Physico-chemical Characteristics of Palm-based Oil Blends for Ice Cream

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INTRODUCTION

Palm oil (PO) and palm kernel oil (PKO) are natural products that have been consumed for many decades. PO is used worldwide as cooking oils and mixed in fat blends for the manufacture of a wide variety of food products. As they are partially solid, PO and its products have desirable physical and chemical characteristics for many food applications including margarine, shortening, vanaspati, ice cream, filled milk and whipped cream.

Dairy fats - cream, butter and anhydrous milk fat (AMF) are widely used in the production of ice cream. They are derived from milk. Milk fat is the major fat in ice cream, contains about 70% saturated fatty acids and has high cholesterol content. Most countries require the use of dairy fat in ice cream, but others like the United Kingdom and Finland, allow substitution with vegetable fats. In the United States, a product made with vegetable fat must be labelled 'Mellorine'. In many Asian countries where there is a limited supply of milk, the higher prices of dairy products have led to growing substitution with vegetable fats for making ice cream.

Ice cream can be formulated using various vegetable oils such as PO, PKO, coconut oil (CNO) and hydrogenated soyabean oil (HSBO). The product range includes premium, standard and low fat ice cream, cone and stick novelty. Innovation has extended the range to low calorie, high fibre and cultured ice cream, which contain lower fat than legally required for ice cream. PKO and CNO are very desirable fats as they have rapid meltdown characteristics. PKO also contains short and medium chain triacylglycerols (TAGs), similar to those in butterfat, that confer the right mouth-feel and melting characteristics (Berger, 1994).

PO and PKO are already used in the local manufacture of ice cream. Some internationally renowned manufacturers use both PO and PKO with other oil blends. The use of PO and its fractions is increasing as they are cheaper than milk fat. These oils can have their characteristics such as melting point, solid fat content, fatty acid, TAG composition and iodine value tailored to specific requirements. Moreover, PO and its fractions have the advantages of being in abundant supply with uniform quality, longer shelf-life and better consistency at room temperature compared to milk fat (Wan Rosnani and Nor Aini, 2000). They also have good natural colour, a bland taste and physical properties similar to milk fat, which allow them to be used as substitutes with no marked changes in the flavour or consistency of the products made.

Nevertheless, incorporating some milk fat and emulsifier still improves the flavour and viscosity of the ice cream mix. The changes in viscosity have been correlated with the changes in the rates of freezing and ice crystal growth in ice cream mixes. Both the viscosity and ice crystal size will affect the texture of the ice cream.

The aim of this study was to determine the effects of blending PO, PKO and AMF on the physico-chemical characteristics of ice cream fats.

MATERIALS AND METHODS

Materials

Refined, bleached and deodorized PO (RBDPO) and refined, bleached and deodorized PKO (RBDPKO) were obtained from Lam Soon (M) Sdn Bhd (Petaling Jaya, Selangor, Malaysia). AMF and spray dried (medium heat) skimmed milk powder were purchased from Promac Enterprise (M) Sdn Bhd (Klang, Selangor,

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Malaysia). Commercial blends of emulsifiers and stabilizers were obtained from Danisco (Denmark). Sucrose was purchased from a local supermarket.

Blend Preparation

Melted PO or PKO was mixed with AMF in the proportion 30:70, 50:50 and 70:30 (w/w).

Slip Melting Point

The slip melting point (SMP) was determined according to MPOB Test Method, p 4.2 (MPOB, 2005).

Solid Fat Content

Solid fat content (SFC) was determined by pulse nuclear magnetic resonance (NMR) using a Bruker NMS 120 Mini Spec NMR analyser (Karlsruhe, Germany) according to MPOB Test Method, p4.9 (MPOB, 2005).

Triacylglycerol Composition

Triacylglycerol composition (TAG) was determined according to MPOB Test Method, p3.3 (MPOB, 2005).

Fatty Acid Composition

Fatty acid composition (FAC) was determined according to MPOB Test Method, p.3.5 (MPOB, 2005).

