0.11	1.9 ± 0.03	0.6 ± 0.08	1.4 ± 0.10	1.8 ± 0.12	7.5 ± 0.06	32.7 ± 0.62	0.9 ± 0.06	12.2 ± 0.08	21.0 ± 0.25	15.8 ± 0.48	2.9 ± 0.12
BL-5	1.6 ± 0.03	1.4 ± 0.09	0.4 ± 0.04	0.6 ± 0.05	1.0 ± 0.08	5.4 ± 0.22	26.4 ± 0.21	0.5 ± 0.11	9.6 ± 0.14	22.4 ± 0.52	26.5 ± 0.51	4.20 ± 0.72
BL-6	0.5 ± 0.06	0.6 ± 0.04	0.3 ± 0.01	0.9 ± 0.08	0.8 ± 0.06	3.4 ± 0.12	20.2 ± 0.10	0.3 ± 0.02	7.2 ± 0.26	23.7 ± 0.23	36.9 ± 0.72	5.2 ± 0.31

[a]Values are mean ± SD. See Table 5 for blends.

TABLE 7
Carbon Number Triglyceride Composition of the Blended Products[a]

Blend no.	Acyl carbon number (% w/w)													
	C_{28}	C_{30}	C_{32}	C_{34}	C_{36}	C_{38}	C_{40}	C_{42}	C_{44}	C_{46}	C_{48}	C_{50}	C_{52}	C_{54}
BL-1	—	—	0.4 ± 0.08	1.0 ± 0.12	3.5 ± 0.32	5.3 ± 0.12	4.4 ± 0.24	3.5 ± 0.24	5.2 ± 0.24	9.1 ± 0.04	11.5 ± 0.32	15.2 ± 0.35	15.8 ± 0.52	25.1 ± 0.25
BL-2	—	0.2 ± 0.06	0.3 ± 0.09	0.8 ± 0.04	2.6 ± 0.22	3.7 ± 0.23	3.4 ± 0.32	2.4 ± 0.36	3.6 ± 0.32	6.8 ± 0.08	8.1 ± 0.21	12.7 ± 0.62	16.0 ± 0.72	39.4 ± 0.79
BL-3	—	—	—	0.5 ± 0.06	1.7 ± 0.08	2.2 ± 0.08	1.9 ± 0.12	1.5 ± 0.12	2.2 ± 0.12	4.0 ± 0.12	5.0 ± 0.25	9.7 ± 0.52	16.8 ± 0.36	55.0 ± 1.12
BL-4	0.1 ± 0.06	0.3 ± 0.04	0.5 ± 0.12	1.1 ± 0.12	3.4 ± 0.13	5.2 ± 0.03	4.4 ± 0.11	3.7 ± 0.04	5.0 ± 0.10	9.1 ± 0.22	11.2 ± 0.31	17.4 ± 0.16	23.2 ± 0.62	15.4 ± 0.42
BL-5	—	0.2 ± 0.02	0.2 ± 0.11	0.9 ± 0.09	2.5 ± 0.20	3.5 ± 0.12	3.4 ± 0.14	2.6 ± 0.42	3.6 ± 0.21	6.8 ± 0.04	8.6 ± 0.04	15.9 ± 0.49	28.4 ± 0.12	23.4 ± 0.62
BL-6	—	—	—	0.4 ± 0.21	1.8 ± 0.08	2.1 ± 0.26	1.8 ± 0.16	1.6 ± 0.31	2.2 ± 0.06	4.0 ± 0.18	5.0 ± 0.23	14.2 ± 0.72	33.7 ± 0.41	33.2 ± 0.72

[a]Values are mean ± SD. See Table 5 for blends.

