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PHYSICAL AND CHEMICAL CHARACTERISTICS OF PALM OIL-BASED SOLID FRACTIONS WITH MORE THAN 20% OF TRIPALMITOYL-GLYCEROL FROM MALAYSIAN FRACTIONATION PLANTS

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ABSTRACT

The varied triacylglycerol composition of palm oil-based solid fractions (POSF) gives unique characteristics to its fractions. The potential to develop specific fractions for specific functionalities is very vital to the Malaysian palm oil industry in order to widen the usage of POSF for food formulations. Fractions with higher amounts of trisaturated triacylglycerols are excellent structural fats for food formulations. This compilation was directed towards obtaining the primary information on the characteristics of POSF available in Malaysia containing more than 20% of tripalmitoyl-glycerol. This information will be vital in guiding food formulators on the wide options of structural fats available in Malaysia. Commercially available POSF were collected and characterised. Their triacylglycerol composition, fatty acid composition, iodine value, dropping point, and solid fat content were determined. The results showed that the characteristics of the POSF were greatly influenced by the amount of tripalmitoyl-glycerol (PPP) present in the fractions. The amount of PPP had a substantial impact on the dropping point and the solid fat content profile. Hence, fractions were categorised according to their percentage of PPP to provide groupings with specific physical and chemical characteristics. The percentage of PPP in Group PPP 1 was 20% to 30%, PPP 2 was 40% to 50%, PPP 3 was 55% to 60%, PPP 4 was 62% to 63% and PPP 5 was 67% to 68%. The range of dropping points recorded for PPP 1 was 54°C to 56°C, PPP 2 was 59°C to 60°C, PPP 3 was 61°C to 62°C PPP 4 was 62.2°C to 62.4°C and PPP 5 was 63.1°C to 63.7°C. The range of solid fat content at 30°C recorded for PPP 1 was 44% to 54%, PPP 2 was 78% to 82%, PPP 3 was 86% to 89%, PPP 4 was 90% to 91% and PPP 5 was 91% to 93%. This compilation shows the extensive range of POSF which are able to provide a specific functionality to facilitate their specialised application in food formulations that are commercially available in Malaysia.

Keywords: palm oil-based solid fractions, structural fats, tripalmitoyl-glycerol, solid fat content.

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INTRODUCTION

The primary role of fats in foods is to impart sensory attributes such as creaminess, mouthfeel, enhancement of food flavours, spreadability, lubrication, cohesiveness and structure. Solid fats provide the crucial characteristics such as structure, texture and firmness in food products. In many food applications, the fat component exists in a semi-solid state (soft homogenous solids) which are bonded by fat crystal network facilitated by solid fats. These solid fats consist mainly of saturated

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triacylglycerols and are classified as structural fats (Marangoni, 2005; Narine and Marangoni, 1999; 2002). The solid fats play a vital role to provide the structural firmness and solid-like behaviour in food products with high percentage of fats (Omonov *et al*., 2010). The most conventional approach to provide structure in margarines and spreads are by incorporating solid fats (Kloek *et al*., 2000; Flöter *et al*., 2006). Solid fats (structural fats) are responsible for crystal structure and crystal network formation in margarines and spreads (Pernetti *et al*., 2007; Rogers, 2009).

Driven by consumer demand, natural plant fats, have become the preferred option across the food processing industry compared to animal and hydrogenated fats. Palm oil and its diversified range of palm oil-based solid fractions (POSF) are excellent natural solid fats which are able to cater for a wide range of food products. POSF are extensively used in manufacturing shortenings, margarines, confectionary fats, frying fats, milk fat replacers, and ice cream fats which in turn are used to make a wide range of products including breads, biscuits, cakes, cookies, chocolates, ice creams and pastries (Lai *et al*., 1998; Ming *et al*., 1999). POSF are highly recommended as they are cost efficient, easily available, have high solid fat content (SFC), free of *trans* fatty acids and have high oxidative stability (long shelf-life) (Braipson-Danthine and Gibon, 2007).

Fractionation of oils and fats is a separation process, which involves fractional crystallisation of oils and fats by controlled cooling (Liu *et al*., 2010). This process involves specific crystallisation of triacylglycerols to form solid fats, followed by filtration processes to separate the solid fats from the liquid fractions (Kellens *et al*., 2007). The fractionation process is based on the ability of the triacylglycerols to produce crystals under specific cooling conditions. The ability of the triacylglycerols to produce crystals depends on their melting points, degree of saturation, molecular weight and difference in solubility of the solid triacylglycerols in the liquid phase (Braipson-Danthine and Gibon, 2007; Kellens *et al*., 2007).

Palm oil is the most widely fractionated oil in the world due to its diverse triacylglycerol composition, boasting an equal amount of unsaturated to saturated fatty acid composition (Deffense, 1985; Vuillequez *et al*., 2010). This unique composition of palm oil opens endless opportunity in the production of liquid oils and solids fats. Dry fractionation process separates palm oil into two fractions, liquid fraction (palm olein) and palm solid fraction. Palm olein is rich in low melting point triacylglycerols and is used mainly as cooking oil (Norizzah *et al*., 2004; Ahmad Tarmizi and Ismail, 2008). Whereas POSF contains substantial amounts of saturated triacylglycerols which provide solid fraction with a higher melting point (Pande and Akoh, 2013). The continuous advancement in fractionation technology has led the way to produce POSF with a high degree of selectivity. Fractionation can be carried out in single or multiple steps, giving rise to a wide range of POSF. The POSF were subjected to double or even triple fractionation to obtain POSF with an increasing enrichment of a specific triacylglycerol for special applications. These multi stage fractionation routes are continuously improved by the industry resulting in very specialised and high valued POSF (Calliauw *et al*., 2007).

This characterisation work was directed toward compiling basic information on the physical and chemical characteristics of different POSF. This compilation of information will be of great interest to food formulators as it will provide a rather comprehensive information on the wide range of natural POSF available in Malaysia. Commercially available POSF were evaluated for their triacylglycerol composition, fatty acid composition, iodine value, dropping point and SFC.

MATERIALS

POSF samples were obtained from local fractionation plants. The POSF obtained were mainly produced by the dry fractionation process. The POSF collected in this study were from diversely varied processing conditions applied by industry, single or multi-stage fractionation [hydrogenated and interesterified (chemical or enzymatic) POSF were excluded from this study].

METHODS

The characteristics of POSF were based on their triacylglycerol composition, fatty acid composition, iodine value, dropping point, and solid fat content, hence these analyses were carried out.

Triacylglycerol Composition Analysis

The POSF samples were prepared by dissolving 0.015 g litre^{-1} in acetone. The samples were then filtered through a 0.2 μm nylon membrane filter to remove any solid impurities. The triacylglycerol profiles were determined using high performance liquid chromatography (HPLC) (Agilent 1100 Series, USA). The 10 μl of sample was injected into two Purospher® STAR RP-18 endcapped column (25 cm length x 4 mm i.d with of 5 μm particle size) (Merck KGaA, Darmtadt, Germany) connected in series. The column was kept in an oven at 30°C. The mobile phase used was acetone: acetonitrile (75:25% vol/vol), at a flow rate of 1.0 ml min^{-1} under isocratic conditions. The individual peaks

were identified by a refractive index detector and the total run time was 45 min per sample. The chromatograms were identified by comparing retention times with standards and quantified using the area normalisation method (Ramli *et al*., 2008). All analysis was carried out in triplicates.

Iodine Value

Iodine value denotes the degree of unsaturation of fatty acids in oils and fats. Determination of IV was carried out according to MPOB Test Method p3.2: 2004 (Kuntom *et al*., 2005). The 20 g of totally melted and homogenised sample and 20 ml of solvent (1:1 cyclohexane: glacial acetic acid) were weighed into a conical glass flask fitted with a round glass stopper. The 25 ml of Wijs reagent was added, the stopper was replaced, the solution swirled by hand and placed in a dark for room for 1 hr. A blank test was prepared with the solvent and reagent, omitting the test portion. At the end of the reaction time, 20 ml of potassium iodide and 150 ml of water were added. The solution was then titrated with standard sodium thiosulphate solution. The blank test was similarly treated and titrated. Calculation of the ioden value was carried out, the iodine values were expressed as g of I_2/100 g of oil (Aini *et al*., 2010). All analysis was carried out in triplicates.