Thermal Analysis by Differential Scanning Calorimetry

Differential scanning calorimetry (DSC) was carried out using a model DSC-7 calorimeter (Perkin-Elmer, Norwalk, Connecticut, USA), which was attached to a data processing unit (Perkin-Elmer Thermal Data Station). The instrument was equipped with a dry box with nitrogen purging and an external cooling source (Intra-cooler). Calibrations were carried out using the Indium standard. A sample of fat (3-5 mg) was placed in the DSC pan and melted at 70°C for 30 min before cooling to 0°C, where it was held for 90 min before transferring to the DSC head. The pan was held at –50°C for 5 min prior to measurement. The DSC melting and crystallization curves were recorded at a heating rate of 5°C per min from –50°C to 60°C.

Statistical Analysis

Statistical analysis was done using analysis of variance (ANOVA) on Microsoft Excel 2000. The significance level was set at 95%.

RESULTS AND DISCUSSION

Effect of Blending on the Slip Melting Point

The slip melting point (SMP) of PO, PKO and AMF were 36.4°C, 27.7°C and 34.2°C, respectively (*Table 1*). Addition of AMF to PO lowered its SMP to 29.7°C (PO:AMF 30:70), 30.5°C (PO:AMF 50:50) and 34.3°C (PO:AMF 70:30). Addition of AMF to PKO also lowered its SMP to 26.6°C (PKO:AMF 30:70), 25.8°C (PKO:AMF 50:50) and 25.5°C (PKO: AMF 70:30). In the PKO-based blends, higher AMF increased the SMP of the blends, while in the PO-based blends, higher AMF reduced the SMP, mostly due to more of the shorter fatty acid chains in AMF. The addition of 30% to 70% AMF to PO and PKO were found suitable for ice cream fat as the SMPs was dropped below body temperature. The ice cream produced from these fats had a slightly buttery flavour, which should improve consumer acceptance.

Adding more AMF to PKO slightly decreased the melting point of the blends and imparted a quicker melt in the mouth. The low SMP of PKO was due to its high content of C12 - a medium chain triacylglycerol (MCT). According to Madsen (1984), the best result for fats/oils in ice cream is achieved with hardened coconut oil or PKO having a melting point of 30°C to 33°C. The blends of PO:AMF 50:50

TABLE 1. SLIP MELTING POINTS (SMP) OF DIFFERENT ICE CREAM FATS AFTER 16 hr TEMPERING

Ice cream fat	SMP (°C*) (16 hr)
Palm oil (PO)	36.40
Palm kernel oil (PKO)	27.70
Anhydrous milk fat (AMF)	32.40
PO:AMF 30:70	29.70
PO:AMF 50:50	30.50
PO:AMF 70:30	34.30
PKO:AMF 30:70	26.60
PKO:AMF 50:50	25.80
PKO:AMF 70:30	25.50

*Mean of triplicate determinations.

and PO:AMF 70:30 were the most suitable blends to replace hardened CNO or PKO as ice cream fat.

Effect of Blending on Solid Fat Content

Figures 1a and *1b* show the SFC profiles of the fats used in ice cream. PKO with a higher solid content at 5°C (70%) had a very steep solid fat profile compared to PO (65% SFC at 5°C) and AMF (60% SFC at 5°C). PO had a similar solids profile but with much flatter solids fat curve than AMF. PO thus had a much wider plasticity range and higher solids content at lower temperature. AMF had a lower solid content at all temperatures compared to PKO. At 35°C, PO and AMF had about 4% solids while PKO was totally liquid. All the three fats/oils are suitable for ice cream as they exhibit narrow plastic ranges and low solids contents at body temperature.

Addition of 30%, 50% and 70% AMF to PO decreased the SFC of the blends at 5°C from 66% to 47%, 51% and 56%, respectively. At higher temperature (37°C), the SFC was less than 2% in all the samples. Addition of 30%, 50% and 70% AMF to PKO also decreased the SFC from 73.2% to 66.4%, 62.1% and 61.8%, respectively. Blending PKO with AMF changed its solid fat profile from a steep to a flatter curve. The blend of 70% AMF in PKO had about 0.04% solids at 35°C.