TABLE 8
Slip Point and Solid Fat Content (SFC) Values of the Blended Products of the Stearin Fraction ($BOST_{25}$) of Anhydrous Milk Fat (obtained from isopropanol fractionation at 25°C) with Liquid Oils Like SFO and SBO[a]

Blend no.	Composition of the blend (% w/w)	Slip point (°C)	SFC by NMR at °C		
			10	20	30
BL-7	$BOST_{25}$ + SFO (70:30)	40.0 ± 0.16	45.1 ± 0.36	30.6 ± 0.04	19.7 ± 0.16
BL-8	$BOST_{25}$ + SFO (50:50)	38.8 ± 0.24	40.0 ± 0.22	20.2 ± 0.42	12.1 ± 0.19
BL-9	$BOST_{25}$ + SFO (30:70)	37.2 ± 0.21	36.4 ± 0.23	16.4 ± 0.31	6.4 ± 0.23
BL-10	$BOST_{25}$ + SBO (70:30)	38.0 ± 0.28	50.2 ± 0.25	35.3 ± 0.62	24.0 ± 0.68
BL-11	$BOST_{25}$ + SBO (50:50)	37.2 ± 0.56	39.1 ± 0.30	21.1 ± 0.72	13.4 ± 0.72
BL-12	$BOST_{25}$ + SBO (30:70)	36.0 ± 0.78	32.2 ± 0.52	18.6 ± 0.12	6.7 ± 1.22

[a]Values are mean ± SD. See Tables 1 and 2 for abbreviations.

TABLE 9
Fatty Acid Composition of the Blended Products[a]

Blend no.	Fatty acid composition (% w/w)										
	$C_{4:0}$	$C_{6:0}$	$C_{8:0}$	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$
BL-7	2.4 ± 0.08	2.2 ± 0.14	1.5 ± 0.23	1.4 ± 0.15	2.0 ± 0.30	7.1 ± 0.42	31.1 ± 0.25	0.6 ± 0.21	12.6 ± 0.42	19.4 ± 0.21	19.7 ± 0.34
BL-8	1.5 ± 0.23	1.2 ± 0.12	1.0 ± 0.24	1.4 ± 0.10	1.0 ± 0.08	5.6 ± 0.23	24.3 ± 0.28	0.5 ± 0.04	10.1 ± 0.34	21.4 ± 0.24	31.8 ± 0.36
BL-9	0.9 ± 0.04	0.8 ± 0.16	0.5 ± 0.26	1.8 ± 0.12	0.7 ± 0.02	3.6 ± 0.09	16.6 ± 0.24	0.2 ± 0.01	7.6 ± 0.36	24.5 ± 0.26	43.3 ± 0.72
BL-10	2.3 ± 0.12	2.1 ± 0.16	1.6 ± 0.16	1.7 ± 0.23	2.1 ± 0.12	8.2 ± 0.16	33.7 ± 0.26	0.7 ± 0.06	12.5 ± 0.48	17.2 ± 0.28	17.9 ± 0.68
BL-11	1.6 ± 0.11	1.3 ± 0.12	1.1 ± 0.04	1.4 ± 0.09	1.1 ± 0.11	5.7 ± 0.36	27.2 ± 0.62	0.6 ± 0.12	10.2 ± 0.51	19.8 ± 0.25	30.0 ± 0.32
BL-12	0.8 ± 0.06	0.9 ± 0.11	0.6 ± 0.02	0.8 ± 0.04	0.6 ± 0.14	3.4 ± 0.18	21.0 ± 0.58	0.5 ± 0.02	7.2 ± 0.32	22.5 ± 0.28	41.7 ± 0.62

[a]Values are mean ± SD. See Table 8 for blends.

TABLE 10
Slip Point and Solid Fat Content of the Products Made by Lipozyme-Catalyzed Interestification of Some Blends of the Stearin Fraction and Liquid Oils Like SFO and SBO[a,b]

Blend no.	Composition of the blend (% w/w)	Slip point (°C)	SFC by NMR at °C		
			10	20	30
BL-7	$BOST_{25}$ + SFO (70:30)[c]	32.6 ± 0.16 (40.0 ± 0.12)	37.7 ± 0.24 (45.1 ± 0.49)	21.2 ± 0.08 (30.6 ± 0.64)	10.8 ± 0.11 (19.7 ± 0.15)
BL-10	$BOST_{25}$ + SBO (70:30)	35.1 ± 0.18 (38.0 ± 0.30)	44.4 ± 0.27 (50.2 ± 0.52)	26.9 ± 0.32 (35.3 ± 0.49)	14.6 ± (24.0) ±

[a]Values are mean ± SD. See Tables 1 and 4 for abbreviations.
[b]Conditions: lipase, *Mucor miehei;* temperature, 60°C; time, 5 h.
[c]Parentheses represent the values of the corresponding blends before interesterification.