Physico-Chemical Characteristics of Palm-Based Oil Blends for the Production of Reduced Fat Spreads

Habi Mat Dian Noor Lida [a,*] and A. RahimMd. Ali[b]

[a]Palm Oil Research Institute of Malaysia, Ministry of Primary Industries, No. 6, Persiaran Institusi, 43000 Kajang, Selangor, Malaysia, and [b]National University of Malaysia, 43600 Bangi, Selangor, Malaysia

ABSTRACT: The effect of blending and interesterification on the physicochemical characteristics of fat blends containing palm oil products was studied. The characteristics of the palm-based blends were tailored to resemble oil blends extracted from commercial reduced fat spreads (RFS). The commercial products were found to contain up to 20.4% *trans* fatty acids, whereas the palm-based blends were free of *trans* fatty acids. Slip melting point of the blends varied from 26.0–32.0°C for tub, and 30.0–33.0°C for block RFS. Solid fat content at 5 and 10°C (refrigeration temperature), respectively, varied from 10.9–19.7% and 8.5–17.6% for tub, and 28.2–38.6% and 20.8–33.5% for block RFS. Melting enthalpy of the tub RFS varied from 35.0–54.3 J/g and that of block RFS varied from 58.0–75.4 J/g. To produce block RFS, 65% palm oil (PO) and 18% palm kernel olein (PKOo) could be added in a ternary blend with sunflower oil (SFO), but only 47% PO and 10% PKOo are suggested for tub RFS. Higher proportion of PO, i.e., 72% for block RFS and 65% for tub RFS, could be used after the ternary blend was interesterified. Although a ternary blend of palm olein (POo)/SFO/PKOo was not suitable for RFS formulation, after interesterification as much as 90% POo and 26% PKOo could be used in the block RFS formulation. For tub RFS a maximum of 30% POo was found suitable.
JAOCS 75, 1625–1631 (1998).

KEY WORDS: Chemical interesterification, differential scanning calorimetry, palm kernel olein, palm oil, palm olein IV60, reduced fat spreads, ternary blends.

Influenced by official dietary guidelines, product pricing structure, and evolving consumer life styles, the market for fat spreads is undergoing radical changes. The general trend toward reduced fat consumption is being achieved somewhat by the use of reduced fat spreads (RFS). In addition, the demand for convenience (e.g., spreadable at refrigeration temperature) and health (inclusion of polyunsaturated fat and absence of *trans* fatty acids) is reflected in the composition of the fat spreads available in the market today.

RFS normally contain 41 to 60% fat (1,2) and are used chiefly for spreading on bread (1). In RFS, the fat/oil, al-though a small constituent in the emulsion, exerts a major influence. It affects the sensory properties and consumer acceptability by imparting palatability, texture, and nutritive value. The texture, i.e., the consistency, plasticity, and structure, is the most important characteristic of RFS and is primarily determined by the physical properties of the fats and oils used. The formulation of fat/oil phase is based primarily on the relationship between specific physical measurements, in particular the solid fat content (SFC), and the composition of the fat/oil blend. Processing conditions exert a secondary influence on the formulation of the fat/oil phase (2); these will not be discussed in this paper.

SFC, i.e., the amount of fat crystals in the blends, is responsible for many product characteristics including general appearance, ease of packing, organoleptic properties, ease of spreading, and oil exudation. The SFC between 4 and 10°C determines the ease of spreading of the product at refrigeration temperature. An SFC of not greater than 32% at 10°C is essential for good spreadability at refrigeration temperature. The SFC at 20 and 22°C determines the product's stability and resistance to oil exudation at room temperature; a value of not less than 10% is essential to prevent oiling off. The SFC between 35 and 37°C determines the thickness and flavor release properties of the RFS in the mouth (2,3).

Besides the amount of solid fat, the crystalline form of the fat/oil blend is also very important. The primary forms are α, β′, and β. The β′ is a metastable form, but it is the most desirable form because it provides a fine arrangement and a large surface area of solid crystals. This is what structures the liquid oil and stabilizes water droplets most effectively. The β form, although the most stable, is not desirable in large amounts because the large crystals of this arrangement will result in a coarse and grainy texture (4).

Palm oil (PO), which tends to crystallize as β′, is an attractive option when blending ingredients for fat spreads production. It also contains a substantial proportion of higher-melting triglycerides (with a relatively low solid content at 10°C), and this combination is particularly favorable for formulating fat spreads for semitropical climates. In temperate regions, PO should be added with other fats as the solid/temperature characteristics of PO alone do not result in products that melt

quickly on the palate, and relatively slow crystallization properties can result in a rather brittle structure. To improve the melting properties, PO may be interesterified with fats that contain shorter-chain fatty acids, such as palm kernel oil, to give blends with quicker melting characteristics. Palm olein (POo) may also be used extensively in these formulations (1).

