

# Characteristics of Eutectic Compositions of Restructured Palm Oil Olein, Palm Kernel Oil and Their Mixtures

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Received: 3 May 2010/Revised: 16 April 2011/Accepted: 22 April 2011/Published online: 17 May 2011  
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**Abstract** The physico-chemical characteristics of blends of palm olein and palm kernel oil which were further modified by chemical interesterification were studied. The slip melting points of non-interesterified blends were 19.7, 16.2, 14.5, 14.5 and 14.4 °C while those of the chemically interesterified blends were 17.7, 16.2, 19.8, 18.7 and 18.7 °C at 40, 30, 20, 10 and 0% palm kernel oil, respectively. Chemical interesterification lowered the solid fat content of the pure samples and blends across different temperatures except 90% palm olein at 15 °C where the solid fat content was higher than for non-interesterified samples. Palm kernel oil, palm olein and their blends before and after chemical interesterification, crystallized mainly in the  $\beta'$  form. However, chemical interesterification modified the microstructure from a combination of fat particles with void regions of crystalline materials to fat particles without regions of void crystalline materials. Palm olein and palm kernel oil blends are mainly used for food preparation in Nigeria. This study has shown that there are no significant differences in the physical and chemical properties of non-chemically interesterified and chemically interesterified blends of palm olein and palm kernel oil. This implies that blending of palm olein and palm kernel

oil without chemical interesterification can provide the fluidity desirable at ambient temperatures for food applications in the tropics.

**Keywords** Palm olein · Palm kernel oil · Eutectic mixtures · Chemical interesterification · Blending · Slip melting point

## Introduction

A shortage in the supply of frying oils in Nigeria has led to the packaging of palm kernel oil and its blends with palm oil and palm olein for frying purposes. Palm kernel oil however congeals at room temperature (25 °C) and is therefore difficult to pour. Also, the cost of dry fractionation and membrane filtration equipment is equivalent to the refining (dry degumming, bleaching, deacidification/deodorization) equipment and this cost combination is sometimes above the investment capacity of the average refiner in Nigeria. Therefore, only the refining equipment is procured. The cost of pure palm olein for household frying is exorbitant for the average consumer. Therefore, this cost is reduced when palm olein is blended with palm kernel oil. Since household frying is the major market for vegetable oils in Nigeria, refiners produce eutectic mixtures of palm kernel oil and palm oil to avoid fractionation. Currently, blends containing 70% palm kernel oil and 30% palm oil are refined and packaged for food frying. This blend ratio is however not the optimum ratio to achieve the highest eutectic and desirable sensory effects. Improvement in sensory and chemical characteristics of palm oil and palm kernel oil products designed for household consumption can be achieved through appropriate blending, randomization (interesterification and intraesterification), fractionation, etc.

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A recent trend has been the increased use of interesterification to manipulate the properties of fats and oils [1].

Blending helps to extend the range of applications of oils and fats. Although very little is known about the cumulative effect of the physico-chemical properties of the oils present in a blend, blending has proved very useful in meeting consumer expectation in food products. Being able to relate predictive changes in physical properties to observed changes in chemical properties is important in optimizing a blend to perfectly suit an application. In blending therefore, it is important to know certain information about the fat intended for blending such as melting point, fatty acid composition, solid fat content at different temperatures, polymorphism, etc. Blending has been used to overcome the health problems posed by hydrogenated fats. In an effort to enhance the structural (e.g., creaminess), and crystallization habit ( $\beta'$  crystals) of fats intended for shortening production, hydrogenation has been used over the years. In recent times, it is common knowledge that the elaidic acid (*trans* fatty acid) formed during hydrogenation accelerate cholesterolemic problems [2, 3]. With blending of refined and unrefined oils, desirable product characteristics are achievable without the risk of *trans* fatty acids formation.

Interesterification is an acyl rearrangement reaction used to modify triglyceride melting and crystallization properties while maintaining their nutritional quality (although some nutritional quality may be lost by removal of beneficial fatty acids from the *sn*-2 position of a triglyceride molecule). Interesterification causes a rearrangement of fatty acids within, and between triacylglycerols on a glycerol backbone [4]. In enzymatic interesterification, biocatalysts such as microbial lipases are used for the acyl migration around the glyceride molecule. The acyl exchange can proceed in a controlled manner by replacing the chemical catalysts with biocatalysts [4, 5].