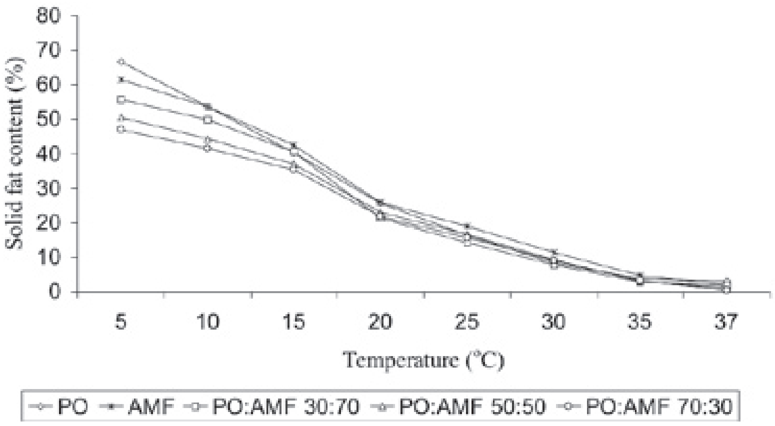

Figure 1a. Solid fat profiles of palm oil (PO), anhydrous milk fat (AMF) and PO:AMF blends at different ratios.

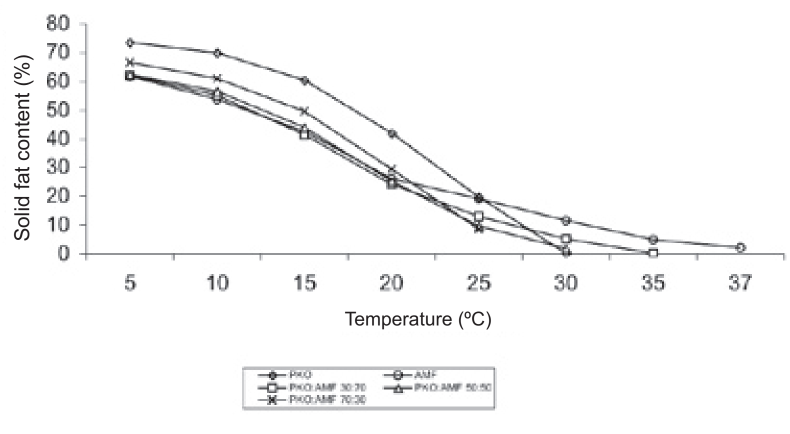

Figure 1b. Solid fat profiles of palm kernel oil (PKO), anhydrous milk fat (AMF) and PKO:AMF blends at different ratios.

Effect of Blending on the Triaclyglycerol and Fatty Acid Composition

Tables 2a and *2b* show the TAG composition and FAC of fats and oils used in ice cream. The TAG composition determines the physical characteristics of fats and oils, and can affect their crystallization behaviour. PO contained higher C50 (41.8%) and C52 (37.2%) whereas AMF and PKO are higher in C38 (17.2% and 15.9%) and C36 (14.0% and 20.6%), respectively. Addition of 30%, 50% and 70% AMF to PO decreased the long chain TAG C50 and C52 to 31.8%, 24.0% and 17.2%, and 30.4%, 21.8% and 15.7% respectively.

Addition of 30%, 50% and 70% AMF to PKO decreased the short chain TAG C36 of PKO from 20% to 9.6%, 10.9% and 11.1%, respectively. The long chain TAGs also decreased - C48 from 6.3% to 5.7%, 5.3% and 4.8%. However, TAG C50 in PKO increased from 2.8% to 4.1%, 5% and 5.8% and TAG C52 from 3.6% to 4.5%, 5.1% and 5.7%, respectively.

AMF is rich in C14:0 (13%), C16:0 (35.6%), C18:0 (12.3%) and C18:1 (16.9%) acids. Lower C16:0, C18:1 and C18:2 and a higher amount of C18:0 are found in AMF compared to PO. AMF and PKO contain a wider range of fatty acids, including short, medium and long chain fatty acids. The major fatty acids in PKO are C12:0 (50.3%), C14:0 (16.1%) and C18:1 (13.8%). No other fatty acid is present at more than 10% and the predominance of lauric acid gives PKO its sharp melting property, meaning hardness at room temperature caused by its low melting point (Pantzaris and Ahmad, 2001). In the PKO-based blends, additions of 30%, 50% and 70% AMF decreased C12:0 from 50% to 38%, 29.0% and 19.1% while C16:0 increased from 8.4% to 15.8%, 21.4% and 26.8%, respectively. The unsaturated fatty acids, C18:1 and C:18:2, also increased with the AMF content.