Dropping Point

The dropping point indicates the temperature where the frozen POSF becomes liquid and is able to flow. Determination of dropping point was carried out in accordance to MPOB Test Method f1.2: 2004 (Kuntom *et al*., 2005). A Mettler Toledo dropping point analysing system with central processor FP90 (AG, Schwerzenvach, Switzerland) was used to determine the dropping point of the POSF. The sample cup (inner diameter 2.8 mm Mettler No. 18732) was placed in the freezer (below -5°C) for a minimum of 10 min. The POSF sample was melted, homogenised and filled into the sample cup. The filled cup was kept in the freezer for 15 min. The dropping point analyser was set at 10°C below the expected dropping point. The heating rate was set at 1°C min^{-1}. The sample was removed from the freezer and immediately placed into the dropping point measuring cell. The dropping point was recorded. All analysis was carried out in triplicates.

Fatty Acid Composition

Fatty acid composition (FAC) was determined as fatty acid methyl esters (FAME). The samples (0.05 g) were weighed and dissolved in 1 ml hexane. The mixture was then added with sodium methoxide solution [0.2 ml of $NaOCH_3$ (2M) in anhydrous methanol] and then mixed for 1 min with a vortex mixer. After sedimentation of sodium glycerolate, 1 μm of clear supernatant was injected into Rtx 2330 fused silica capillary column (60 m × 0.25 mm × 0.25 μ) (Restex Corporation, USA) and analysed using a Burker gas chromatography system Model 430-GC (Burker Daltonics, CA, USA) equipped with a flame ionisation detector (FID) and Galaxie Chromatography Data System. Injection and detection temperatures were set at 240°C. The oven temperature was set at 190°C. The column temperature was isothermal at 185°C. The carrier gas was helium with flow rate of 1 ml min^{-1}. The peaks were identified by comparing retention times with FAME standards and quantified using peak area normalisation methods. All analysis was carried out in triplicates.

Solid Fat Content

Solid fat content (SFC) denotes the amount of solid present at a specific temperature. Determination of SFC was performed according to MPOB Test Method (MPOB p4.8: 2004) (Kuntom *et al*., 2005). The SFC was measured with Bruker Minispec PC 120 pulse. Samples were totally melted at 80°C to erase all crystal memory. The totally melted samples were homogenised and filled into tubes (10 mm o.d x 75 mm length) up to 3 cm in height. The samples were tempered at 70°C in a water bath for 30 min, before chilling at 0°C for 90 min. These tubes were conditioned in pre-equilibrated thermostated baths for 30 min prior to the measurement. The measuring temperatures were 0°C, 5°C, 10°C, 15°C, 20°C, 25°C, 30°C, 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C and 70°C. The direct method was employed for the measurements. All analysis was carried out in triplicates.

RESULTS AND DISCUSSION

Triacylglycerol composition, FAC, iodine value, dropping point, and SFC of the commercial POSF were determined and the grouping of the POSF were based on these analyses results. The characteristics of the POSF were greatly influenced by the triacylglycerol composition which was reflected in the corresponding FAC, iodine value, dropping point, and SFC. In the formulation of high fat foods such as margarines, shortenings, cooking fats, vanaspati and spreads the SFC profile plays a crucial role in the selection of fats. Hence, the grouping of the POSF in this compilation was based on the factor that expressively influenced the SFC in order to facilitate the selection of POSF for food formulations. Saturated triacylglycerol implicitly influences the SFC profile of fats (Okawachi *et al*., 1985). POSF contains saturated triacylglycerol such as tripalmitoyl-glycerol (PPP), dipalmitoyl- stearoyl-

glycerol (PPS), distearoyl-palmitoyl-glycerol (PSS) and dipalmitoyl-myristoyl-glycerol (MPP) which dominate the SFC profiles. The amount of PPP in the POSF were substantially higher than the other saturated triacylglycerol, hence this relates to the prevailing influence of PPP on the SFC of the POSF, hence PPP was used as the crucial factor in the grouping of the POSF. The percentage of PPP in Group PPP 1 was 20% to 30%, PPP 2 was 40% to 50%, PPP 3 was 55% to 60%, PPP 4 was 62% to 63% and PPP 5 was 67% to 68%. These groups were discussed at length in the following segments to provide a better understanding of the physical and chemical characteristic of the POSF.

POSF of Group PPP 1 with 20% to 30% of PPP Content

POSF of Group PPP 1 were obtained through single fractionation of palm oil. *Table 1* shows that the trisaturated triacylglycerols composition ranged from 29.36% to 35.43% with 23.08% to 28.43% of PPP. The monounsaturated triacylglycerols ranged from 39.51% to 45.00%, with POP content ranging from 28.11% to 32.74%. The percentage of diunsaturated and triunsaturated triacylglycerols ranged from 19.24% to 22.38% and 4.99% to 5.39% respectively. The dropping points of the POSF in group PPP 1 were in the range of 54.3°C to 56.4°C. The corresponding iodine value obtained were 31.43 to 34.48 g of I_2/100 g of oil, as shown in *Table 2*. It was reported by Kellens *et al*. (2007) that palm stearin with PPP percentage of 26.5% gave an iodine value of 34.4 I_2/100 g (Kellens *et al*., 2007). It was also reported that palm stearin with an iodine value of 32 I_2/100 g obtained via single fractionation gave a melting point of 54°C (Kellens and Hendrix, 2000). The percentage of polyunsaturated fatty acids ranged from 5.0% to 7.0%.

The results also indicates that the percentage of monounsaturated fatty acids which consist of mostly oleic acid were 25.12% to 27.22%. The percentage of saturated fatty acids were the highest, ranging from 65.95% to 69.36% with 58.98% to 62.99% of palmitic acid as shown in *Table 2*. These fractions are good source of palmitic acid. Zou *et al*. studied the synthesis of human milk fat substitutes by combining methods such as enzymatic acidolysis with blending of various oils such as basa catfish oil, sesame oil, flaxseed oil, sunflower oil, palm kernel oil, palm stearin (C16:0 of 61%), alga oil and microbial oil. Palm stearin was included in the oil blends as the source of palmitic acid (Zou *et al*., 2016).

The SFC profiles of POSF in group PPP 1 exhibited similar trends as shown in *Figure 1*. The SFC profile of this group of solids did not exhibit a sharp drop at the temperatures investigated but decreased in a gradual manner with a decrease of 15% to 20% solids per 10°C increase between 10°C to 50ºC. The percentages of solids detected at 50°C for this group of POSF were as high as 12% to 17%. The high percentage of trisaturated triacylglycerols with high melting points has led to high solid fat content values at all the evaluated temperatures (Zhou *et al*., 2010). The percentage of trisaturated triacylglycerols varied from 29% to 35% with 23% to 28% of PPP present. Hence, these fractions are very suitable to be used as backbone structures in the formulation of margarines and shortenings (used in non-refrigerated storage conditions).

POSF of Group PPP 2 with 40% to 50% of PPP Content

POSF in Group PPP 2 were obtained through fractionation of POSF of IV 30. The trisaturated triacylglycerols ranged from 51.99% to 61.34% with PPP content of 42.35% to 48.80% as shown in *Table 3*. The monounsaturated triacylglycerols ranged from 24.84% to 36.17%, with POP content ranging from 17.80% to 26.70%. The percentage of diunsaturated and triunsaturated triacylglycerol ranged from 6.15% to 10.67% and 4.04% to 5.81% respectively. The dropping points of the POSF in Group PPP 2 were also strongly influenced by the content of trisaturated triacylglycerols as the dropping points recorded for this group of POSF were in the range of 59.0°C to 60.0°C. The corresponding iodine values obtained were 17.94 to 20.60 I_2/100 g as shown in *Table 4*.