Although PO, palm kernel oil, and their products are commonly used in the preparation of blends for yellow fat spreads, reports on blending of these fats in the preparation of RFS, especially those involving multicomponent systems, and correlating the physical characteristics of such blends are not available. The lack of this information has caused difficulties in determining the optimal proportion of each fat required for specific RFS. The objective of this work was to study the physicochemical characteristics and interactions that occur in a model of ternary systems containing PO or POo, with palm kernel olein (PKOo) and sunflower oil (SFO), with respect to the palm oil-based RFS formulation.

MATERIALS AND METHODS

Commercial samples of PO, POo IV60, PKOo, and SFO were obtained from Lam Soon Malaysia Sdn. Bhd., Petaling Jaya, Malaysia. These oils were blended in various ratios (Table 1) in a ternary system of PO/SFO/PKOo and POo/SFO/ PKOo according to the method of Md. Ali and Dimick (5). The blends were subjected to chemical interesterification under the following conditions: temperature, 110°C; catalyst, 0.2% sodium methoxide; reaction time, 30 min; stirring speed, 500 rpm. The blends were then studied for their physicochemical properties such as fatty acid composition (FAC), slip melting point (SMP), polymorphic behavior, and SFC. Melting characteristics of the blends were also studied.

FAC. Oil (50 mg) was weighed into a 2-mL screw-capped vial. Hexane (1 mL) and sodium methoxide solution (0.05 mL)

TABLE 1
Ratio of PO or POo, SFO, and PKOo in the Ternary System of PO/SFO/PKOo or POo/SFO/PKOo

Code	PO(POo)/SFO/PKOo ratio
A	1:0:0
B	3:1:0
C	1:1:0
D	1:3:0
E	0:1:0
F	0:3:1
G	0:1:1
H	0:1:3
I	0:0:1
J	1:0:3
K	1:0:1
L	3:0:1
M	4:1:1
N	1:4:1
P	1:1:4
Q	1:1:1

[a]Abbreviations: PO, palm oil; POo, palm olein; SFO, sunflower oil; PKOo, palm kernel olein.

were added to the oil. The mixture was shaken with a vortex mixer and allowed to stand for 5 min (6). One microliter of the upper clear ester layer was injected into a Hewlett-Packard (Palo Alto, CA) 5890 II gas chromatograph, fitted with a polar SP-2340 (Supelco, Bellefonte, PA) capillary column (0.25 mm i.d. × 60 m × 0.2 µm). Gas chromatograph conditions were: injector temperature, 240°C; flame-ionization detector (FID), 240°C; oven temperature programming: 120–185°C at 4°C/min (7).

X-ray diffraction analysis. The polymorphic forms of fat crystals in the blends were determined by X-ray diffraction using an Enraf Nonius Diffractic X-ray generator Model FR592 (Delft, the Netherlands) and an Enraf Nonius Guinier camera Model FR552 with temperature-controlled sample holder operated at 5°C. Samples were heated at 70°C for 30 min to destroy any "memory" of earlier crystals, followed by crystallization at 0°C for 90 min. The samples were then tempered at 5°C for 2 d prior to measurement.

SMP. SMP was measured according to official AOCS method Cc 3-25 (8). SMP is the temperature at which a fat in a capillary tube placed in water becomes soft enough to slip or rise up the tube. The fat slips in the capillary tube when about 5% solid fat is present (9).

SFC. SFC was determined with a Bruker Minispec pulse Nuclear Magnetic Resonance (pNMR) Analyser Model No. 120 (Rheinstetten, Germany). The PORIM parallel method was used, in which the sample in the NMR tube was first melted at 70°C for 30 min, chilled at 0°C for 90 min, and then held at each measuring temperature for 30 min prior to measurement (10).

Differential scanning calorimetry (DSC). The melting profile was determined using a Perkin-Elmer Differential Scanning Calorimeter Model DSC-7 (Perkin-Elmer, Norwalk, CT). The instrument was attached to a data processing unit (Perkin-Elmer Thermal Data Station). Calibration was undertaken with an indium standard. About 7 mg of a precisely weighed (± 0.005 mg) fat sample was placed in the sealed DSC pan and was melted at 70°C for 30 min before cooling to 0°C, after which it was held for 90 min before being transferred to the DSC head. The pan was held at –50°C for 5 min prior to measurement. DSC melting curves were recorded at a heating rate of 10°C/min from –50°C to a maximum temperature of 60°C.

Statistical analysis. Analyses of general linear models (GLM) and response surface were performed using SASV5 Package on an IBM (White Plains, NY) computer (5). R^2 values, which indicate model fits of each of the constructed ternary diagrams (Figs. 2–8) were determined and were found to be greater than 0.95.