Currently, interesterification is still the least practiced fat modification technology probably because the current areas of fats and oils product applications demand other fat modification technologies such as hydrogenation, fractionation, blending etc [6]. However, as the debate about the health aspects of *trans* fatty acids continues, it will certainly become of increasing importance. It is applied directly on refined, hydrogenated, or fractionated oils and fats. As a result of interesterification, the overall melting profile is made smoother and the plasticity is improved as the crystallization properties are changed. Interesterification thus offers a great potential for the production of a wide variety of specialty fats with improved functional and nutritional properties.

Eutectic phenomenon is observed in fat mixtures that are not compatible with each other [7, 8]. Eutectic interactions are said to have taken place in fats and oils when the physical characteristics such as melting point of components of a fat blend do not represent linear combinations of

the components [9]. Eutectic interaction in the binary system of palm oil and palm kernel oil was previously reported by Timms [10]. Eutectic interaction tends to occur when the fats differ in molecular volume, shape or polymorph. Eutectic mixtures of palm oil and palm kernel oil are important in the Nigerian market because they eliminate the need for a fractionation equipment and therefore aid the production of low-cost frying oil.

The objective of this study therefore was to investigate the physico-chemical characteristic of palm olein and palm kernel oil eutectic mixtures restructured by chemical interesterification.

## Materials and Methods

### Materials

The fats used in this experiment were refined, bleached and deodorized palm olein and crude palm kernel oil. Samples were obtained from FFM Berhad, Malaysia and PRESCO Nig. Plc. The palm kernel oil was refined in a short path distillation unit. All chemicals were purchased from Fisher Scientific (St. Louis, MO) and Sigma Chemical Co. (St. Louis, MO) and used without further purification. The catalyst, sodium methoxide, was stored at room temperature under nitrogen atmosphere and in the dark to prevent decomposition.

### Short-Path Distillation

Short-path distillation of palm kernel oil free fatty acids was carried out with a KDL-4 (UIC Inc., Joliet, IL) unit under the following conditions: heating oil temperature, 185 °C; cooling water temperature, 20 °C; pump vacuum, <100 mTorr; feed rate, 100 mL/h. The oil was passed through the system once to reduce the free fatty acid content from 2 to 0.07%. Free fatty acid content was determined according to AOCS official method, Ca 5a-40 [11]. Percent free fatty acid was expressed in terms of lauric acid and oleic acid for palm kernel oil and palm olein, respectively.

### Blend Preparation

Liquefied palm kernel oil and palm olein were mixed in proportions: 40, 30, 20 and 10% palm kernel oil in palm olein.

### Chemical Interesterification

Portions (25 g) of the blends were mixed with 0.3% sodium methoxide and randomized under vacuum for

30 min at  $80 \pm 2$  °C in a 125 ml Buchner flask stirred with an electromagnetic stirrer bar. The reaction was terminated by adding 20 ml of 20% citric acid solution in a separatory funnel and water washed with  $3 \times 94$  ml of de-ionized water. Residual water was removed with 10% (wt of oil) anhydrous sodium sulfate followed by vacuum drying at 120 °C for 3 min.

#### Purification of Reaction Products by Counter Gradient Solid Phase Extraction Column Chromatography (CGSPECC)

Silica gel ( $18 \pm 0.1$  g) was weighed and 7 g transferred into the mortar to which 5 g sample (liquid) was added. The silica gel and samples were mixed until a free flowing powder was obtained.

The bottom of the econo-column flow adaptor was covered with a Whatman glass microfiber filter of 2.4 cm diameter. The sample/silica gel mixture was transferred into the column and the remaining silica gel (11 g) was added. The column was gently tapped so that the bed would be properly packed. Another microfiber filter paper of 2.4 cm in diameter was placed on top of the bed before inserting the econo-column flow adaptor. The column was connected with size 13 Tygon tubing to the solvent reservoir through the motor drive. The solvent reservoir consisted of petroleum ether and diethyl ether in ratio 9:1. The solvent was pumped upwards through the column with a Millipore motor drive consisting of a master flex pump head (Cole-Palmer). It has three roller rotors and provides the peristaltic action to propel the solvent through the tubing. Eluted samples were collected in a series of test-tubes. The eluted samples in the test-tubes were spotted on thin layer plates to determine at what point only triglycerides were eluted. In this study, 350 mL of the solvent mixture was used to isolate most of the triglycerides which was desolventized in a rotary evaporator at about 50 °C. Thin layer chromatography solvents were petroleum ether, diethyl ether, and formic acid in ratio 60/40/1.6. Silica gel (column chromatography grade) was SELECTO scientific silica gel of particle size 21,945 and Whatman 60 A° 70–230 mesh. The experiment required about 15 min to run 250 mL solvent mixture. About 220 ml of the solvent was collected with a dead volume of about 30 mL. The samples eluted from the silica gel was 89.38% of initial sample weight.