The percentage of polyunsaturated fatty acids ranged from 3.19% to 3.98%. The percentage of monounsaturated fatty acids which consist of mostly oleic acid were 14.21% to 16.45%. The percentage of saturated fatty acid was the highest ranging from 80.29% to 82.60% with 72.23% to 76.19% of palmitic acid as shown in *Table 4*. Structural fat for the production of margarine was produced by interesterification of non-hydrogenated high melting palm solid fraction and non-hydrogenated palm kernel fraction. The requirement of hard palm fraction used in this structural fat was more than 70% of palmitic acid. The palmitic acid contributes to the structure of the hard stock (Ullanoormadam, 2004).

POSF of Group PPP 2 exhibited high SFC profiles below 20°C, with SFC values above 90%. The percentage of SFC ranged from 88% to 90% at 20°C and decreased 5% in SFC with the increase in temperature to 83% to 87% at 25°C. The SFC decreased approximately 7% to 8% for the corresponding increase of 10°C from 30°C to 40°C as shown in *Figure 2*. The SFC values of these POSF were higher than 50% at 40°C with readings as high as 56% to 67%. The SFC decreased approximately 10 % for the corresponding increase of 10°C from 40°C to 50°C, the SFC values were 35% to 47% at 50°C. The SFC decrease 15% from 50°C to 55°C with SFC value

TABLE 1. TRIACYLGLYCEROL COMPOSITION OF PALM OIL-BASED SOLID FRACTIONS OF PPP 1 WITH 20% TO 30% OF PPP CONTENT

	1	2	3	4	5	6	7
LLL	0.26 ± 0.00	0.23 ± 0.00	0.14 ± 0.01	0.17 ± 0.03	0.25 ± 0.01	0.13 ± 0.00	0.18 ± 0.00
PLL	1.48 ± 0.01	1.39 ± 0.01	1.09 ± 0.02	1.25 ± 0.03	1.17 ± 0.07	0.99 ± 0.03	1.15 ± 0.03
MLP	0.39 ± 0.05	0.57 ± 0.36	0.56 ± 0.35	0.39 ± 0.15	0.28 ± 0.07	0.39 ± 0.01	0.46 ± 0.01
OOL	1.06 ± 0.02	0.84 ± 0.03	1.09 ± 0.21	0.90 ± 0.04	1.05 ± 0.02	0.81 ± 0.03	0.90 ± 0.01
POL	5.62 ± 0.09	4.65 ± 0.17	5.40 ± 0.23	4.50 ± 0.17	5.23 ± 0.06	4.24 ± 0.05	4.31 ± 0.08
PLP	7.18 ± 0.10	5.93 ± 0.02	6.10 ± 0.11	6.58 ± 0.49	6.70 ± 0.25	5.55 ± 0.13	5.88 ± 0.18
MPP	1.24 ± 0.02	1.44 ± 0.13	1.63 ± 0.06	1.27 ± 0.16	1.14 ± 0.17	1.31 ± 0.02	1.01 ± 0.01
OOO	3.88 ± 0.05	3.93 ± 0.16	3.77 ± 0.05	3.93 ± 0.34	4.00 ± 0.07	4.08 ± 0.05	4.30 ± 0.04
POO	14.02 ± 0.04	12.42 ± 0.15	12.95 ± 0.13	11.86 ± 0.12	12.71 ± 0.13	12.91 ± 0.1	12.54 ± 0.05
POP	30.52 ± 0.04	32.74 ± 0.11	30.59 ± 0.22	30.56 ± 0.07	28.11 ± 0.13	29.86 ± 0.21	28.90 ± 0.14
PPP	23.08 ± 0.02	23.66 ± 0.13	24.82 ± 0.14	26.82 ± 0.07	26.97 ± 0.05	26.99 ± 0.08	28.43 ± 0.02
SOO	1.26 ± 0.04	0.97 ± 0.02	1.07 ± 0.10	1.04 ± 0.14	1.23 ± 0.14	1.27 ± 0.01	1.25 ± 0.03
POS	4.46 ± 0.10	5.30 ± 0.02	4.65 ± 0.07	4.54 ± 0.34	4.09 ± 0.11	5.01 ± 0.01	4.31 ± 0.02
PPS	4.51 ± 0.07	4.73 ± 0.17	4.97 ± 0.16	5.16 ± 0.01	5.78 ± 0.03	5.20 ± 0.05	5.39 ± 0.01
SOS	0.51 ± 0.07	0.46 ± 0.01	0.52 ± 0.01	0.42 ± 0.02	0.34 ± 0.04	0.60 ± 0.01	0.38 ± 0.01
PSS	0.53 ± 0.04	0.50 ± 0.01	0.66 ± 0.03	0.61 ± 0.05	0.94 ± 0.09	0.67 ± 0.03	0.60 ± 0.0
SSS	29.36 ± 0.17	30.33 ± 0.09	32.08 ± 0.60	33.86 ± 0.1 7	34.84 ± 0.01	34.17 ± 0.03	35.43 ± 0.07
SUS	43.06 ± 0.12	45.00 ± 0.24	42.41 ± 0.05	42.49 ± 0.22	39.51 ± 0.03	41.41 ± 0.33	39.94 ± 0.17
SUU	22.38 ± 0.07	19.43 ± 0.26	20.51 ± 0.39	18.65 ± 0.16	20.35 ± 0.04	19.41 ± 0.13	19.24 ± 0.18
UUU	5.20 ± 0.02	4.99 ± 0.09	5.01 ± 0.06	5.01 ± 0.08	5.30 ± 0.09	5.01 ± 0.16	5.39 ± 0.16

Note: M - myristic, P - palmitic, S - stearic, O - oleic, L - linoleic, SSS - trisaturated, SUS - disaturated, SUU - monosaturated, UUU - triunsaturated.
Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

TABLE 2. FATTY ACID COMPOSITION, IODINE VALUES AND DROPPING POINTS OF PALM OIL-BASED SOLID FRACTIONS OF PPP 1 WITH 20% TO 30% OF PPP CONTENT