Comparisons of the physicochemical properties were made with oils extracted from RFS samples purchased in 1995 from supermarkets in the United States.

RESULTS AND DISCUSSION

Characteristics of commercial RSF. FAC. Both types of commercial RFS showed similar FAC profiles. The products gen-

TABLE 2
Fatty Acid Composition of Commercial Reduced Fat Spread Blends and Those of the Native Oils Used in This Study[a]

	Fatty acid composition [mean] (%)					
Fatty acid	Tub RFS (n = 11)	Block RFS (n = 9)	PO	POo	PKOo	SFO
Caproic [$C_{6:0}$]					0.3	
Caprylic [$C_{8:0}$]					4.3	
Capric [$C_{10:0}$]					3.6	
Lauric [$C_{12:0}$]					44.8	
Myristic [$C_{14:0}$]	0.1–0.2 [0.1]	0.1–0.2 [0.1]	1.0	1.0	14.1	0.1
Palmitic [$C_{16:0}$]	6.1–10.3 [9.0]	8.2–10.5 [9.9]	42.9	35.8	8.4	6.3
Stearic [$C_{18:0}$]	5.2–6.9 [6.0]	6.6–8.2 [7.6]	4.4	3.8	2.5	3.7
Oleic [$C_{18:1}$]	21.8–56.5 [38.4]	37.2–55.1 [49.2]	40.8	46.0	19.4	25.1
Linoleic [$C_{18:2}$]	23.7–52.6 [40.7]	23.6–45.7 [30.2]	10.2	12.5	2.4	64.1
Linolenic [$C_{18:3}$]	1.3–8.2 [4.8]	1.1–4.4 [2.6]	0.1	0.2	0.1	0.1
Aracidic [$C_{20:0}$]	0.1–0.3 [0.2]	0.1–0.3 [0.1]	0.2	0.2	0.1	0.1
Trans	6.5–11.7 [8.7]	13.9–20.4 [17.5]				

[a]RFS, reduced fat spreads; for other abbreviations see Table 1.

erally had a high proportion of oleic as well as linoleic acids, in the range of 21.8–56.5% and 23.6–52.6%, respectively (Table 2). They also contained a high proportion of *trans* fatty acids. The *trans* FAC of the tub RFS, which was relatively lower than those of block RFS, ranged from 6.5–11.7% (mean = 8.7%), while those of block RFS ranged from 13.9–20.4% (mean = 17.5%). Judging from the *trans* FAC, it was apparent that all the commercial RFS contained some hydrogenated fats.

Table 2 also shows the FAC of the PO, POo, PKOo, and SFO. The PO and POo were characterized by a higher content of palmitic and oleic acids. Lauric, myristic, and oleic acids were the major fatty acids in PKOo. PKOo also contained appreciable amounts of short-chain fatty acids, e.g., caprylic and capric acid. The SFO was high in oleic and linoleic acids.

SMP. All the commercial products had SMP below body temperature. Generally SMP of the tub RFS was slightly lower than those of block RFS, ranging from 26.0–32.0°C (mean = 30.0°C), and from 30.0–33.0°C (mean = 31.8°C), respectively.

SFC. Table 3 shows the SFC profiles of the commercial samples. Data on SFC at 5 and 10°C are more of our concern, as they indicate spreadability at refrigeration temperature. The tub RFS had SFC ranging from 10.9–19.7% (mean = 15.9%) at 5°C. At 10°C, the SFC ranged from 8.5–17.6%

with a mean of 13.0%. The block RFS had a relatively higher SFC at 5 and 10°C, with means of 33.8 and 29.0%, respectively. None of the RFS had SFC of more than 5% at 35°C.
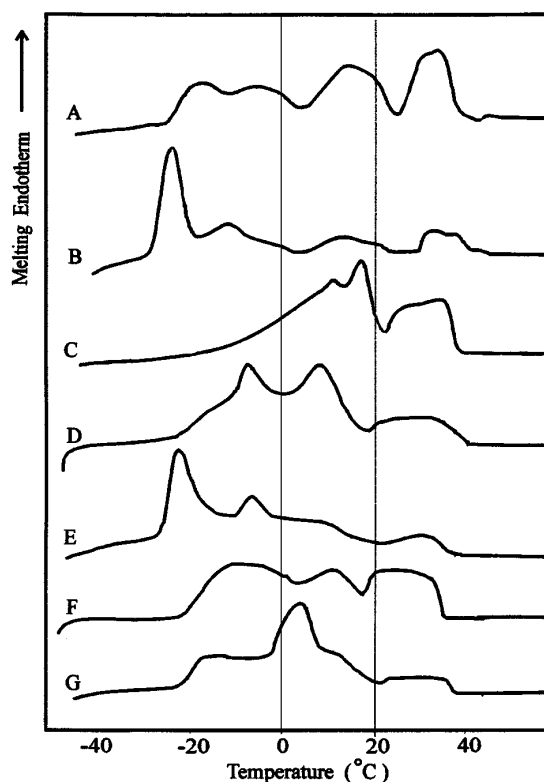
FIG. 1. Differential scanning calorimetry thermograms of commercial reduced fat spreads (RFS) and experimental blends which had similar characteristics to those of commercial products. (A) Commercial block RFS; (B) commercial tub RFS; (C) AMF; (D) PO/SFO/PKOo 4:1:1; (E) PO/SFO/PKOo 1:1:0; (F) interesterified PO/SFO/ PKOo 4:1:1; (G) interesterified POo/SFO/ PKOo 3:1:0. Abbreviations: AMF, an hydrous milk fat; PO, palm oil; SFO, sunflower oil; PKOo, palm kernel olein; POo, palm olein.