#### Fatty acid Composition

Fatty acid composition was determined as fatty acid methyl esters (FAME). A liquid oil sample (100 mg) was measured into a test tube and 40  $\mu$ L heptadecanoic acid was added to the sample in the test tube. Methanolic-hydrochloric acid

solution (3 mL of 6% HCl in CH<sub>3</sub>OH) was added and the mixture vortexed for 1 min and then incubated for 2 h in an oven preheated to 75–80 °C. The sample was removed from the oven and chilled on ice prior to addition of 2 mL of hexane and 1 mL of 0.1MKCl solution. The mixture was vortexed for 1 min and centrifuged at 1,000 rpm for 3 min. The upper layer (hexane layer) was drawn off and dried over anhydrous sodium sulfate.

Fatty acid profiles of the test samples were analyzed with Agilent GC 6890 N equipped with a LAN communication interface board, an auto-liquid sampler, a DB-225 fused-silica capillary column ( $30 \times 0.25$  mm i.d.) (J&W Scientific, Folsom, CA) and flame ionization detector. Injector and detector temperatures were 250 and 260 °C, respectively. The column temperature was 80 °C for 3 min, 20 °C per min to 215 °C and held isothermally at 215 °C for 30 min. Data handling and processing was carried out by an on-line CHEMSTATION software. A computer program quantified the relative content of the component fatty acids as mole percent, with heptadecanoic acid as internal standard.

#### Slip Melting Point (SMP)

The SMP was determined according to AOCS Method Cc.3.25 [11]. The samples were melted and filtered through filter paper (Whatman No. 4) to remove traces of moisture. Capillary tubes were dipped in the liquid sample so that the sample rose about 10 mm high in the tubes. Samples were then chilled at once by holding the end of the capillary tube that contained the sample against ice until the sample solidified. The tubes were placed in marked test-tubes and kept in the refrigerator ( $-4$  °C) overnight. The tubes were then removed from the refrigerator and attached to the thermometer with a rubber band so that the end of the thermometer and the sample capillary tube were even. The thermometer was suspended in a 600 mL beaker of clear distilled water and the bath starting temperature was adjusted to about 4 °C with ice cubes. The heating was at the rate of about 1 °C/min with agitation. Slip melting point was taken at the temperature the column of fat was raised in the tube. All experiments were performed in triplicate.

#### Solid Fat Content (SFC)

The solid fat content was determined according to AOCS official method Cd 16b-81 [11]. The samples were heated in a 70 °C oven until liquid and 3 g of the liquid samples and reference were weighed into NMR sample tubes. The tubes were reheated to 60 °C in a water bath for about 5 min. The sample and reference tubes were transferred to a 0 °C refrigerator for 60 min. The sample and reference tubes were then transferred to a water bath, preset at the

measuring temperature. Six temperatures were used as follows: 60, 30, 25, 20, 15, and 10 °C. The samples and reference tubes were tempered at the desired temperature for 30 min, wiped with absorbent paper and placed in the NMR sample holder as quickly as possible for measurement.

### X-ray Diffraction

Samples purified by counter-gradient solid phase extraction chromatography were melted at about 60 °C, poured into rectangular plastic molds and tempered at ambient temperature for 6 h prior to treatment in a freezer for 12 h at 0 °C.

An ARL Scintag XDS 2000 (Ecublens, Switzerland) automated diffractometer was used to collect the data. The sample holder was kept at sub-ambient temperature with dry ice. The diffractometer had a  $2\theta$  configuration, a solid-state detector, and a cobalt tube as the X-ray source. Generation power for all sample runs was set at 40 kV and 40 mA. The  $2\theta$  range used was from 18° to 32°, and the scan rate was 2.0°/min.

### Microstructure

Crystal network microstructure was imaged by polarized light microscopy (PLM) using an Olympus BH light microscope. Samples were melted at 60 °C for 15 min to destroy crystal memory and 10  $\mu$ L of liquid sample were placed on a preheated glass microscope slide. A pre-heated glass cover slip was placed on top of the sample, creating a uniform thin film of approximately 20  $\mu$ m thickness. Glass slides were placed in agar in a petri dish to maintain sub-ambient temperatures during image acquisition.

Samples were then tempered at room temperature for 6 h, transferred to a refrigerator at 6 °C for 12 h and kept at 0 °C for 12 h. Images of the crystal network were acquired using a Sony XC-75 CCD video camera (Sony Corp., Atsugi-shi, Japan), an LG-2 PCI frame grabber and Scion Image software (Scion Corporation, Frederick, MD). An automatic blank field subtraction was performed using the software. Experiment was replicated thrice and twenty shots of each sample were taken.

