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COMPARATIVE STUDY ON PHYSICAL CHARACTERISTICS OF PALM-BASED SHORTENING AND LARD

NurIlliyin Mohamed Roslan[1], *Siti Salwa Abd Gani[1,2], Miskandar Mat Sahri[3], Uswatun Hasanah Zaidan[4], MohdIzuan Effendi Halmi[2]

[1]Halal Products Research Institute, Universiti Putra Malaysia, Putra Infoport, 43400 UPM Serdang, Selangor, Malaysia
[2]Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[3]Malaysian Palm Oil Board, No. 6, Persiaran Institusi, Bandar BaruBangi, 43000 Kajang, Selangor D.E., Malaysia
[4]Department of Biochemistry, Faculty of Biotechnology and Biomolecular, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
E-mail:*ssalwaag@upm.edu.my

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Abstract
A study was conducted to compare physical characteristics of palm-based shortening and lard. The formulation for palm-based shortening was done by blending palm fractions and soybean oil namely; F91 (70:30) and F141 (65.2: 34.8). The blended shortening and lard were compared in terms of their hardness, microstructure, thermal behavior, fatty acid content, triacylglycerol (TAG) distribution and polymorphic forms. For textural analysis, the palm-based shortening was found to display higher hardness values than lard. Microstructures of the palm-based shortening were arranged and smaller as compared to lard. In terms of melting curves, there were more peaks found in the palm-based shortening as compared with lard. The amount of palmitic acid and oleic acid of palm-based shortening were comparable to those of lard. TAG pattern of the palm-based shortening was similar to lard where mono-diunsaturated group was predominant, followed by disaturated-monounsaturated. X-ray diffraction analyses showed that palm-based shortening and lard displayed β' and β polymorphic forms.

Keywords--Palm-based shortening, lard, physical properties

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INTRODUCTION

Shortening are edible fats that have gone through a few steps of processing to produce products that possess definite physical characteristics. Shortening are primarily used in food cooking and baking. The main function of shortening is to 'shorten' or tenderize foods by interruption of fat film which prevent protein and carbohydrate components from being hardened (Devi & Khatkar, 2016). It improves texture and palatability of food as well as providing heat and energy to the body. Shortening is formulated with 100% fat from either animal or vegetable oils (Yanty*et al*., 2019). Properties differ with shortening from margarine products which included other aqueous phase blending such as water, milk products and other ingredients (Dadalı & Elmacı, 2019; Ghani *et al,.* 2019).

Lard or pork fat is normally used as shortening in food products such as cookies, cakes, pastries and bread due to its abundance. Lard has good properties such as good plasticity and bakery products' palatability (Noor Raihana *et al*., 2017; Yanty*et al*., 2012; Silva *et al*.,2011; Hugo & Roodt, 2007). Nevertheless, there are prohibitive food practices among the Muslims and Jews believers as pork is regarded as unclean and consumption of its flesh or any material derived from the animal is forbidden (NurIlliyin*et al*., 2013; Regenstein, Chaudry & Regenstein, 2003).

It is known that palm oil has become the second most consumed oil in the world since 1985, after soybean oil. Presently, palm oil remains to stand among the most commonly used vegetable oil in the world with competitive price (Anon, 2018; Islam *et al.,* 2016; Sue & Pantzaris, 2009). Palm oil balance of fatty acid content is around 48% saturated fatty acid (SFA) and 52% unsaturated (UFA). SFA content is higher than other oils like sunflower, olive or rapeseed which is known as healthy liquid oil, and below coconut oil that possess SFA of myristic and lauric (Gesteiro*et al*., 2019).Due to its abundance, a new formulation of shortening could be produced in attempt at optimizing the use of palm oil and its derivatives. In terms of effect of shortening on health, palm oil and its fractions are the most suitable fat because of its nutritional value. The demand for cost effective shortening has increased. Most vegetable oils are expensive compared to palm oil (Osorio *et al*., 2015). Hence, the present study was undertaken to compare the physical properties of palm-based shortening and lard.

MATERIALS AND METHODOLOGY

Materials

Lard used was extracted following procedures of Marikkar*et al*. (2001). Palm oil and its fractions were collected from the Malaysian Palm Oil Board, Malaysia (MPOB). While soybean oil was purchased from a supermarket in Bangi, Selangor, Malaysia. Distilled monoglyceride (DMG), a food emulsifier (Dimodan HP-M) from edible, fully hydrogenated palm-based (monopalmitin and monostearin) was purchased from Danisco Malaysia Sdn. Bhd. All chemicals used were of analytical and HPLC grade.