TABLE 3
Solid Fat Content Profiles of Commercial RFS Blends[a]

Measurement temperature (°C)	Solid fat content [mean] (%)	
	Tub RFS (n = 11)	Block RFS (n = 9)
5	10.9–19.7 [15.9]	28.2–38.6 [32.9]
10	8.5–17.6 [13.0]	20.8–33.5 [27.4]
15	6.6–12.5 [9.9]	13.9–26.4 [20.3]
20	4.9–9.5 [7.2]	9.8–18.6 [13.9]
25	2.5–5.9 [4.3]	6.6–12.1 [8.5]
30	1.5–2.9 [2.4]	4.0–6.9 [4.8]
35	0–0.7 [0.4]	0–1.1 [0.7]

[a]For abbreviation see Table 2.

TABLE 4
Polymorphic Form(s) of Noninteresterified (non-IE) and Interesterified (IE) Blends of PO/SFO/PKOo and POo/SFO/PKOo[a]

| | | Polymorphic form(s) | | | |
| | PO(POo)/SFO/PKOo | PO/SFO/PKOo | | POo/SFO/PKOo | |
Code	ratio	Non-IE	IE	Non-IE	IE
A	1:0:0	β′	β > β′	β >> β′	β′ > β
B	3:1:0	β′ > β	β > β′	β′ >> β	β >> β′
C	1:1:0	β′	β >> β′	Liquid	β >> β′
D	1:3:0	Liquid	Liquid	Liquid	Liquid
E	0:1:0	Liquid	Liquid	Liquid	Liquid
F	0:3:1	Liquid	Liquid	Liquid	Liquid
G	0:1:1	β′ >>> β	β′	β′ >>> β	β′
H	0:1:3	β′	β′	β′	β′
I	0:0:1	β′	β′	β′	β′
J	1:0:3	β′	β′	β′	β′
K	1:0:1	β′	β′	β′ > β	β′
L	3:0:1	β′	β′	β′	β′
M	4:1:1	β′	β′ = β	β′	β′
N	1:4:1	β′	β′	Liquid	Liquid
P	1:1:4	β′	β′	β′	β′
Q	1:1:1	β′	β′	β′	β′ >> β

[a]For abbreviations see Table 1.

Fats exhibit their SMP when the SFC is reduced to 5% (9). This indicates that all the samples were able to melt completely in the mouth during mastication.

DSC. Typical examples of DSC melting thermograms for commercial tub and block RFS are shown in Figures 1A and B, respectively. Both types of RFS showed endothermic heat flow over a wide range during scanning from –50 to 60°C, indicating the presence of low-melting (<0°C), middle-melting (about 5°C), and high-melting (>20°C) fractions. The content of high-melting fraction was much lower in the tub RFS than in the block RFS. The tub RFS also had lower melting enthalpy, ranging from 35.0–54.3 J/g (mean = 50.9 J/g), while the melting enthalpy of the block RFS ranged from 58.0–75.4 J/g with a mean of 71.9 J/g. The melting enthalpy of all samples, however, was generally lower than those of anhydrous milk fat (AMF) (80.1 J/g), indicating that they were softer than butter. This was expected, since AMF contains less low-melting fractions than the commercial RFS (Fig. 1C).