PO contains a balance of saturated and unsaturated fatty acids C16:0 (44.9%) and C18:1 (38.8%) making it a semi-solid without any need to add hydrogenated fat. PO used in ice cream can, therefore, be free of *trans* fatty acids. Addition of 30%, 50% and 70% AMF to PO increased the shorter chain fatty acids C6:0 and C8:0 (from the short chain TAG and MCT), and C10:0 and C12:0 in the PO-based blends.

TABLE 2a. TRIACYLGLYCEROLS (TAG) OF PALM OIL (PO), ANHYDROUS MILK FAT (AMF), PALM KERNEL OIL (PKO) AND THEIR BLENDS AT DIFFERENT RATIOS

			Blend of PO:AMF		
Triacylglycerol	PO (%)	AMF (%)	30:70 (%)	50:50 (%)	70:30 (%)
C32	-	3.6	1.9	1.3	0.8
C34	-	7.8	4.2	3.1	1.8
C36	-	14	8.3	6.0	3.4
C38	-	17.2	10.9	7.3	3.9
C40	-	13.0	8.4	5.6	2.9
C42	-	7.2	5.0	3.4	1.9
C44	0.1	6.5	4.4	2.1	1.8
C46	1.1	6.2	4.8	3.6	2.5
C48	11.8	4.2	7.1	8.7	8.6
C50	41.8	7.1	17.2	24	31.8
C52	37.2	6.6	15.7	21.8	30.4
C54	7.4	3.3	1.4	3.2	6.8
			Blend of PKO:AMF		
Triacylglycerol	PKO (%)	AMF (%)	30:70 (%)	50:50 (%)	70:30 (%)
C32	6.1	3.6	3.4	2.7	2.6
C34	8.7	7.8	4.9	4.8	5.2
C36	20.6	14	11.1	10.9	9.6
C38	15.9	17.2	10.5	11.8	11.3
C40	10.0	13.0	7.3	8.8	9.3
C42	9.6	7.2	5.5	6.2	6.1
C44	7.2	6.5	4.3	5.0	5.5
C46	5.9	6.2	4.4	4.9	6.2
C48	6.3	4.2	4.8	5.3	5.7
C50	2.8	7.1	5.8	5.0	4.1
C52	3.6	6.6	5.7	5.1	4.5
C54	1.9	3.3	1.8	1.1	2.3

Effect of Blending on the Melting and Crystallization Profiles

Figures 2a and *2b* are the DSC thermographs of the melting and crystallization of the individual fats and oils used in ice cream mix. PKO has a melting profile resembling that of AMF, while PO a crystallization profile resembling that of AMF. The melting profile shows endothermic heat flow over a wide range during scanning from -30ºC to 40ºC, indicating the presence of low melting (< 0ºC), middle melting (5ºC) and high melting (> 20ºC) fractions. PO has double peaks of melting while PKO double peaks of crystallization. The sharp crystallization peaks of PKO were due to the high solids content at lower temperatures *(Figure 3b)*. From their thermal characteristics, PO and PKO can be separated under controlled thermal conditions into two components - stearin (solid fraction) and olein (liquid fraction). The presence of solids in these oils at any temperature was due to crystallization occurring as a consequence of their chemical characteristics. The different molecular structures of the TAGs resulted in different chemical characteristics, which, in turn, imparted the different crystallization and melting behaviours of the oils.

The melting and cooling thermographs of the PO:AMF blends are shown in *Figures 3a* and *3b*, respectively. The multiple phases in the melting curves were caused by crystals of the various fat molecules and the less stable polymorphs. The heating curve showed that the blends at all

TABLE 2b. FATTY ACID COMPOSITIONS (FAC) OF PALM OIL (PO), ANHYDROUS MILK FAT (AMF), PALM KERNEL OIL (PKO) AND THEIR BLENDS AT DIFFERENT RATIOS