## Results and Discussion

### Fatty Acid Composition

Table 1 shows the fatty acid composition of palm kernel oil, palm olein and their blends. Chemical interesterification did not alter the fatty acid composition of the randomized fat or fat blend. The fatty acid profile of palm

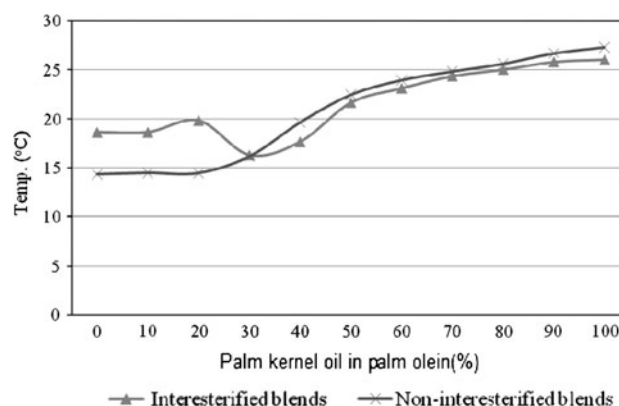
kernel oil shows that lauric acid ( $C_{12:0}$ ) and myristic acid ( $C_{14:0}$ ) predominates with a total of about 64.13% in the fatty acid pool of palm kernel oil while palmitic acid ( $C_{16:0}$ ) 31.94%, oleic acid ( $C_{18:1}$ ) 47.94% and linoleic acid ( $C_{18:2}$ ) 20.08% were the major fatty acids in palm olein with a total of 99.96% of the fatty acids as expected. This implies that palm kernel oil is a medium chain saturated fatty acid oil while palm olein is a long chain unsaturated fatty acid oil. The fatty acid profile of the blends of palm kernel oil and palm olein as expected showed that lauric and myristic acids decreased while palmitic acid, oleic acid and linoleic acids increased with the addition of palm olein. Eutectic blends of 40, 30, 20 and 10% palm kernel oil in palm olein contained mixtures of short, medium and long chain fatty acids with potentially beneficial physical, chemical and nutritional characteristics.

### Slip Melting Point

The slip melting point (SMP) measures equivalent melting temperatures. Results show that prior to interesterification, palm kernel oil had a slip melting point of 27.3 °C while palm olein had a slip melting point of 14.4 °C (Fig. 1).

By their fatty acid composition (FAC) (Table 1), palm olein is higher in unsaturated fatty acid than palm kernel oil. As expected, the slip melting point of the binary blends should decrease linearly as the proportion of palm olein increases. However, the decrease in SMP at 40, 30, 20 and 10% palm kernel oil in palm olein did not represent linear combinations of the two oils. The points at which the SMPs of the blends were lower than the SMPs of the pure components as shown in the curve (Fig. 1) are known as eutectic interaction points indicating that the two fats were not compatible with each other at those mixtures [7, 8].

In blends of non-interesterified palm kernel oil and palm olein, eutectic interaction was observed at between 40 and 10% palm kernel oil. Maximum eutectic effect was



**Fig. 1** Slip melting point of interesterified and non-interesterified blends of palm olein and palm kernel oil. **a** Chemically interesterified samples **b** non-interesterified samples