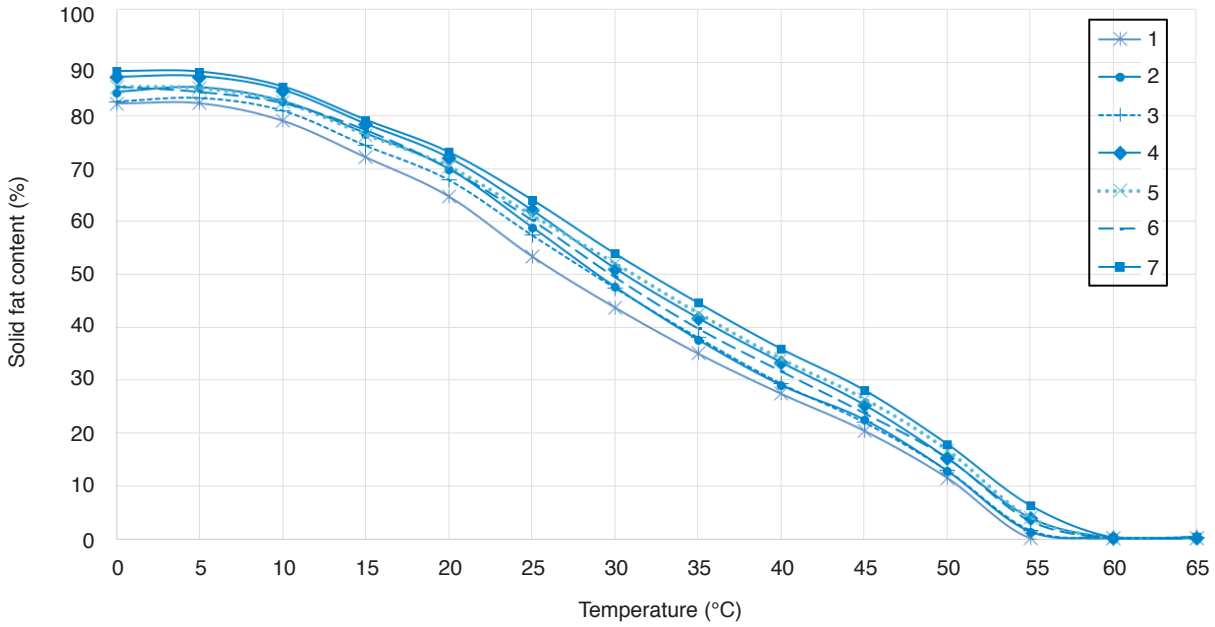
	1	2	3	4	5	6	7
Fatty Acids							
C 12:0	0.19 ± 0.00	0.16 ± 0.00	0.17 ± 0.00	0.38 ± 0.00	0.17 ± 0.00	0.22 ± 0.00	0.12 ± 0.00
C 14:0	1.22 ± 0.01	1.30 ± 0.00	1.34 ± 0.00	1.43 ± 0.00	1.26 ± 0.00	1.33 ± 0.00	1.24 ± 0.01
C 16:0	58.98 ± 0.06	60.58 ± 0.01	60.69 ± 0.04	62.39 ± 0.02	61.56 ± 0.05	61.63 ± 0.01	62.99 ± 0.06
C 16:1	0.12 ± 0.01	0.11 ± 0.01	0.12 ± 0.00	0.10 ± 0.00	0.10 ± 0.00	0.12 ± 0.01	0.10 ± 0.00
C 18:0	5.21 ± 0.02	5.07 ± 0.01	4.94 ± 0.00	4.70 ± 0.01	5.17 ± 0.01	4.99 ± 0.00	4.67 ± 0.00
C 18:1	27.22 ± 0.01	26.67 ± 0.01	26.43 ± 0.01	24.97 ± 0.00	25.31 ± 0.04	25.89 ± 0.01	25.02 ± 0.01
C 18:2	6.37 ± 0.01	5.40 ± 0.01	5.62 ± 0.01	5.40 ± 0.00	5.79 ± 0.01	5.08 ± 0.00	5.22 ± 0.05
C 18:3	0.19 ± 0.01	0.16 ± 0.01	0.15 ± 0.01	0.10 ± 0.16	0.09 ± 0.00	0.15 ± 0.00	0.10 ± 0.00
C 20:0	0.34 ± 0.01	0.37 ± 0.00	0.34 ± 0.01	0.33 ± 0.00	0.35 ± 0.00	0.35 ± 0.00	0.35 ± 0.00
Saturated	65.95 ± 0.05	67.45 ± 0.02	67.49 ± 0.05	69.23 ± 0.01	68.51 ± 0.05	68.53 ± 0.01	69.36 ± 0.07
Monounsaturated	27.34 ± 0.00	26.77 ± 0.02	26.54 ± 0.01	25.07 ± 0.00	25.41 ± 0.02	26.01 ± 0.00	25.12 ± 0.02
Polyunsaturated	6.56 ± 0.02	5.56 ± 0.01	5.77 ± 0.01	5.50 ± 0.01	5.89 ± 0.02	5.23 ± 0.00	5.32 ± 0.05
Iodine value (I_2/100 g)	34.48 ± 0.11	33.14 ± 0.18	32.76 ± 0.18	32.14 ± 0.19	32.06 ± 0.16	31.77 ± 0.05	31.43 ± 0.12
Dropping point (°C)	54.3 ± 0.01	54.4 ± 0.14	54.6 ± 0.21	55.9 ± 0.14	56.0 ± 0.07	55.6 ± 0.21	56.4 ± 0.14

Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

of 20% to 30% at 55°C. The SFC values were below 1% at 60°C for all samples in Group PPP 2, reflecting the melting of 20% to 30% solids from 55°C to 60°C.

POSF of Group PPP 3 with 55% to 60% of PPP Content

POSF in Group PPP 3 were obtained through dry fractionation process of POSF of iodine value 20. The trisaturated triacylglycerols ranged from 66.78% to 70.63% and PPP content contributing 55.70% to 60.54% of the POSF as shown in *Table 5*. The monounsaturated triacylglycerols ranged from 19.22% to 21.82%, with POP content ranging from 13.95% to 16.11%. The percentage of diunsaturated and triunsaturated triacylglycerols ranged from 5.23% to 7.20% and 3.59% to 4.80% respectively. The dropping points of POSF in group PPP 3 were also strongly influenced by the content of trisaturated triacylglycerols as the dropping points recorded for



Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

Figure 1. Solid fat content of palm oil-based solid fractions of PPP 1 with 20% to 30% of PPP content.

TABLE 3. TRIACYLGLYCEROL COMPOSITION OF PALM OIL-BASED SOLID FRACTIONS OF PPP 2 WITH 40% TO 50% OF PPP CONTENT

	1	2	3	4	5	6
LLL	0.16 ± 0.00	0.58 ± 0.00	0.61 ± 0.00	0.00 ± 0.00	0.69 ± 0.00	0.47 ± 0.00
PLL	0.25 ± 0.00	0.00 ± 0.00	0.20 ± 0.00	0.33 ± 0.00	0.32 ± 0.00	0.11 ± 0.00
MLP	0.41 ± 0.00	0.00 ± 0.00	0.39 ± 0.00	0.13 ± 0.00	0.47 ± 0.00	0.15 ± 0.00
OOL	0.49 ± 0.00	0.59 ± 0.00	0.72 ± 0.00	0.42 ± 0.04	0.79 ± 0.03	0.51 ± 0.00
POL	1.88 ± 0.00	2.76 ± 0.00	2.63 ± 0.07	1.73 ± 0.04	2.32 ± 0.00	2.15 ± 0.00
PLP	4.81 ± 0.00	4.33 ± 0.00	4.09 ± 0.01	4.25 ± 0.07	3.62 ± 0.00	3.63 ± 0.04
MPP	0.71 ± 0.00	0.65 ± 0.00	0.76 ± 0.00	0.72 ± 0.04	0.68 ± 0.00	0.46 ± 0.00
OOO	3.39 ± 0.03	4.29 ± 0.01	4.28 ± 0.01	3.79 ± 0.04	4.32 ± 0.05	4.26 ± 0.02
POO	4.93 ± 0.05	6.83 ± 0.01	7.17 ± 0.01	3.80 ± 0.13	6.16 ± 0.00	5.34 ± 0.04
POP	26.70 ± .13	20.92 ±0.05	19.82 ± 0.13	23.15 ±0.15	17.80 ± 0.04	18.89±0.15
PPP	42.35 ±0.21	44.63 ±0.14	45.41± 0.26	47.36 ±0.28	48.76 ±0.12	48.80 ± .16
SOO	0.74 ± 0.00	0.49 ± 0.00	0.65 ± 0.00	0.30 ± 0.03	0.56 ± 0.00	0.30 ± 0.00
POS	3.97 ± 0.01	3.21 ± 0.08	3.087 ± 0.00	3.04 ± 0.04	2.92 ± 0.00	2.52 ± 0.00
PPS	8.02 ± 0.01	9.45 ± 0.00	9.074 ± 0.01	9.57 ± 0.12	9.47 ± 0.00	10.61±0.04
SOS	0.27 ± 0.00	0.0 ± 0.00	0.00 ± 0.00	0.31 ± 0.13	0.00 ± 0.00	0.34 ± 0.00
PSS	0.92 ± 0.00	1.22 ± 0.01	1.05 ± 0.00	1.11 ± 0.14	1.04 ± 0.00	1.47 ± 0.00
SSS	51.99 ±0.21	55.97 ±0.28	56.30 ± 0.24	58.76 ±0.17	59.96 ± 0.21	61.34±0.24
SUS	36.17 ±0.15	28.46 ±0.06	27.39 ± 0.09	30.88 ±0.09	24.84 ± 0.11	25.53±0.17
SUU	7.80 ± 0.07	10.08 ±0.14	10.67 ± 0.06	6.15 ± 0.16	9.37 ± 0.08	7.89 ± 0.07
UUU	4.04 ± 0.01	5.47 ± 0.02	5.63 ± 0.01	4.21 ± 0.00	5.81 ± 0.06	5.24 ± 0.07

Note: M - myristic, P - palmitic, S - stearic, O - Oleic, L - linoleic, SSS - trisaturated, SUS - disaturated, SUU - monosaturated, UUU - triunsaturated.
Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

this group of POSF were in the range of 61.0°C to 62.4°C. The corresponding iodine value obtained were 13.69 to 14.70 I_2/100 g as shown in *Table 6*.