			Blend of PO:AMF		
Fatty acid	PO (%)	AMF (%)	30:70 (%)	50:50 (%)	70:30 (%)
C6 : 0	-	2.6	1.5	1.0	1.2
C8 : 0	-	1.9	1.0	0.7	0.8
C10 : 0	-	3.7	2.2	1.6	1.8
C12 : 0	0.2	4.3	2.7	2.1	2.3
C14 : 0	0.9	13.0	8.6	6.8	7.3
C16 : 0	44.9	35.6	34.1	38.6	34.2
C18 : 0	4.2	12.3	12.5	7.5	12.7
C18 : 1	38.8	16.9	26.0	30.7	29.2
C18 : 2	10.2	0.7	5.7	6.4	5.5
			Blend of PKO:AMF		
Fatty acid	PKO (%)	AMF (%)	30:70 (%)	50:50 (%)	70:30 (%)
C6 : 0	0.3	2.6	1.9	1.4	0.9
C8 : 0	4.5	1.9	2.9	3.3	3.8
C10 : 0	3.8	3.7	3.7	3.8	3.7
C12 : 0	50.3	4.3	19.1	29.0	37.6
C14 : 0	16.1	13.0	13.9	14.8	15.2
C16 : 0	8.4	35.6	26.8	21.4	15.8
C18 : 0	2.2	12.3	9.0	7.0	4.9
C18 : 1	13.8	16.9	14.9	14.0	14.2
C18 : 2	0.4	0.7	0.6	0.4	0.5

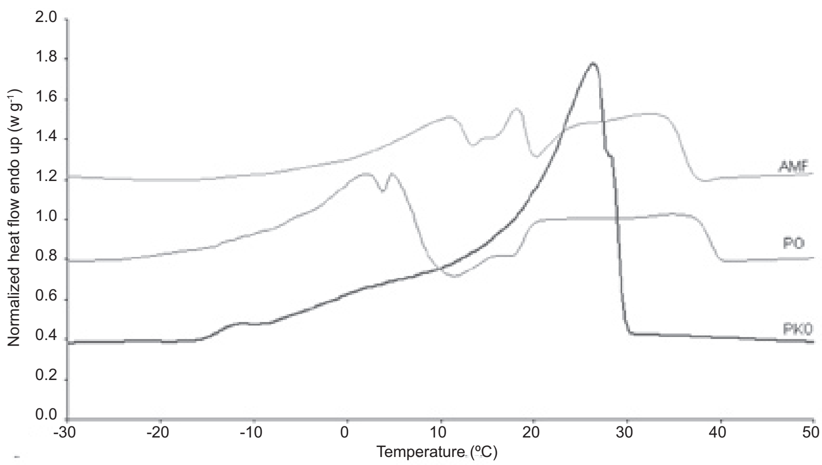

Figure 2a. Heating thermograms of palm oil (PO), palm kernel oil (PKO) and anhydrous milk fat (AMF).

ratios melted between –10°C to 40°C. At body temperature (37°C), the blends should therefore melt almost completely. These data are consistent with the SFC values in *Figure 2b* where the PO:AMF blends at ratios 30:70, 50:50 and 70:30 contained 1.70%, 0.86% and 0.54% solids, respectively, at 37°C.

The melting range of PO showed a similar profile as those of its blends. The DSC measurements of this oil are generally related to its SFC values. Crystallization of the high- and low-melting TAGs appeared as multiple negative peaks in the cooling curve. The crystallization temperature of the oil was slightly higher than that reported in the literature (Siew, 2000) for typical PO of 20°C to –10°C. This was due to the higher content of C16:0 and C18:1 in the PO used in this study.

The melting and cooling thermographs of the PKO:AMF blends are shown in *Figures 4a* and *4b*, respectively. The multiple phases in the melting curve were caused by the formation of different crystals and rearrangement of the less stable forms to more stable polymorphs. The heating curves showed that the blends of oils at all ratios melted between –20°C to 45°C. At body temperature, the blend melted almost completely. These data are consistent with the SFC values in *Figure 2b* where the PKO:AMF blends at all ratios (30:70, 50:50 and 70:30) did not contain any solid at 37°C. The melting range of PKO was narrower - from 10°C to 30°C - compared to those of its blends. The DSC measurements of these fats generally corresponded to their SFC values.