**Table 1** Fatty acid composition by gas liquid chromatography of palm kernel oil and palm olein blends

Fatty acid (mole %)	100% PKO	40% PKO	30% PKO	20% PKO	10% PKO	100% POo
C <sub>6:0</sub>	1.34 ± 0.11	0.62 ± 0.00	0.60 ± 1.44	0.435 ± 0.01	0.37 ± 0.06	0
C <sub>8:0</sub>	0.12 ± 0.01	0.05 ± 0.01	0.05 ± 0.07	0.07 ± 0.01	0.06 ± 0.01	0.11 ± 0.02
C <sub>10:0</sub>	2.35 ± 0.07	1.24 ± 0.07	1.045 ± 0.05	0.81 ± 0.01	0.53 ± 0.04	0.12 ± 0.00
C <sub>12:0</sub>	52.52 ± 0.95	28.96 ± 1.12	22.65 ± 1.45	17.96 ± 0.13	10.10 ± 0.42	1.87 ± 0.06
C <sub>14:0</sub>	17.15 ± 0.18	9.74 ± 0.20	8.08 ± 0.08	6.14 ± 0.05	3.74 ± 0.06	1.15 ± 0.01
C <sub>16:0</sub>	8.97 ± 0.16	19.52 ± 0.01	23.43 ± 0.48	24.85 ± 0.1	29.74 ± 0.81	31.00 ± 0.04
C <sub>18:0</sub>	0.39 ± 0.04	0	0.24 ± 0.17	0	0	0.05 ± 0.00
C <sub>18:1</sub>	14.58 ± 0.59	28.85 ± 1.27	30.82 ± 0.07	35.49 ± 0.18	38.96 ± 1.03	46.54 ± 0.03
C <sub>18:2</sub>	2.5 ± 0.11	10.85 ± 0.25	11.89 ± 0.63	14.65 ± 0.08	16.26 ± 0.35	19.50 ± 0.02
C <sub>18:3</sub>	0.09 ± 0.06	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.00	0.06 ± 0.00	0.08 ± 0.00
C <sub>20:1</sub>	0	0.12 ± 0.01	0.13 ± 0.02	0.17 ± 0.00	0.21 ± 0.00	0.26 ± 0.00

observed at 20% palm kernel oil in non-interesterified (NIE) blend but at 30% palm kernel oil in chemically interesterified (IE) oil blend.

After chemical interesterification, eutectic interactions were also observed but the SMP of the IE blends were generally lower than those of NIE blends until 30% palm kernel oil when the SMP of both the chemically interesterified and non-interesterified blends were the same (~16.3 °C). This report however differs from earlier observations of IE palm oil in which the SMP of IE palm oil was higher than the SMP of NIE palm oil. In this study, chemical interesterification lowered the SMP of palm kernel oil and its blend with palm olein except at 30–10% palm kernel oil in palm olein where the SMP of IE blends were higher than SMPs of NIE blends. Laning [13] and Haumann [6] observed a decrease in the dropping point and differential scanning calorimetry peaks of palm kernel oil and an increase in the dropping point of palm oil after interesterification. The reduction in the dropping point reported for randomized palm kernel oil was due to increase of triacylglycerol species with intermediate degrees of unsaturation while those of palm oil were due to increase in high melting triglycerides. The SMP of NIE palm olein and palm kernel oil were, respectively, 14.4 and 27.3 °C whereas IE palm olein and palm kernel oil had 18.7 and 26.1 °C, respectively. In a fat mixture, Timms [10] had reported that eutectic interaction tends to occur in a fat blend when the fats differ in molecular volume, shape or polymorph. SMP can therefore be used to study fat compatibility at different blending proportions. The eutectic phenomenon in this study indicated that palm kernel oil and palm olein were incompatible at mixtures of 40–10% palm kernel oil.

#### Solid Fat Content

The solid fat content (SFC), i.e. the amount of fat crystals in a fat or fat blend, is responsible for many of the spread

characteristics including general appearance, ease of packing, organoleptic properties and oil exudation. The SFC at 10 °C determines the ease of spread of the products at very low temperature conditions while the SFC at 25 °C determines the product stability and resistance to oil exudation at room temperature. The SFC at 35 °C determines the thickness and flavor release properties of the fat spread in the mouth [12].

Changes in the triglyceride profiles of mixtures of oils after interesterification are usually accompanied by changes in the SFC of the oil blends [13–18].

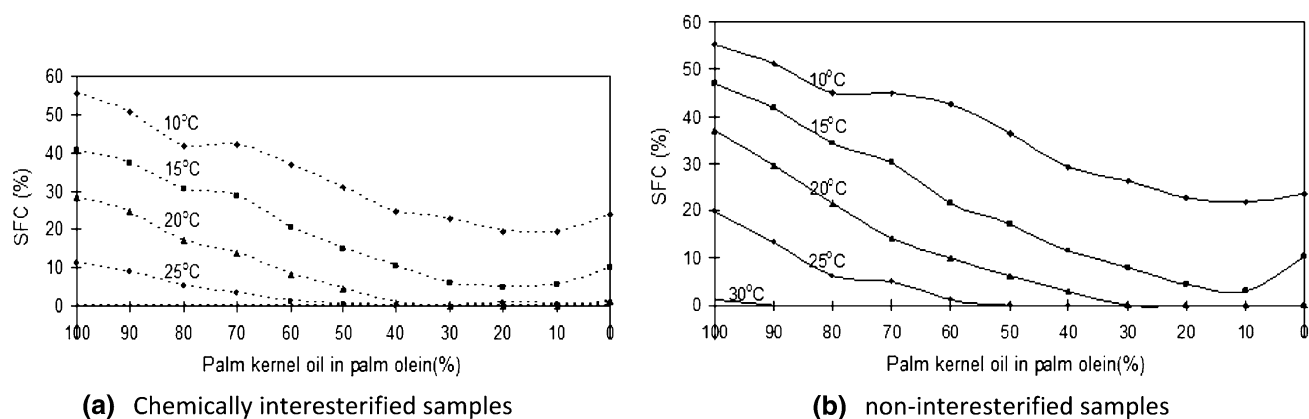
The rate of SFC evolution was dependent on both temperature and proportion of each fat in the blends (Figs. 2, 3). Eutectic phenomena were observed at blends of 40–10% of palm kernel oil depending on the temperature for the same blend ratios. For instance at 10 °C, eutectic phenomena were observed at NIE blends of 20 and 10% PKO while at 15 °C, eutectic phenomena were observed at 30, 20 and 10% PKO for NIE blends. IE blends showed eutectic compositions at 40, 30, 20 and 10% PKO. However, SFC of 20% PKO was lower than 10% PKO at 15 °C.