Preparation of Shortening

The shortenings were prepared following procedures of Abdul Azis*et al*., (2011) with some modifications. Palm-based shortenings were prepared with different compositions of palm fractions and soybean oil namely; F91 (70:30) and F141 (65.2: 34.8) with the addition of 1% DMG each. Before mixing, the fats were melted at 70°C and stirred constantly with a magnetic stirrer at 10°C for10 minutes. The prepared shortenings were kept at 5°C overnight and later stored at room temperature before being used.

Determination of Fatty Acid Contents
Fatty acid methyl ester (FAME) was prepared by dissolving 50 mg portions of shortening samples in 0.8 ml of hexane and adding 0.2 ml of 1 M sodium methoxide (PORIM, 1995) and subsequently analyzed by using a gas chromatograph (Agilent Technologies, Singapore) fitted with an FID detector. Polar capillary column DB-wax (with 0.25 mm internal diameter, 30 m length and 0.25 µm film thickness; Agilent Technology, USA) was used.

The oven temperature was programmed as follows: initial temperature of 50°C (for 1 min), programmed to increase to 200°C at 8°C /min. Both injector and detector temperatures were maintained at 200°C throughout the analysis. The carrier gas (helium) flow rate was 1.0 mL/ min and the split ratio was 58:1.

Identification of the samples' peaks was done with reference to a chromatographic profile containing FAME Standards (Supelco, Bellefonte, PA). The percentage of fatty acids was calculated as the ratio of partial area to total peaks area (Yanty, Marikkar & Miskandar, 2011).

Determination of Triacyglycerol (TAG)
The TAG composition was determined using Waters Model 2695 Liquid chromatography, equipped with a differential refractometer Model 2414 as a detector. The TAG separation was conducted by using a Zorbax RP-18 column (5 µm particle size, L × I.D. 25 cm × 4.6 mm). The mobile phase used was solvent of acetone: acetonitrile (63.5:36.5), with flow rate of 1.0 mL/min.

The oven temperature was maintained at 30°C. The injector volume was 10 µL of 5% (w/w) fat blended in chloroform. Each sample was chromatographed three times, and the data were recorded as area percentages (Yanty, Marikkar & Miskandar, 2011).

Identification of peaks of samples was done using a set of TAG standards purchased from Sigma-Aldrich (Deisehofen, Germany) as well as TAG profiles of lard (NurIlliyin*et al*., 2013), palm oil (Lida*et al*., 2002) and soybean oil (Fauzi, Rashid & Omar, 2013), as reported previously.

Texture Analysis
Determination of hardness was carried out using TA (HD plus; Stable Micro System, Surrey, UK) according to the method described by NurIlliyin*et al.*, (2013) with modifications. Before analysis, samples were taken out from 5°C storage and kept at 25°C for 15 minutes.

Hardness of the samples was performed as follows. A 5-mm cylinder (P/5) was used as probe with a 5 kg load cell. A 5 g surface trigger was attached to the probe. During the test, the probe was released to penetrate samples to a depth of 5 mm with a pre-test speed of 1mm/s, test speed of 2 mm/s, and post-test speed of 1 mm/s. The measurements were performed in triplicates for each sample.

Microscopy Analysis
Each sample was tempered on a glass slide and a glass cover slip was placed on top of the smear and was gently pressed by a finger. The microstructure was observed at 25°C by Polarized Light Microscopy (PLM) (Miskandar*et al*., 2007).

Thermal Characteristics
Thermal analysis was carried out using a Mettler Toledo differential scanning calorimeter (DSC) (Model DSC 823), equipped with a thermal analysis data station (STARe software, Version 9.0x, Schwerzenbach, Switzerland).

Before the analysis, calibration of the instrument was done using Indium as the metallic standard, based on onset temperature of fusion and heat of the indium's fusion. Nitrogen (99.99% purity) was used as the purge gas at a rate of 20 mL/min. Approximately 4-8 mg of molten sample was placed in a standard DSC aluminum pan and subsequently hermetically sealed.

An empty and hermetically sealed DSC aluminum pan was used as control. The samples were subjected to the following temperature program: 70°C isotherm for 1 min, cooled at 5 °C/min to -70°C. The samples were held at -70°C isotherm for 1 min, and heated at 5°C/min to reach 70°C (Yanty, Marikkar & Miskandar, 2011).