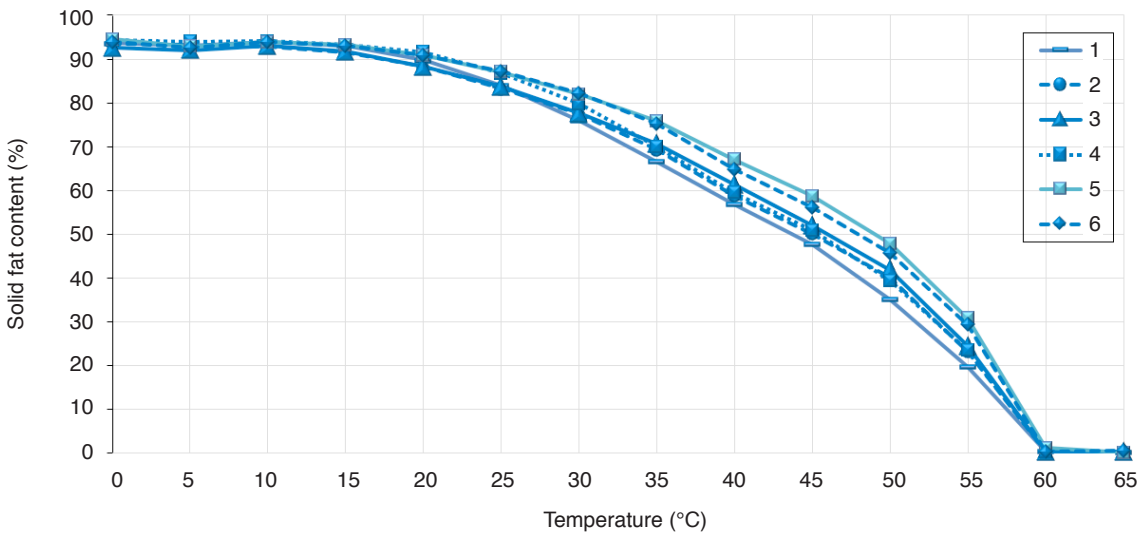
The percentage of saturated fatty acids were the highest ranging from 85.50% to 86.92% with 78.43% to 80.53% of palmitic acid as shown in *Table 6*. The percentage of monounsaturated fatty acids which consist of mostly oleic acid were 10.89% to 12.10%. The percentage of polyunsaturated fatty acids ranged from 2.10% to 2.76%.

POSF of Group PPP 3 exhibited high solid fat profiles with readings above 90% for temperatures below 25°C. The percentage of solid ranged from 80% to 90% between the range of 25°C to 35°C.

TABLE 4. FATTY ACID COMPOSITION, IODINE VALUES AND DROPPING POINTS OF PALM OIL-BASED SOLID FRACTIONS OF PPP 2 WITH 40% TO 50% OF PPP CONTENT

	1	2	3	4	5	6
Fatty Acids						
C 12:0	0.08 ± 0.00	0.10 ± 0.00	0.10 ± 0.00	0.08 ± 0.02	0.11 ± 0.00	0.10 ± 0.00
C 14:0	1.33 ± 0.00	1.42 ± 0.00	1.35 ± 0.00	1.45 ± 0.06	1.35 ± 0.00	1.52 ± 0.00
C 16:0	73.30 ± 0.12	72.45 ± 0.11	72.23 ± 0.13	76.19 ± 0.07	74.30 ± 0.06	74.31 ± 0.05
C 16:1	0.06 ± 0.00	0.11 ± 0.09	0.11 ± 0.07	0.00 ± 0.00	0.14 ± 0.00	0.10 ± 0.00
C 18:0	5.25 ± 0.00	5.76 ± 0.11	5.74 ± 0.01	5.43 ± 0.09	6.01 ± 0.00	6.23 ± 0.00
C 18:1	16.39 ± 0.02	16.19 ± 0.15	15.91 ± 0.01	14.74 ± 0.04	14.12 ± 0.00	14.11 ± 0.00
C 18:2	3.20 ± 2.22	3.47 ± 0.04	3.75 ± 0.02	2.59 ± 0.12	3.29 ± 0.00	3.05 ± 0.00
C 18:3	0.06 ± 0.00	0.10 ± 0.00	0.28 ± 0.10	0.13 ± 0.05	0.22 ± 0.00	0.14 ± 0.00
C 20:0	0.33 ± 0.00	0.41 ± 0.00	0.58 ± 0.00	0.40 ± 0.05	0.47 ± 0.00	0.44 ± 0.00
Saturated	80.29 ± 0.02	80.13 ± 0.11	80.55 ± 0.21	83.41 ± 0.13	82.23 ± 0.15	82.60 ± 0.21
Monounsaturated	16.45 ± 0.02	16.30 ± 0.06	16.02 ± 0.08	14.74 ± 0.04	14.26 ± 0.09	14.21 ± 0.18
Polyunsaturated	3.26 ± 0.00	3.57 ± 0.00	3.98 ± 0.09	2.72 ± 0.08	3.51 ± 0.05	3.19 ± 0.16
Iodine value (I_2/100 g)	20.60 ± 0.13	20.31 ± 0.14	20.09 ± 0.15	20.90 ± 0.12	18.32 ± 0.09	17.94 ± 0.14
Dropping point (°C)	59.00 ± 0.15	59.50 ± 0.25	60.10 ± 0.15	60.0 ± 0.11	60.10 ± 0.15	60.00 ± 0.15

Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).



Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

Figure 2. Solid fat content of palm oil-based solid fractions of PPP 2 with 40% to 50 % of PPP content.

The SFC decreased approximately 7% to 8% for the corresponding increase of 10°C from 35°C to 45°C as shown in *Figure 3*. The SFC from 40% to 45% at 55°C decreased to 4% to 13% at 60°C as the fraction experienced a drastic melting of approximately 30% to 35% of solids. This drastic drop in SFC was experienced due to the melting of 69% to 71% of trisaturated triacylglycerols. The distinctive SFC profile of these POSF qualifies it as an excellent structural fat. This type of POSF was used in the formulation of low saturated fatty acids, margarines and spreads. The required characteristic of the hard palm fraction in this patent was similar to POSF in this group which was to have a SFC of above 75% at 40°C, with a corresponding melting point of more than 57°C (Ullanoormadam, 2010).