Chemical interesterification lowered the solid fat content of the blends across various temperatures except at 10 and 0% PKO where the proportions of palm olein were much higher and the SFC of IE blends were slightly higher than NIE blends at 15 °C. The general decrease in solid fat content of IE blend at >30%PKO is probably due to the increase of triglyceride species with intermediate degrees of unsaturation [19].

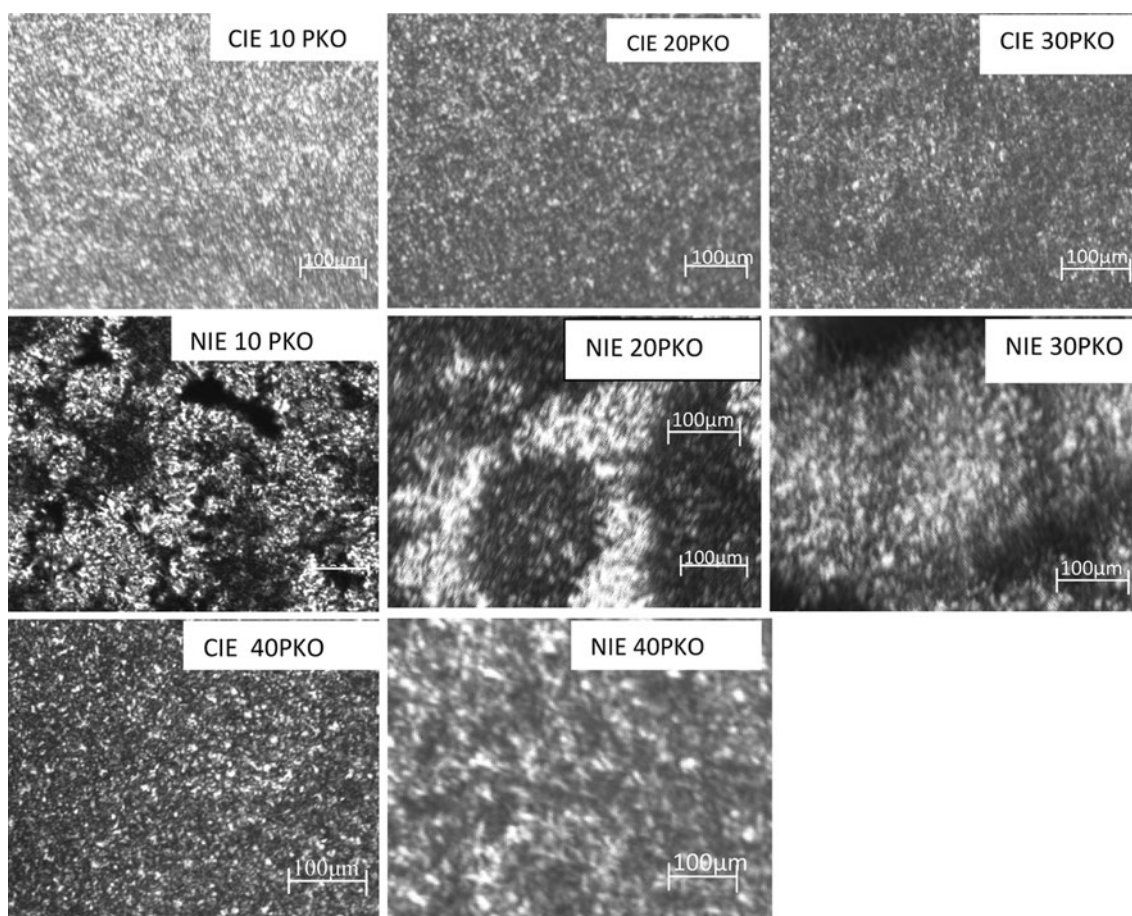
#### Polymorphism

Palm olein and palm kernel oil crystallized predominantly in the  $\beta'$  (orthorhombic perpendicular subcell) crystalline form at between 3.81 and 4.45 Å.