Polymorphism by X-ray Diffraction (XRD)
The polymorphic forms of fat crystals were analyzed using a wide-angle X-ray diffraction (WAXD) machine (D8 Advance Bruker AXS, Karlsruhe, Germany). The power used was 40 kv, 40 mA with the source of beam from Cu Kα1 X-ray beam (λ=0.15406 Å).

The samples were scanned from 15°2θ to 25°2θ, with a step size of 0.025°/0.1 sec (Ribeiro, 2009b). Evaluation Diffract plus software was used to measure the short spacing of the diffractogram. The short spacings at 4.2 and 3.8 Å refer to β′ formed while β formed at 4.6 Å (D'Souza, deMan & deMan., 1991).

Statistical Analysis
All results from analysis were indicated as the mean value ± standard deviation. Data were statistically analyzed by one-way analysis of variance (ANOVA) using Tukey's test of MINITAB (Version 14) statistical package at 0.05 probability level.

RESULTS AND DISCUSSION
Determination of Fatty Acid Content
Table 1 shows the composition of fatty acids. Saturated fatty acids of lard comprised largely of palmitic (C16:0) and stearic acid (C18:0). Similar majority groups of saturated fatty acids were also recorded for F91and F141. The amount of palmitic acids in the palm-based shortening were comparable to lard: (F91 and F141: 34.04% and 32.44 respectively) and (lard: 36.43%).

It was also observed that shortening of F91 and F141 had 35.59% and 34.61% oleic acids respectively, a close approximation to lard (39.23%). Linoleic acids content recorded comparable content of fatty acid composition with lard (20.7%) blends F9 (22.70%) and F141 (24.90%). The formulated shortening (F91 and F141) had the tendency to simulate the main fatty acid composition of lard.

Determination of Triacyglycerol
Table 2 shows triacylglycerol (TAG) content of F91, F141, and lard. The major TAG groups found in the palm-based shortening were PLO, POO and POP. Similarly, TAG molecular groups of PLO and POO were also dominant in lard. These were followed by SPO and POP with lesser values in the prepared shortening.

The TAG molecular group can be classified as trisaturated (SSS) TAGs; disaturated–monounsaturated (SSU); monosaturated–diunsaturated (SUU); and triunsaturated (UUU). As in Table 2, shortening F91 and F141 possessed higher SUU than SSU group where similar pattern was displayed by lard.

However, the former content (SUU) was lower and the later (SSU) was higher than lard, suggesting higher hardness in F91 and F141 (Figure 1).

The presence of TAG molecular groups contributed to the main crystal backbone of texture. The lower hardness of lard was due to higher content of SUU group (65.1%) than in F91 (43.84%) and F141 (43.15%) (Wiederman, 1978).

Table 1. Fatty acid composition of F91, F141 and Lard

	F91	F141	Lard
C14:0	0.73±0.01^{b}	0.69±0.01^{c}	1.32±0.03^{a}
C16:0	34.04±0.01^{a}	32.44±0.15^{b}	23.17±0.34^{c}
C16:1	-	-	-
C18:0	4.66±0.02^{b}	4.67±0.06^{b}	11.70±0.13^{a}
C18:1	35.59±0.03^{b}	34.61±0.79^{b}	39.23±0.66^{a}
C18:2	22.70±0.01^{b}	24.90±0.16^{a}	20.72±0.19^{c}
C18:3	1.91±0.01^{b}	2.27±0.01^{a}	0.99±0.03^{c}
C20:0	0.34±0.00^{ab}	0.34±0.01^{ab}	0.24±0.00^{c}
C20:1	-	-	0.84±0.03^{a}

Each value represents mean of 3 replicates. Means within each row with different letters are significantly different ((p<0.05)

Table 2. TAG distribution of F91, F141 and Lard

TAG	F91	F141	Lard
LnLnL	0.38± 0.01^{b}	0.84±0.17^{a}	-
LLLn	2.47±0.04^{b}	3.52±0.34^{a}	2.18±0.04^{bc}
LLL	8.33±0.06^{b}	9.99±0.36^{a}	-
OLL	5.29±0.11^{b}	6.77±0.19^{a}	4.47±0.03^{c}
PLL	7.29±0.12^{b}	7.20±0.08^{b}	8.37±0.09^{a}
OOL	-	-	6.59±0.01^{a}
PLO	14.6±0.09^{b}	14.81±0.4^{b}	25.37±0.04^{a}
PLP	7.86±0.54^{a}	6.3±0.38^{b}	-
POO	20.08±0.47^{b}	19.11±0.46^{bc}	28.23±0.04^{a}
POP	23.37±0.17^{a}	21.50±0.27^{b}	9.56 ± 0.12^{c}
PPP	4.58±0.14^{a}	3.52±0.23^{b}	-
SOO	1.87±0.04^{b}	2.03±0.25^{b}	3.06 ±0.05^{a}
SPO	3.87±0.07^{b}	3.77±0.73^{b}	10.97±0.04^{a}
PPS	-	-	-
SOS	-	-	0.48 ±0.02^{a}
SSS	-	-	0.72±0.09^{a}
UUU	16.47	21.12	13.24
SUU	43.84	43.15	65.10
SSU	35.10	31.57	21.01
SSS	4.58	3.52	0.72