Characteristics of PO-based oil blends. X-ray diffraction analysis. The polymorphic crystal behavior of the PO-based blends is displayed in Table 4. Results indicated that except for blends D, E, and F, which were liquid at 5°C, other blends of PO/SFO/PKOo were stable in β′ crystalline form. This is consistent with what was reported by Timms (11,12). According to Timms, the stable polymorph of PO is normally β′-2, although it contains high proportions of symmetrical triglycerides, particularly POP (31.4%) (13), and significant amounts of PPO, PLinP (10%), and PPP (6%), where P = palmitate, O = oleate, and Lin = linoleate. POP cannot achieve its stable β-3 form in the presence of PPO and PLinP. The PPP forms a solid solution with POP and also does not seem able to exhibit its stable β-2 form (12).

In the 100% POo, more β crystalline form was observed.

Most probably, this is because POo does not contain PPP, which has a tendency to inhibit the transformation of POP from the metastable (β′) to the stable (β) form. Addition of PKOo into the blends promoted stabilization in the β′ crystalline form. This is also consistent with what was reported previously by Timms (11). According to Timms, lauric fats tend to possess a stable β′ polymorph because of their mixed chainlength triglycerides, which are due, in turn, to the presence of various chainlength fatty acids. In the case of PKOo, it comprised about 4.6% short-chain fatty acids (C_6–C_8), 62.5% medium-chain fatty acids (C_{10}–C_{14}), and 32.9% long-chain fatty acids (C_{16}–C_{20}) (Table 2). When POo and PKOo were blended, the triglyceride mixture of the blends became more complex, and the tendency of the blends to crystallize in β polymorphic form declined.

SMP. Figure 2A shows the iso-lines of SMP for the PO/SFO/PKOo blends. Results show that PO increased, whereas SFO reduced, the SMP. The lowering of SMP was largely due to the presence of a high content of polyunsaturated fatty acids in the SFO (Table 2).

Iso-lines of SMP at 30 and 33°C were drawn on Figure 2A based on the SMP range for the commercial block RFS discussed previously. Similarly, iso-lines of SMP at 26 and 32°C were drawn based on the SMP range for the commercial tub RFS. Considering this characteristic, in order to produce a block RFS, the maximum amount of PO and PKOo that could be added in the ternary blend was estimated to be 85 and 30%, respectively. For the tub type, the amount of PO and PKOo could be as high as 80 and 60%, respectively. Too high a PKOo content is undesirable, since it will induce a sharp melting profile at about 20–25°C (SFC figures not given).

Figure 2B indicates that in the POo/SFO/PKOo blends, the increase in SMP was induced mainly by the amount of PKOo present. None of them, however, could be used in an RFS for-
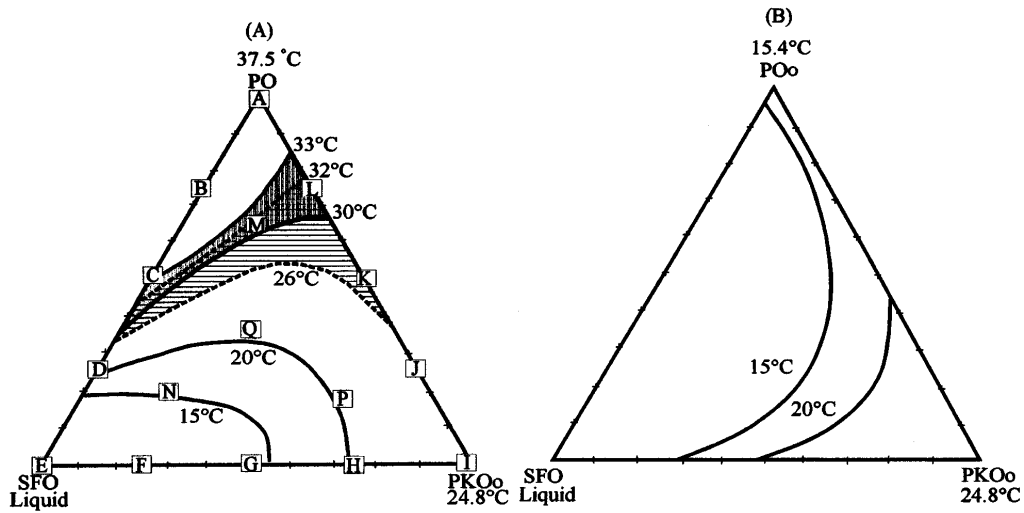
FIG. 2. Iso-line diagram of slip melting point of the PO-based oil blends.

mulation, since their SMP were lower than the minimum range (<26°C) detected in the commercial samples studied.

SFC. Spreadability of a fat is primarily determined by its SFC profile. Figure 3 shows the superimposed iso-lines at 5 and 10°C for the PO/SFO/PKOo blend that represent the range of commercial block and tub RFS. These temperatures were selected because the data obtained could provide information on fat spreadability immediately after removal from the refrigerator. SFC iso-line diagrams for POo/SFO/PKOo blends are not given since SMP analysis showed that none of them could be used for RFS formulation.