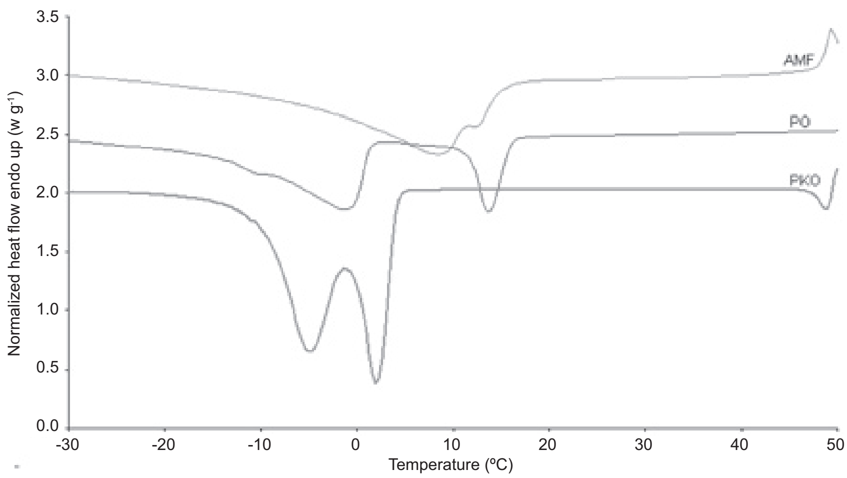

Figure 2b. Cooling thermograms of palm oil (PO), palm kernel oil (PKO) and anhydrous milk fat (AMF).

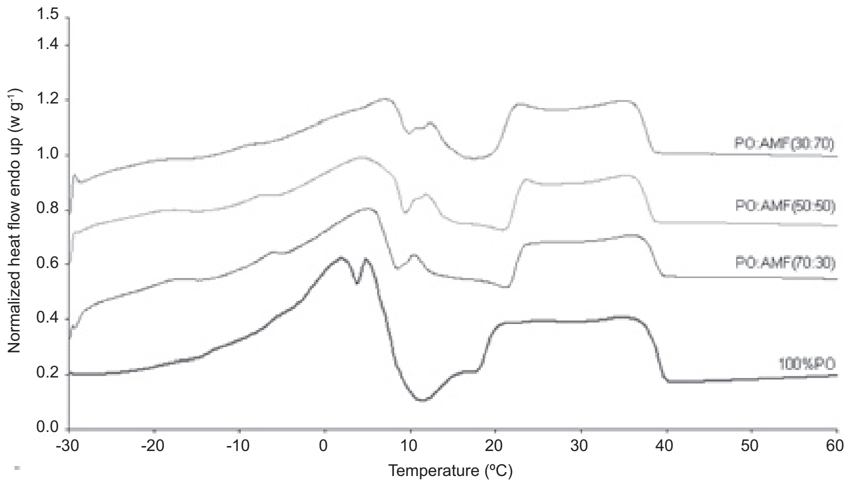

Figure 3a. Heating thermograms of palm oil (PO) and palm oil (PO): anhydrous milk fat (AMF) blends at different ratios.

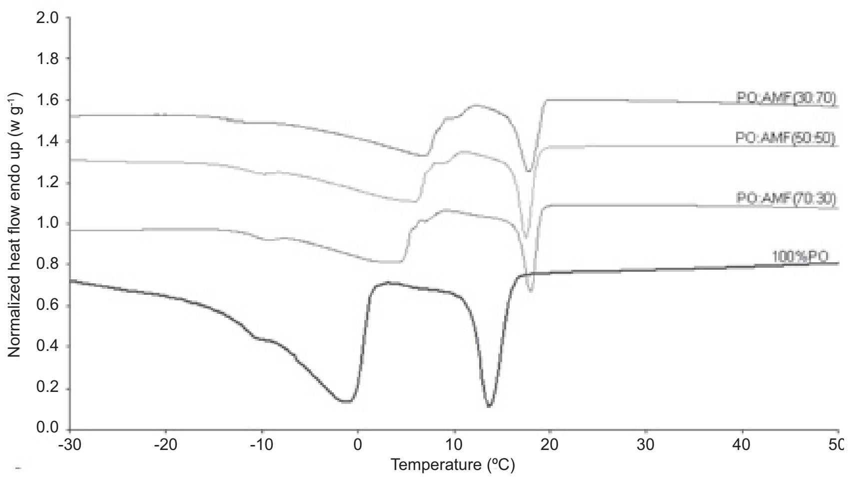

Figure 3b. Cooling thermograms of palm oil (PO) and palm oil (PO): anhydrous milk fat (AMF) blends at different ratios.