Palm kernel oil in its natural form possesses a stable  $\beta'$  polymorphic form because of its mixed chain length



**Fig. 2** Dependence of solid fat content on temperature and interesterified and non-interesterified blends of palm kernel oil and palm olein (a chemically interesterified samples, b non-interesterified samples)



**Fig. 3** Polarized light micrographs of chemically interesterified (CIE) and non-interesterified (NIE) palm kernel oil (PKO), palm oil olein (POo) blends of 10, 20, 30 and 40% PKO crystallized in 20 μm films under a cover-slip

triacylglycerols. The crystallization of a fat into a particular polymorphic form and further transformations depend on the ease with which the triacylglycerol molecules fit within the crystal lattice [20]. Palm kernel oil and its blends with palm olein (interesterified and non interesterified) are

therefore expected to convey a smooth texture to a products in which they are applied [21–23].

Usually, the  $\beta'$  polymorph is stabilized by diversifying the fatty acid chain length in a particular fat mixture. Variations in chain length results in a more disordered

packing near the methyl end regions, leading to less chances of a tightly knit crystal lattice being formed. As  $\beta$  crystals have the most ordered structure, a decrease in the chain length variety will increase their likelihood [24]. Palm kernel oil contains about 4.2% short chain fatty acids ( $C_6$ – $C_8$ ), 69.8% medium chain fatty acids ( $C_{10}$ – $C_{14}$ ) and 25.9% long chain fatty acids ( $C_{16}$ – $C_{20}$ ) (Table 1).

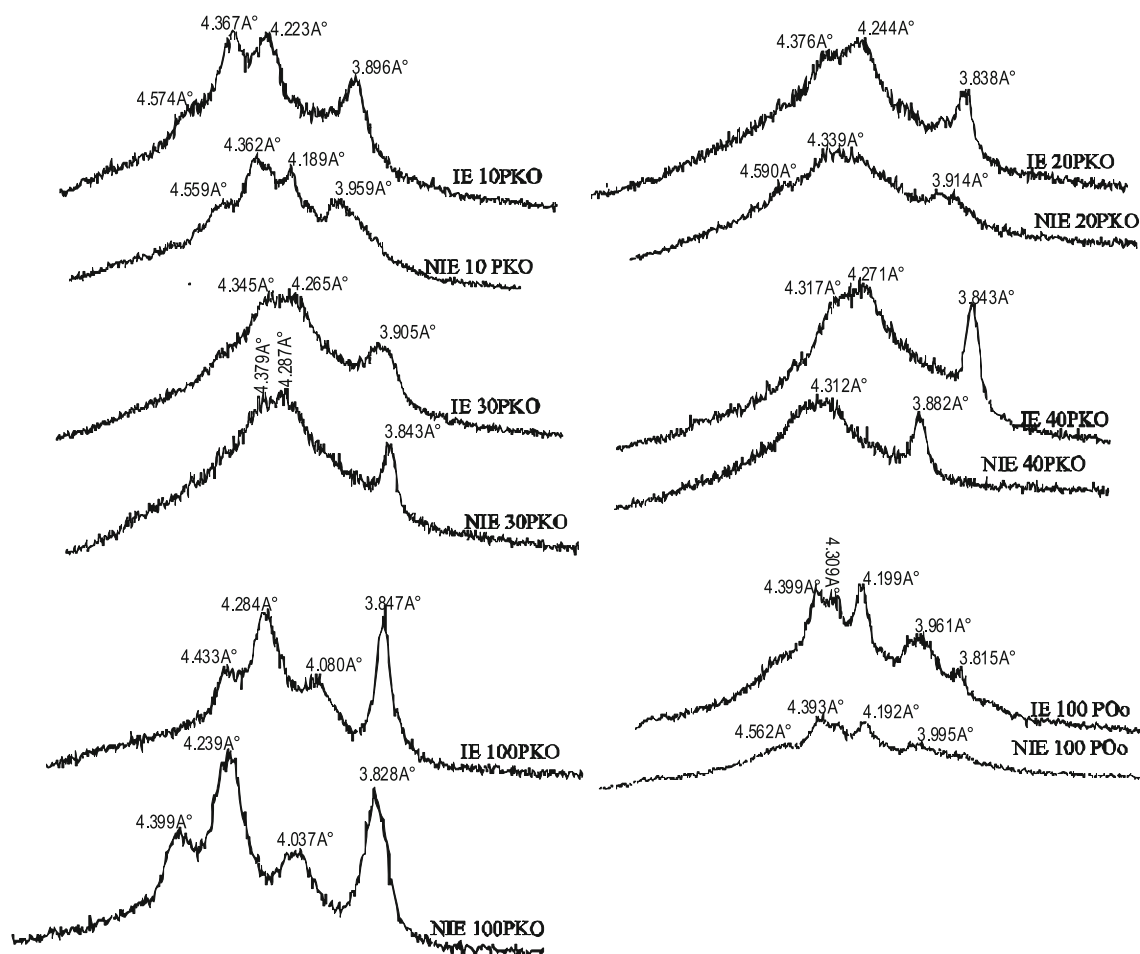
Molecular rearrangement that takes place in chemical interesterification reduces the proportion of the native symmetrical triacylglycerol thereby promoting the formation of  $\beta'$  polymorph. Since palm kernel oil is predominantly in the  $\beta'$  polymorphic form, chemical interesterification did not significantly affect the polymorphic state of the triacylglycerols in the blends. However, the peaks due to chemically interesterified palm olein, palm kernel oil and their blends were more intense indicating a higher proportion of the triacylglycerol crystals contributing to the  $\beta'$  polymorphic state.