Figure 3 shows that SFC at 5°C for the tub-type commercial samples ranged between 10.9 (line Tmin@5) to 19.7% (line Tmax@5), while SFC at 10°C ranged between 8.5 (line Tmin@10) and 17.6% (line Tmax@10). For the block-type commercial samples, the SFC at 5°C ranged between 28.2 (line Bmin@5) and 38.6% (line Bmax@5), while SFC at 10°, C

ranged from 20.8 (line Bmin@10) to 33.5% (line Bmax@10). Shaded areas within the diagram indicate the possible formulation range for each type of RFS. SFC data superimposed on SMP (Fig. 4) indicate that a suitable formulation for block RFS is located close to blend code M (Table 1), i.e., PO/SFO/PKOo 4:1:1. For the tub RFS it is located between blend codes C and D, i.e., PO/SFO/PKOo 1:1:0 and PO/SFO/PKOo 1:3:0, respectively. As can be seen from the DSC thermogram in Figure 1, line D, the melting profile of blend code M was quite similar to that of AMF (Fig. 1, line C). However, it had a lower proportion of high-melting fraction, and instead had a higher proportion of low-melting fraction resembling the commercial block RFS (Fig. 1, line A). The melting thermogram of blend code C (Fig. 1, line E) was almost identical to that of commercial tub RFS (Fig. 1, line B).
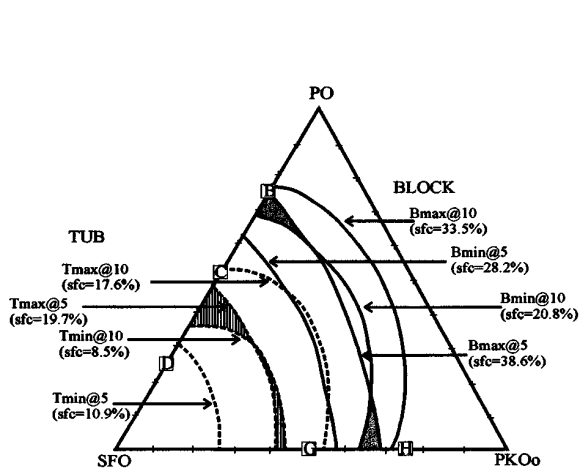

FIG. 3. Superimposed iso-line diagram of solid fat content (SFC) at 5 and 10°C of the blends of PO/SFO/PKOo. For abbreviations see Figure 1.
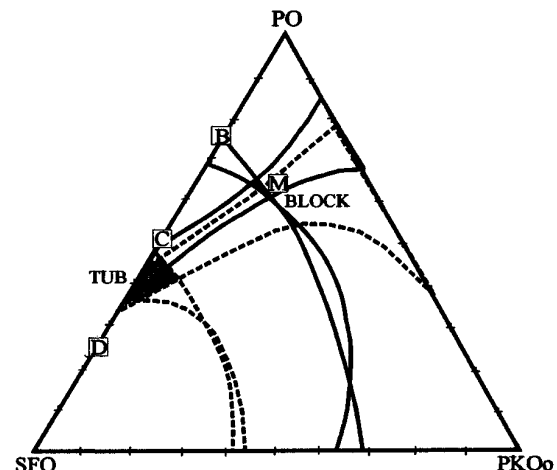

FIG. 4. Superimposed iso-line diagram of SFC with slip melting point of the blends of PO/SFO/PKOo. For abbreviations see Figures 1 and 3.
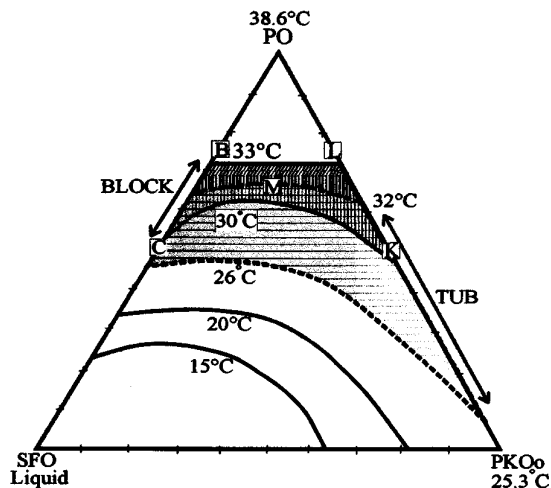
FIG. 5. Iso-line diagram of slip melting point of the interesterified blends of PO/SFO/PKOo. For abbreviations see Figure 1.

Considering both SMP and SFC profiles, it can be concluded that in order to produce a block RFS, the maximum amount of PO and PKOo that could be added in the ternary blends of PO/SFO/PKOo was about 65 and 18%, respectively. For the tub RFS, less PO and PKOo should be incorporated, i.e., 47 and 10%, respectively.