CONCLUSION

Blends of PKO with AMF were found suitable as fat for ice cream due to their narrow plastic range with high solids at low temperature and being almost fully liquid above 37°C. The blend PO:AMF 30:70 had a similar solid fat profile to AMF. Addition of 30% to 70% AMF to PO and PKO produced blends suitable for ice cream fat as their SMPs were lower than body temperature. The DSC heating curves showed that the blends at all ratios melted between –20°C to 45°C. At body temperature, the blends were almost completely melted.

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REFERENCES

BERGER, K G (1994). The use of palm and palm kernel oils in ice cream and whipped cream product. *PORIM Information Series.*

MPOB (2005). *MPOB Test Method.* MPOB, Bangi. 395 pp.

MADSEN, J (1984). The use of vegetable fats in dairy products. *Lipid Forum Symposium.* Goteborg, Swedish Food Institute. p. 45-48.

PANTZARIS, T P and M J AHMAD. (2001). Properties and utilization of palm kernel oil. *Palm Oil Developments No. 35:* 11-23.

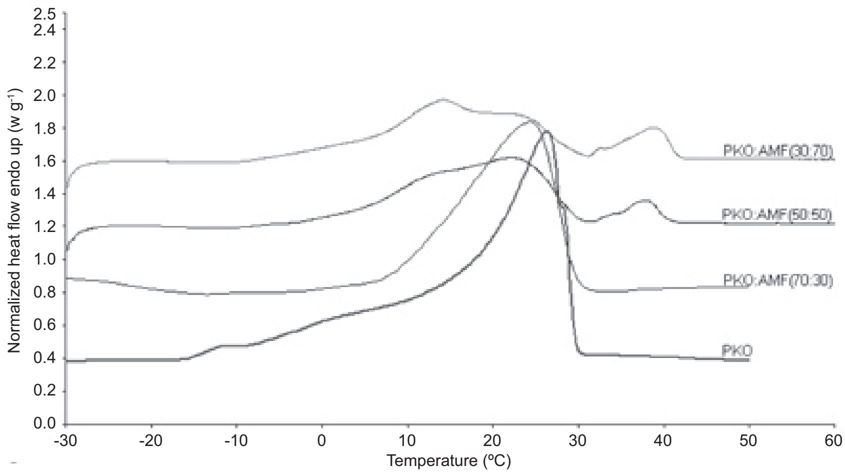

Figure 4a. Heating thermograms of palm kernel oil (PKO) and palm kernel oil (PKO): anhydrous milk fat (AMF) blends at different ratios.

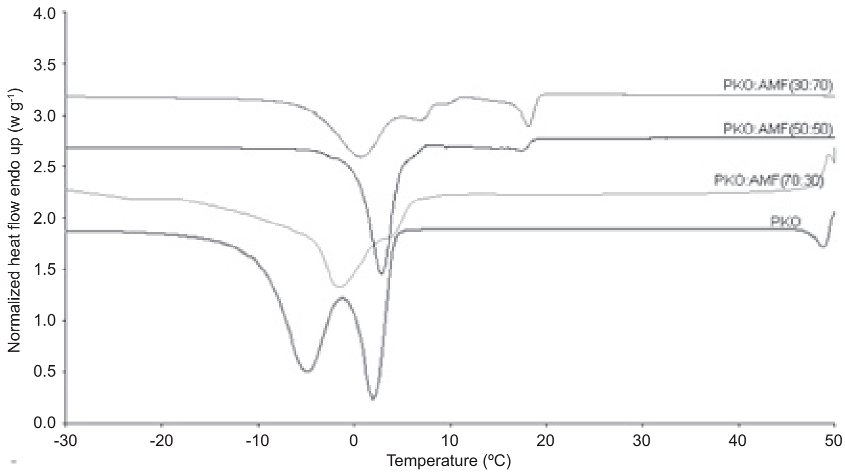

Figure 4b. Cooling thermograms of palm kernel oil (PKO) and palm kernel oil (PKO): anhydrous milk fat (AMF) blends at different ratios.

SIEW, W L (2000). Chemical and physical characteristics of palm oil and palm kernel oils and their crystalisation behaviour. *Lectures on Palm Oil and Its Uses* (M S Zainon and M Johari eds.). MPOB, Bangi. p. 64-85.

WAN ROSNANI, A I and NOR AINI, I (2000). Application of palm products in ice cream. *Palm Oil Developments No. 33*: 8-12.