POSF of Group PPP 4 with 62% to 63% of PPP content

POSF in Group PPP 4 were obtained through dry fractionation of POSF of iodine value 20. The trisaturated triacylglycerols ranged from 71.73% to 74.08% with PPP contributing 62.23% to 63.17% of the POSFs as shown in *Table 7*. Sample 1 on *Table 7* with PPP of 60.59% was included in this group as this POSF exhibited similar characteristic to Group PPP 4 compared to Group PPP 3. The monounsaturated

TABLE 5. TRIACYLGLYCEROL COMPOSITION OF PALM OIL-BASED SOLID FRACTIONS OF PPP 3 WITH 55% TO 60% OF PPP CONTENT

	1	2	3	4	5	6	7
LLL	0.00 ± 0.00	0.00 ± 0.00	0.38 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.20 ± 0.01
PLL	0.15 ± 0.09	0.29 ± 0.02	0.16 ± 0.01	0.28 ± 0.00	0.00 ± 0.00	0.32 ± 0.05	0.00 ± 0.00
MLP	0.00 ± 0.00	0.12 ± 0.01	0.25 ± 0.00	0.13 ± 0.00	0.41 ± 0.00	0.19 ± 0.03	0.00 ± 0.00
OOL	0.31 ± 0.02	0.51 ± 0.01	0.33 ± 0.01	0.44 ± 0.00	0.30 ± 0.00	0.29 ± 0.05	0.22 ± 0.00
POL	1.09 ± 0.06	1.80 ± 0.04	1.78 ± 0.01	1.79 ± 0.00	1.74 ± 0.01	1.47 ± 0.04	1.31± 0.00
PLP	2.37 ± 0.04	3.07 ± 0.22	3.08 ± 0.03	2.79 ± 0.00	2.62 ± 0.01	2.65 ± 0.11	2.52 ± 0.00
MPP	0.64 ± 0.00	0.67 ± 0.10	0.46 ± 0.00	0.43 ± 0.00	0.44 ± 0.00	0.51 ± 0.01	0.48 ± 0.01
OOO	4.50 ± 0.06	3.75 ± 0.04	3.49 ± 0.00	3.58 ± 0.01	3.70 ± 0.01	3.30 ± 0.12	3.18 ± 0.00
POO	3.68 ± 0.15	4.10 ± 0.04	4.92 ± 0.07	4.74 ± 0.00	4.62 ± 0.01	3.93 ± 0.26	4.16 ± 0.01
POP	16.11 ± 0.16	14.45 ± 0.07	16.10 ± 0.01	15.89 ± 0.01	13.95 ± 0.00	14.59 ± 0.12	15.24 ± 0.01
PPP	55.70 ± 0.06	56.99 ± 0.35	56.29 ± 0.01	57.52 ± 0.00	58.28 ± 0.01	59.58 ± 0.82	60.54 ± 0.01
SOO	0.32 ± 0.04	0.93 ± 0.21	0.33 ± 0.01	0.37 ± 0.00	0.48 ± 0.00	0.73 ± 0.23	0.27 ± 0.00
POS	1.83 ± 0.11	2.03 ± 0.03	2.39 ± 0.01	2.50 ± 0.00	2.24 ± 0.00	1.99 ± 0.14	2.27 ± 0.00
PPS	11.89 ± .03	10.23 ± 0.15	9.02 ± 0.01	8.52 ± 0.02	10.20 ± 0.01	9.48 ± 0.05	8.91 ± 0.00
SOS	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.22 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
PSS	1.43 ± 0.14	1.06 ± 0.13	1.01 ± 0.00	0.80 ± 0.00	1.02 ± 0.01	0.98 ± 0.05	0.69 ± 0.00
SSS	69.66 ± 0.16	68.95 ± 0.53	66.78 ± 0.01	67.27 ± 0.02	69.94 ± 0.01	70.54 ± 0.81	70.63 ± 0.00
SUS	20.31 ± 0.09	19.67 ± 0.16	21.82 ± 0.05	21.53 ± 0.01	19.22 ± 0.01	19.42 ± 0.25	20.04 ± 0.01
SUU	5.23 ± 0.15	7.13 ± 0.48	7.20 ± 0.07	7.18 ± 0.01	6.85 ± 0.00	6.44 ± 0.48	5.74 ± 0.00
UUU	4.80 ± 0.08	4.26 ± 0.10	4.20 ± 0.03	4.04 ± 0.01	4.00 ± 0.01	3.59 ± 0.08	3.60 ± 0.01

Note: M - myristic, P - palmitic, S - stearic, O - Oleic, L - linoleic, SSS - trisaturated, SUS - disaturated, SUU - monosaturated, UUU - triunsaturated.
Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

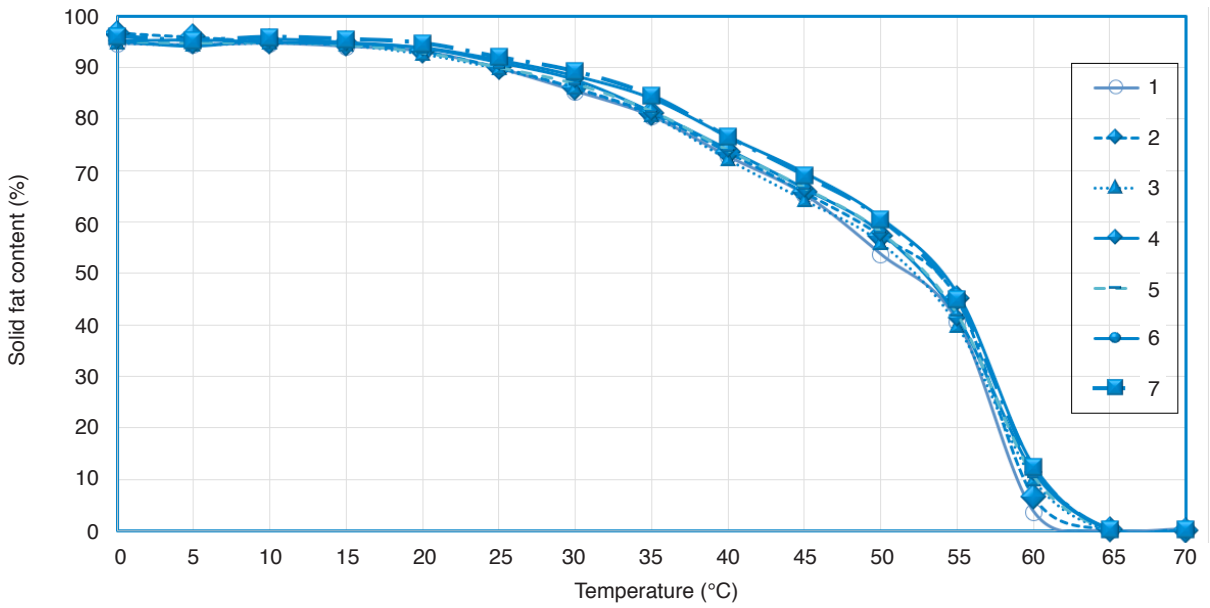
TABLE 6. FATTY ACID COMPOSITION, IODINE VALUES AND DROPPING POINTS OF PALM OIL-BASED SOLID FRACTIONS OF PPP 3 WITH 55% TO 60% OF PPP CONTENT