Characteristics of interesterified PO-based oil blends. X-ray diffraction analysis. In the absence of PKOo, more β crystalline form than β′ was observed in both ternary blends of PO/SFO/PKOo and POo/SFO/PKOo. This could be due to the fact that PO and POo are rich in palmitic and oleic acid. According to Duns (14), the molecular rearrangement that takes place in interesterification undoubtedly reduces the proportion of the native symmetrical triglyceride of POP, and that of PPO increases. This phenomenon facilitates the development of β-2 compound formation attributed to interaction be-
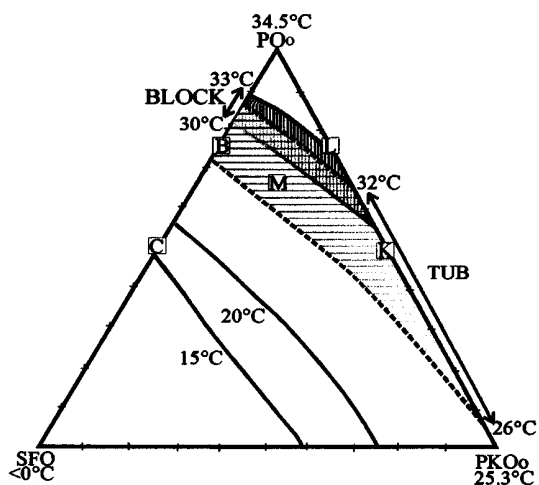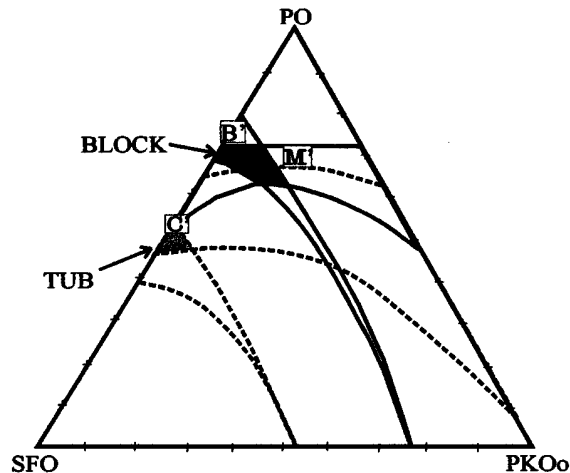

FIG. 7. Superimposed data of solid fat content at 5 and 10°C with slip melting point of the blends of interesterified PO/SFO/PKOo. For abbreviations see Figure 1.

tween the POP (stable in β-3 polymorph) and PPO (stable in β′-3 polymorph), as described by Timms (11). Compound formation may be regarded as the transformation of a mixture of two triglycerides of different polymorphs into a single new polymorph. Blends which contain PKOo were found to stabilize in the β′ crystalline form for reasons discussed earlier.

SMP. Figure 5 shows the SMP iso-lines for the interesterified PO/SFO/PKOo blends. Although there was only a modest change in the SMP of PO and PKOo after interesterification, more PKOo but less PO could be added to the blends for making RFS. The maximum amounts of PO and PKOo that could be added were about 72 and 50% for block RFS and 65 and 90% for tub RFS, respectively. On the other hand, interesterification considerably increased the SMP of POo. Consequently, the iso-line patterns within the ternary blend were

FIG. 6. Iso-line diagram of slip melting point of the interesterified blends of POo/SFO/PKOo. For abbreviations see Figure 1.
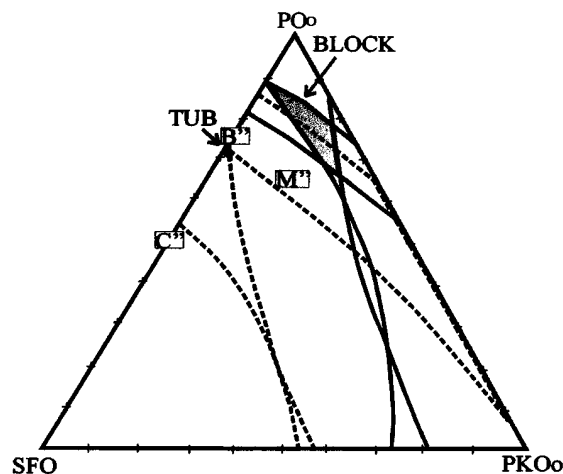

FIG. 8. Superimposed data of solid fat content at 5 and 10°C with slip melting point of the blends of interesterified PO/SFO/PKOo. For abbreviations see Figure 1.

altered drastically (Fig. 6). Results indicate that after inter-esterification, to produce a block RFS, the maximum amounts of POo and PKOo that could be added in the ternary blend were 90 and 43%, respectively. For the tub RFS, the amounts of POo and PKOo could be as high as 87 and 90%, respectively. A high content of SFO (>20% for block RFS, and >30% for tub RFS), however, would result in a product that was too soft.