Each value in the table represents the mean of three replicates. Means within each row bearing different superscripts are significantly (p<0.05) different. O: oleic, P: palmitic, L: linoleic, Ln: linolenic, S: stearic, UUU: triunsaturated, SUU: mono-diunsaturated, SSU: disaturated-monounsaturated, SSS: trisaturated.

Texture analysis

The hardness of palm-based shortening and lard are shown in Figure 1. Hardness of palm-based shortening was higher as compared to lard. In reference to fatty acid composition in Table 1, the hardness was contributed by the amount of palmitic acid which was higher than lard than in the palm-based shortening. The content of palmitic acid in F91 and F141 were 34.04% and 32.44% respectively. Palmitic acid in lard was lesser (23.17%). The higher amount of palmitic acid in the shortening was due to the shortening formulation.

The presence of an emulsifier in the shortening could have contributed to the pronounced hardness in as shown in Figure 1. DMG, which contained mixture of monopalmitin and monostearin could be considered as high melting emulsifier. The microstructures of fat revealed the reason for increase in in hardness in the emulsified shortening (F91 and F141) (Section 3.2). According to Liu *et al*. (2010), there were various factors that may contribute to texture of shortening including fatty acid composition, triacylglycerol and fat crystal networks.

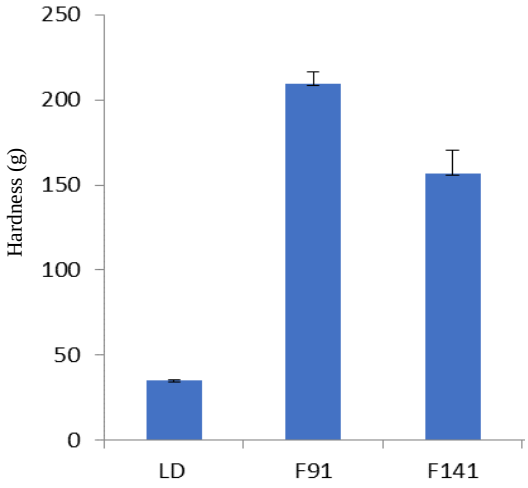

Figure 1. Hardness of Lard (LD), F91 and, F141

Microscopy analysis

The microstructures of F91 and F141and lard were compared as shown in Figure 2. The fat crystals were observed as bright between two crossed-polarized filters, while liquid oils were reported to be dark (Liu *et al*., 2010). The crystals were discrete clusters at the measured temperature of 25 °C. Figure 2 shows (a) lard crystal not homogenous cluster as compared to F91 and F141 (Figures 2b and 2c). F91 and F141 were more homogenous in cluster as with the presence of palm-based component that promoted β' crystallization (Figures 2a and 2b), which was reported to be crucial in the plasticity of shortening giving a smooth texture, good aeration condition and excellent creaming properties (Metzroth, 2005).Compared with lard, F91 and F141 were observed as needle-like shape, usually described for β' crystal type (Chen *et al*., 2002). Needle-like shape observations indicating mixture of β and β' crystals were also reported by NurIlliyin*et al*., (2019). The morphology of lard was observed to be coarser and larger, with disordered spherulites of fat crystals. Fat crystals in F91 and F141 were more arranged and closer to each other. The fat crystal network in lard was structurally weak as compared to F91 and F141 due to the formation of large spherulites thus reducing the number of crystals. Consequently, the situation weakened the strength of total network (Kamphuis & Jongschaap, 1985), linking to the texture of palm-based shortening which possessed higher hardness than lard that as previously mentioned.