	1	2	3	4	5	6	7
Fatty Acids							
C 12:0	0.16 ± 0.00	0.80 ± 0.00	0.10 ± 0.00	0.23 ± 0.00	0.10 ± 0.00	0.07 ± 0.00	0.10 ± 0.00
C 14:0	1.70 ± 0.00	1.55 ± 0.00	1.10 ± 0.00	1.21 ± 0.00	1.30 ± 0.00	1.20 ± 0.01	1.10 ± 0.00
C 16:0	78.43 ± 0.17	78.32 ± 0.19	79.30 ± 0.10	79.86 ± 0.15	79.50 ± 0.23	80.53 ± 0.18	79.70 ± 0.16
C 16:1	0.02 ± 0.03	0.05 ± 0.01	0.20 ± 0.00	0.20 ± 0.00	0.20 ± 0.00	0.14 ± 0.00	0.10 ± 0.00
C 18:0	6.09 ± 0.03	5.46 ± 0.02	4.80 ± 0.01	4.51 ± 0.01	5.10 ± 0.01	4.85 ± 0.00	4.80 ± 0.01
C 18:1	12.26 ± 0.07	10.97 ± 0.01	11.90 ± 0.08	11.48 ± 0.04	11.40 ± 0.02	10.75 ± 0.06	11.90 ± 0.04
C 18:2	2.76 ± 0.02	2.34 ± 0.06	2.40 ± 0.09	2.09 ± 0.01	2.20 ± 0.01	2.10 ± 0.01	2.10 ± 0.01
C 18:3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C 20:0	0.36 ± 0.00	0.29 ± 0.01	0.20 ± 0.00	0.21 ± 0.00	0.20 ± 0.00	0.28 ± 0.00	0.10± 0.00
Saturated	86.70 ± 0.14	86.42 ± 0.21	85.50 ± 0.12	86.02 ± 0.18	86.20 ± 0.24	86.92 ± 0.19	85.80± 0.18
Monounsaturated	12.28 ± 0.04	11.02 ± 0.07	12.10 ± 0.08	11.68 ± 0.09	11.60 ± 0.02	10.89 ± 0.06	12.00 ± 0.00
Polyunsaturated	2.76 ± 0.02	2.34 ± 0.06	2.40 ± 0.09	2.09 ± 0.01	2.20 ± 0.00	2.10 ± 0.01	2.10 ± 0.00
Iodine value (I_2/100 g)	14.01 ± 0.17	13.97 ± 0.12	14.7 ± 0.15	13.85 ± 0.24	13.88 ± 0.18	13.69 ± 0.10	14.1 ± 0.22
Dropping point (^{0}C)	61.40 ± 0.25	61.0 ± 0.15	61.70 ± 0.20	62.35 ± 0.15	62.25 ± 0.25	62.30 ± 0.20	62.25 ± 0.30

Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

triacylglycerols were approximately 14.31% to 17.73% with POP content of 11.01% to 13.02%. The percentage of diunsaturated and triunsaturated triacylglycerol ranged from 5.73% to 6.74% and 3.35% to 4.47% respectively. The dropping points of the POSF in Group PPP 4 were also strongly influenced by the content of trisaturated triacylglycerols as the dropping points recorded for this group of POSF were in the range of 62.2°C to 63.0°C. The corresponding iodine value obtained were from 11.76 to 11.98 g of I_2/100 g of oil as shown in *Table 8*.

The percentage of saturated fatty acids were the highest amounting to 87.86% to 88.86% with 81.44% to 82.80% of palmitic acid as shown in *Table 8*. The percentage of monounsaturated fatty acids which consist of mostly oleic acid was 8.78% to 10.20%. The percentage of polyunsaturated fatty acids were



Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

Figure 3. Solid fat content of palm oil-based solid fractions of PPP 3 with 55% to 60% of PPP content.

TABLE 7. TRIACYLGLYCEROL COMPOSITION OF PALM OIL-BASED SOLID FRACTIONS OF PPP 4 WITH 62% TO 63% OF PPP CONTENT

	1	2	3	4
LLL	0.33 ± 0.31	0.00 ± 0.00	0.00 ± 0.00	0.6 ± 0.005
PLL	0.40 ± 0.08	0.23 ± 0.06	0.24 ± 0.00	0.54 ± 0.00
MLP	0.07 ± 0.10	0.12 ± 0.07	0.00 ± 0.00	0.70 ± 0.00
OOL	0.45 ± 0.14	0.38 ± 0.13	0.29 ± 0.00	0.57 ± 0.00
POL	1.66 ± 0.14	1.70 ± 0.15	1.47 ± 0.00	1.28 ± 0.00
PLP	2.48 ± 0.06	2.16 ± 0.26	2.46 ± 0.00	2.28 ± 0.00
MPP	0.53 ± 0.01	0.48 ± 0.16	0.33 ± 0.00	0.56 ± 0.00
OOO	3.54 ± 0.07	3.34 ± 0.06	3.06 ± 0.00	3.24 ± 0.00
POO	3.98 ± 0.49	3.82 ± 0.34	4.03 ± 0.00	3.47 ± 0.00
POP	13.02 ± 0.42	13.06 ± 0.49	12.94 ± 0.00	11.01 ± 0.00
PPP	60.59 ± 0.53	62.23 ± 1.64	63.05 ± 0.00	63.17 ± 0.00
SOO	0.70 ± 0.10	0.45 ± 0.02	0.53 ± 0.00	0.4 ± 0.003
POS	1.65 ± 0.12	1.81 ± 0.10	1.57 ± 0.00	0.32 ± 0.00
PPS	9.76 ± 0.01	9.41 ± 0.19	9.05 ± 0.00	9.19 ± 0.00
SOS	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
PSS	0.85 ± 0.03	0.82 ± 0.03	0.99 ± 0.00	1.16 ± 0.00
SSS	71.73 ± 0.58	72.94 ± 0.15	73.42 ± 0.00	74.08 ± 0.00
SUS	17.22 ± 0.59	17.15 ± 0.11	16.96 ± 0.00	14.31 ± 0.00
SUU	6.74 ± 0.37	6.20 ± 0.17	6.27 ± 0.00	5.73 ± 0.00
UUU	4.31 ± 0.38	3.71 ± 0.07	3.35 ± 0.00	4.47 ± 0.00

Note: M - myristic, P - palmitic, S - stearic, O - oleic, L - linoleic, SSS - trisaturated, SUS - disaturated, SUU - monosaturated, UUU - triunsaturated.

approximately 1.81% to 2.04%. These type of POSF were used to produce exclusive structural fats for margarine formulations with low SAFA (saturated fatty acids). The margarine fat blend consisted of 93% of sunflower oil and a mere 7% of this structural fat to achieve the required texture and firmness of the product. The double fractionated *trans*-free (non-hydrogenated) palm fraction used in the production of this structural fat had approximately 81% of palmitic acid which contributed to the formation of the firm crystal matrix (Ullanoormadam, 2009).

POSF of Group PPP 4 exhibited higher SFC profiles as compared to PPP1, PPP 2 and PPP 3 between the temperatures of 0°C to 65°C. POSF of group PPP 4 exhibited high SFC profiles with above 90% for temperatures below 30°C as shown in *Figure 4*. The percentage of SFC ranged from 80% to 90% between temperatures of 30°C to 40°C.

The percentage of SFC decreased from 80% to 70% between temperatures of 40°C to 50°C. The SFC from 50% to 52% at 55°C and decreased to 15% to 20% at 60°C. The SFC decreased by approximately 35% between the temperatures of 55°C to 60°C. The SFC of the fractions were below 1% at 65°C, experiencing a drop of 15% to 20% of solids from 60°C to 65°C.

POSF of Group PPP 5 with 67% to 68% of PPP Content

POSF in Group PPP 5 were obtained through fractionation of POSF of iodine value 20. The percentage of diunsaturated and triunsaturated triacylglycerol ranged from 4.06% to 5.34% and 3.19% to 3.23%. The monounsaturated triacylglycerols were 13.91% to 14.55% with POP content of 10.21% to 10.91%. The trisaturated triacylglycerols ranged from 77.46% to 78.21% with 67.23% to 67.67% of PPP content as shown in *Table 9*. These POSF are potential source of tripalmitin, which is used to produce human milk fat replacer for infant formulations (Son *et al*., 2010; Lee *et al*., 2015; Maduko *et al*., 2007; Mukherjee and Kiewitt, 1998). The dropping points of the POSF in Group PPP 5 were also strongly influenced by trisaturated triacylglycerol content as the dropping points recorded for this group of POSF were in the range of 63°C to 64°C. The corresponding IV obtained were approximates 9.64 to 10.10 I_2/100 g of oil as indicated in *Table 10*. The results also show the percentage of saturated fatty acids were the highest with approximately 89.73% to 90.54% with 84.38% to 84.735% of palmitic acid as shown in *Table 10*. Whilst, the percentage of monounsaturated fatty acids which consist of mostly of oleic acid were 7.87% to 8.38%. The percentage of polyunsaturated fatty acids is approximately 1.49% to 1.60%.