According to Knightly [25] and Baldwin et al., [26], the  $\beta'$  form is best for fats used in bread and cakes whereas the

$\beta$  form is best for pie crusts. Where air incorporation is important,  $\beta'$  crystals in dough enhance the formation of many small bubbles and greater loaf volume whereas  $\beta$  crystals allow the incorporation of relatively little air [27].

#### Polarized Light Microscopy and Image analysis

The shape and sizes of the crystals and crystal aggregates (microstructural elements) found in a fat network is affected by the polymorphic form of the crystals to a different extent in different fats [20, 28–30]. Also, the crystal aggregates (fat particles) are affected by the configuration of the fatty acids in the triacylglycerols. Triacylglycerols that are homogenous in terms of spatial distribution and fatty acids tend to aggregate into common fat particles. Therefore, in a physical blend of different oils with non-homogenous triacylglycerols, the microstructure is a combination of fat particles as well as regions of void crystalline materials which may contain liquid fat or very small crystals. In a completely randomized fat or native fat



**Fig. 4** X-ray crystallographs of pure palm kernel oil, palm olein and their eutectic blends of 10, 20, 30, and 40% Palm kernel oil. *IE*: chemically interesterified, *NIE*: non interesterified

system where most triacylglycerols have identical fatty acids in similar spatial distribution, the microstructure is equivalent to a fat particle without regions of void crystalline materials.

The different microstructures obtained upon crystallization of palm olein, palm kernel oil and their blends are shown in Figs. 3 and 4 below. NIE blends of 10–40% palm kernel oil showed crystal aggregates as well as regions of void crystalline material, which in turn contained liquid fat or very small crystals. Particle–particle interaction between crystals of triacylglycerol with similar fatty acid structure explains the different crystal network observed in the microstructure of non-interesterified blends of 10, 20 30 and 40% palm kernel oil that resulted in a more heterogeneous spatial distribution of mass. The micrographs show that when these blends were interesterified, granular morphology composed of a large number of small crystals was observed. Chemical interesterification is known to evenly distribute the fatty acids within the reacting triacylglycerols. This gives the triacylglycerols identical characteristics and increases their affinity for each other during crystallization. Changes in microstructure of a fat resulting from its modification has been reported [31–34].

The greater the proportion of crystals and the smaller the crystal size, the firmer the product, because there is greater opportunity for crystals to inter-associate [35].

## Conclusion

Palm olein and palm kernel oil blends are mainly used for food preparation in Nigeria. This study has shown that there are no significant differences in the physical and chemical properties of non-chemically interesterified and chemically interesterified blends of palm olein and palm kernel oil. This implies that blending of palm olein and palm kernel oil without chemical interesterification can provide the fluidity desirable at ambient temperatures for food applications in the tropics.

**Acknowledgments** The authors wish to acknowledge the University of Georgia, Athens and the Nigerian Institute for Oil Palm Research for supporting this study. The supply of palm olein samples from FFM Berhad, Malaysia through Dr Lai Oi Ming of the Universiti Putra Malaysia and PRESCO Nig. Plc is gratefully acknowledged.

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