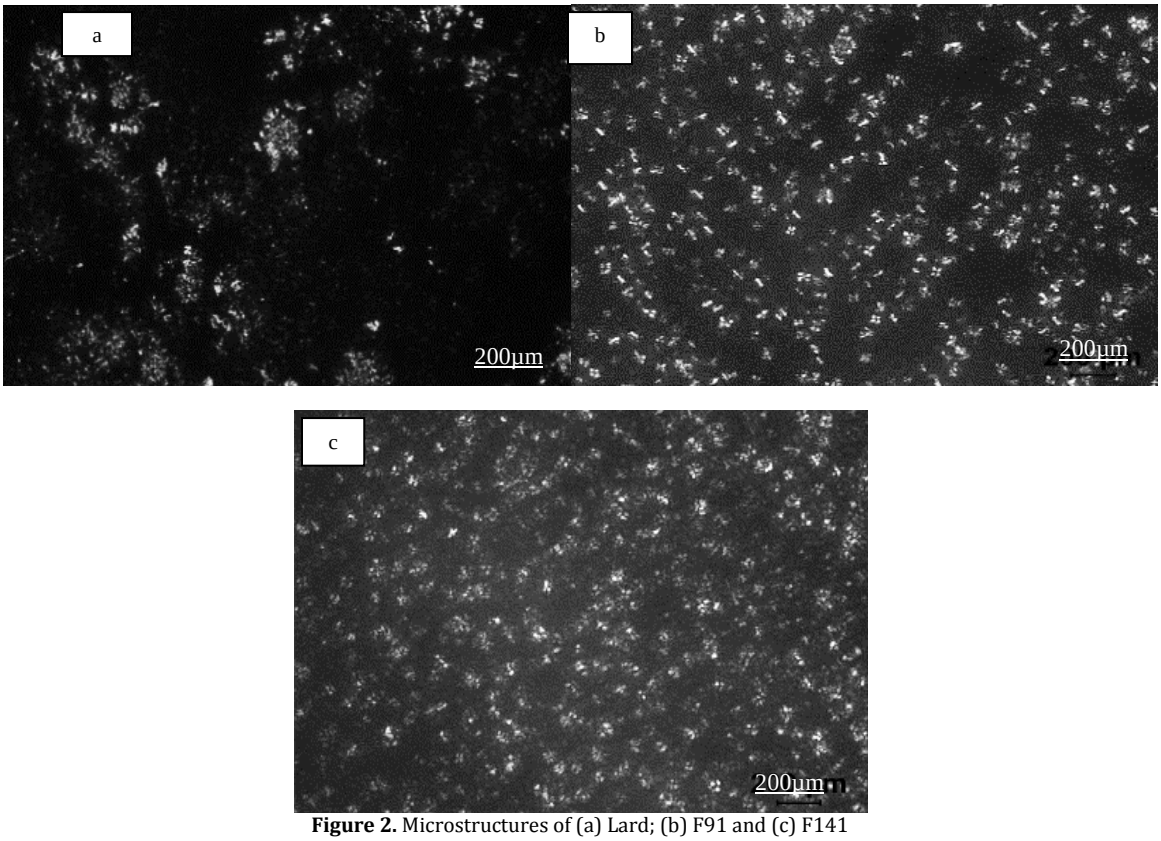

Figure 2. Microstructures of (a) Lard; (b) F91 and (c) F141

Thermal characteristics by differential scanning calorimetry

Figure 3 shows thermal characteristics by differential scanning calorimetry (DSC) of F91 and F141 and lard. Two major peaks (A2 and A3) and a minor peak of A1 were found in lard. There were more peaks found in F91 and F141 since the prepared shortening were combined by a few types of vegetable oils that may give more series of fat melting thermal behavior.

The peaks appeared in the thermogram refer to the presence of crystallized fat and polymorphic transitions phenomenon as described by Fredrick *et al*., (2008).

The different melting peaks between the prepared shortening and lard were due to the different amount of TAG molecular group as shown in Table 2. Lard contained higher UUU group thus exhibited less peaks as compared to F91 and F141.

Meanwhile, the peaks in F91 were broader than F141 in which the former (F91) indicated higher content of SSU and SSS group of TAG that created the different crystallized fats observed in the melting curves.