SFC. Figure 7 shows the superimposed iso-lines of SFC at 5 and 10°C with SMP, for the interesterified PO/SFO/PKOo blends that delineate the range of commercial tub and block RFS, respectively. The diagram indicates that suitable formulation for block RFS is located between blend codes M′ and B′, i.e., PO/SFO/PKOo 4:1:1 and PO/SFO/PKOo 3:1:0. For tub RFS it is located close to blend code C′, i.e., PO/SFO/PKOo 1:1:0. Results indicate that generally there was only a modest change in optimal formulation after interesterification. However, direct blending provides a wider choice for tub RFS formulation, whereas after interesterification a wider choice for block RFS formulation was observed.

Suitable formulations for RFS could be obtained from the POo-based blends shown in Figure 8. Tub RFS could be formulated using the blend of POo/SFO/PKOo close to blend code B″ 3:1:0. The shaded area located between blend codes A″ (100% POo) and M″ 4:1:1 was suitable for block RFS. DSC thermograms of the blends are shown in Figure 1, lines F and G. Blend code M″ had a melting profile resembling commercial block RFS, but with a greater proportion of both high- and low-melting fractions. Blend code B″ had a lower proportion of high-melting fraction, similar to the commercial tub RFS.

After interesterification, higher proportions of PO and POo could be used in RFS formulation. In order to produce block RFS, the maximal amount of PO that could be incorporated in the ternary blend of PO/SFO/PKOo was about 72%. For tub RFS, the maximal amount was about 65%. In the ternary blend of POo/SFO/PKOo, a maximal amount of about 90% POo could be used for block RFS formulation. For the tub RFS, a maximum of about 30% POo is suggested.

ACKNOWLEDGMENTS

REFERENCES

1. Moran, D.P.J., Reduced Calorie Spreads, *PORIM Technology* No. 15, Palm Oil Research Institute of Malaysia, Kuala Lumpur, (1993).
2. Charteris, W., and K. Keogh, Fats and Oils in Table Spreads, *Lipid Technol. 3(1)*:16–22 (1991).
3. Krawczyk, G.R., G.S. Buliga, D.T. Bertrand, and W.M. Humphreys, Reviewing the Technology of Low Fat Spreads, *IN-FORM 7*:635–639 (1996).
4. Hoffmann, G., Production of Edible Fat Products of High Fat Content, in *The Chemistry and Technology of Edible Oils and Fats and Their High Fat Products*, Academic Press, San Diego, California, 1989, pp. 279–338.
5. Md. Ali, A.R., and P.S. Dimick, Thermal Analysis of Palm Mid Fraction, Cocoa Butter and Milk Fat Blends by Differential Scanning Calorimetry, *J. Am. Oil Chem. Soc. 71*:299–302 (1994).
6. Timms, R.E., Artifact Peaks in the Preparation and Gas–Liquid Chromatographic Determination of Methyl Esters, *Aust. J. Dairy Technol. 33*:4–6 (1978).
7. *PORIM Test Methods*, Palm Oil Research Institute of Malaysia, Kuala Lumpur, 1995, pp. 92–101.
8. *Official and Recommended Practices of the American Oil Chemists' Society*, edited by R.O. Walker, AOCS, Champaign, 1980, Vol. 1.
9. Timms, R.E., Physical Properties of Oils and Mixtures of Oils, *J. Am. Oil Chem. Soc. 62*:241–248 (1985).
10. *PORIM Test Methods*, Palm Oil Research Institute of Malaysia, Kuala Lumpur, 1995, pp. 134–142.
11. Timms, R.E., Phase Behaviour of Fats and Their Mixtures, *Prog. Lipid Res. 23*:1–38 (1984).
12. Timms, R.E., Crystallization Behavior of Palm Oil, *Symposium Proceedings: New Developments in Palm Oil*, edited by K.G. Berger, Palm Oil Research Institute of Malaysia, Kuala Lumpur, 1990, pp. 38–44.
13. Nor Aini, I., M.S. Embong, A. Aminah, A.R. Md. Ali, and C.H. Che Maimon, Physical Characteristics of Shortenings Based on Modified Palm Oil, Milk Fat and Low Melting Milk Fat Fraction, *Fat Sci. Technol. 97*:253–260 (1995).
14. Duns, M.L., Palm Oil in Margarines and Shortenings, *J. Am. Oil Chem. Soc. 62*:408–410 (1985).