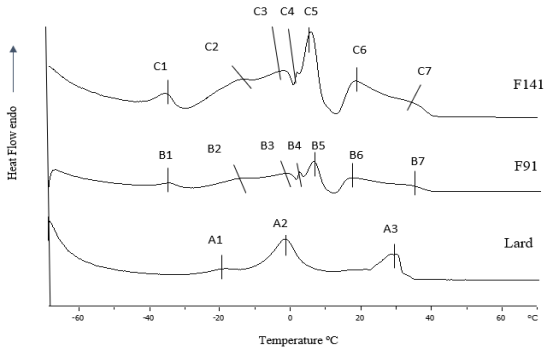

Figure 3. Melting curve of Lard, F91 and F141

More peaks displayed in the palm-based shortenings show the melting of variety TAG components in the blends (Sonwai, Kaphueakngam & Flood, 2012). However, the position of highest melting peak was higher in lard's curve of lard exhibiting the presence of high melting TAG group. In comparison with lard, the

lower melting peaks B3 (0.5 °C) and C4 (0.6°C) indicated closeness of melting temperature as lard (A2; -1.89 °C) for the F91 and F141 respectively. Meanwhile, the higher melting peak shown by B7 (33.0 °C) and C7 (32.8°C) indicated closer melting temperature as lard (A3; 29.6 °C) for the F91 and F141 respectively.

Determination of polymorphism

The diffractogram shown in Figure 4 presents the polymorphic form of palm-based shortening of F91 and F141 compared with lard. According to Figure 3, the diffractogram of lard indicated peak at 4.6 which represent the β form. However, the peaks at 3.8 and 4.2 were also recognized as they refer to β' form. This was in agreement with Nurlliyin*et al.* (2019) who reported the presence of mixture of β'and β crystal forms in lard.

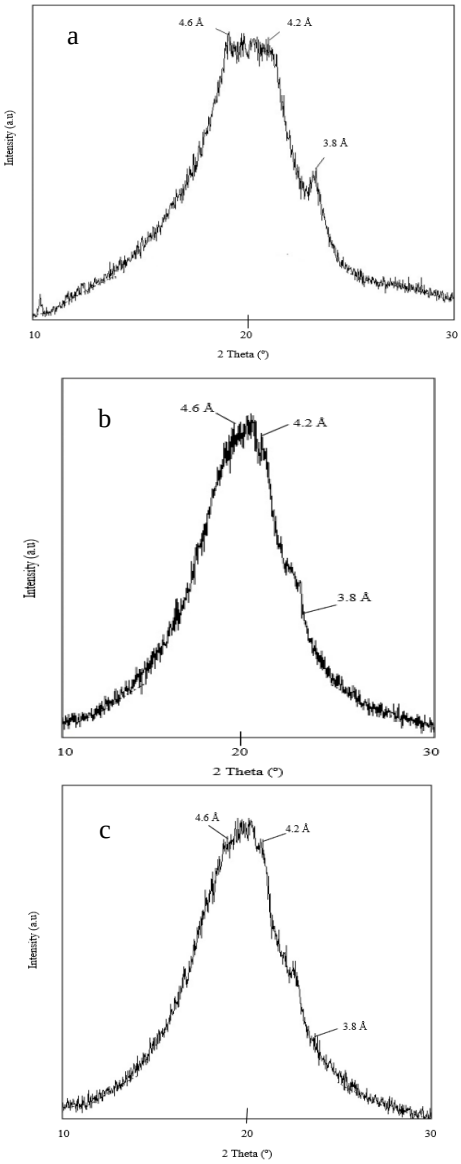

Figure 4. Polymorphic forms of a; Lard, b; F91 and c; F141

In Figure 4, the crystal forms of F91 and F141 also presented similar to lard which contained the mixture of β'and β. It is known that palm oil exists in β' form. In the present study, the β crystal was also found in the palm-based shortening. The β crystal form was probably resulted from handling and storage of palm-based shortening (Deffense and Tirtiaux,1989). In addition, the phase system of palm oil can be found in β', β and liquid phase (two solids and one liquid) as the stable β' plus β co-occurred at high temperatures (Chong *et al*., 2007). In the development of a shortening, the β' form was the desirable polymorphic because it provides better textural properties due to the to the smaller size crystals and smoother end products (Yu *et al*., 2017).

CONCLUSION

The present study demonstrated the physical properties of palm-based shortening in comparison with lard. The comparisons were done in terms of texture, microstructure, thermal behavior, fatty acid composition, TAG distribution as well as polymorphism.The hardness of palm-based shortenings was found higher than lard, which was reflected by the different fatty acid composition, the TAG molecular group and microstructures. The higher content of palmitic acid and the SSU group in the palm-based shortening contributed to the preferable texture property. The microstructures of palm-based shortening were arranged in alignment and smaller in size as compared to lard. However, few similarities were observed on fatty acid composition, pattern of TAG distribution, thermal behavior and polymorphic forms between palm-based shortening and lard.

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