POSF of Group PPP 5 exhibited higher SFC profiles as compared to PPP 1, PPP 2, PPP 3 and PPP 4 between the temperatures of 0°C to 65°C. POSF of Group PPP 5 exhibited high solid fat profiles with readings above 90% for temperatures below 30°C as shown in *Figure 5*. The percentage of SFC decreased 7% with the increase of 5°C between the temperatures of 40°C to 50°C. The percentage of SFC decreased from 84% to 70% between the temperatures of 40°C to 50°C. The SFC from 57% to 59% at 55°C decreased to 27% to 29% at 60°C. The SFC decreased by approximately 30% between the temperatures of 55°C to 60°C. The SFC of the fractions were below 1% at 65°C, experiencing a drop of 27% to 29% of solids from 60°C to 65°C. These fractions were totally melted above 65°C.

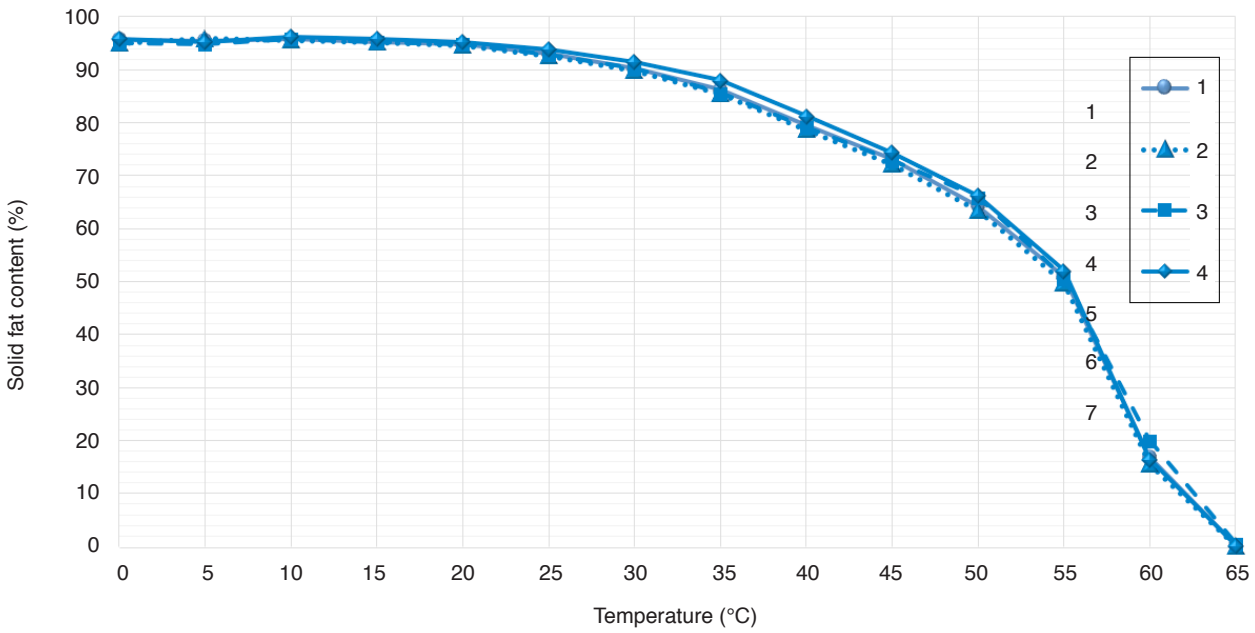
CONCLUSION

Natural and *trans* fatty acids free solid fats are in great demand for food formulations as the consumer market is increasingly driven by this preference. POSF have this advantage as these fractions are natural, *trans* fatty acids free and has the additional advantage of being cholesterol free as they are of vegetable oil origin. This compilation of this physical and chemical characteristics of POSF which contains more than 20% of PPP from Malaysian fractionation plants will provide a basic but nevertheless crucial information required by high fat food formulators. The characteristics of the POSF were greatly influenced by the

TABLE 8. FATTY ACID COMPOSITION, IODINE VALUES AND DROPPING POINTS OF PALM OIL-BASED SOLID FRACTIONS OF PPP 4 WITH 62% TO 63% OF PPP CONTENT

	1	2	3	4
Fatty Acids				
C 12:0	0.06 ± 0.00	0.06 ± 0.00	0.11 ± 0.00	0.1 ± 0.00
C 14:0	1.25 ± 0.01	1.13 ± 0.00	1.02 ± 0.00	1.09 ± 0.00
C 16:0	81.44 ± 0.03	81.66 ± 0.02	82.80 ± 0.09	82.12 ± 0.00
C 16:1	0.15 ± 0.00	0.00 ± 0.02	0.20 ± 0.00	0.11 ± 0.00
C 18:0	4.83 ± 0.03	4.78 ± 0.00	4.38 ± 0.01	5.23 ± 0.00
C 18:1	9.87 ± 0.03	9.91 ± 0.00	9.59 ± 0.03	8.67 ± 0.00
C 18:2	2.04 ± 0.05	1.98 ± 0.01	1.73 ± 0.00	2.02 ± 0.00
C 18:3	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.00	0.12 ± 0.00
C 20:0	0.27 ± 0.00	0.25 ± 0.00	0.00 ± 0.00	0.32 ± 0.00
Saturated	87.86 ± 0.08	87.89 ± 0.01	88.33 ± 0.10	88.86 ± 0.00
Monounsaturated	10.02 ± 0.03	9.91 ± 0.01	9.79 ± 0.03	8.78 ± 0.00
Polyunsaturated	2.04 ± 0.05	1.98 ± 0.00	1.81 ± 0.00	2.14 ± 0.00
Iodine value (I_2/100 g)	11.98 ± 0.11	11.78 ± 0.21	11.76 ± 0.00	11.98 ± 0.00
Dropping point (°C)	62.2 ± 0.25	62.3 ± 0.25	62.95 ± 0.15	62.40 ± 0.25

Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).



Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

Figure 4. Solid fat content of palm oil-based solid fractions of PPP 4 with 62% to 63% of PPP content.

TABLE 9. TRIACYLGLYCEROL COMPOSITION OF PALM OIL-BASED SOLID FRACTIONS OF PPP 5 WITH 67% TO 68% OF PPP CONTENT

	1	2	3
LLL	0.00 ± 0.00	0.07 ± 0.00	0.00 ± 0.00
PLL	0.16 ± 0.00	0.42 ± 0.01	0.00 ± 0.00
MLP	0.00 ± 0.12	0.23 ± 0.01	0.24 ± 0.00
OOL	0.23 ± 0.01	0.19 ± 0.00	0.20 ± 0.00
POL	1.05 ± 0.00	1.17 ± 0.00	1.29 ± 0.00
PLP	2.04 ± 0.04	1.89 ± 0.00	1.89 ± 0.00
MPP	0.26 ± 0.02	0.26 ± 0.00	0.28 ± 0.02
OOO	2.95 ± 0.05	2.94 ± 0.00	3.03 ± 0.00
POO	2.68 ± 0.02	3.30 ± 0.00	3.81 ± 0.01
POP	10.91 ± 0.00	10.21 ± 0.00	10.36 ± 0.01
PPP	67.27 ± 0.07	67.23 ± 0.01	67.67 ± 0.00
SOO	0.16 ± 0.00	0.27 ± 0.01	0.24 ± 0.00
POS	1.59 ± 0.07	1.59 ± 0.01	1.49 ±0.01
PPS	9.57 ± 0.10	9.37 ± 0.01	8.84 ±0.00
SOS	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
PSS	1.11 ± 0.01	0.87 ±0.00	0.67 ± 0.01
SSS	78.21 ± 0.05	77.73 ± 0.01	77.46 ± 0.01
SUS	14.55 ± 0.03	13.91 ± 0.00	13.97 ± 0.01
SUU	4.06 ± 0.02	5.16 ± 0.01	5.34 ± 0.01
UUU	3.19 ± 0.06	3.20 ± 0.00	3.23 ± 0.00

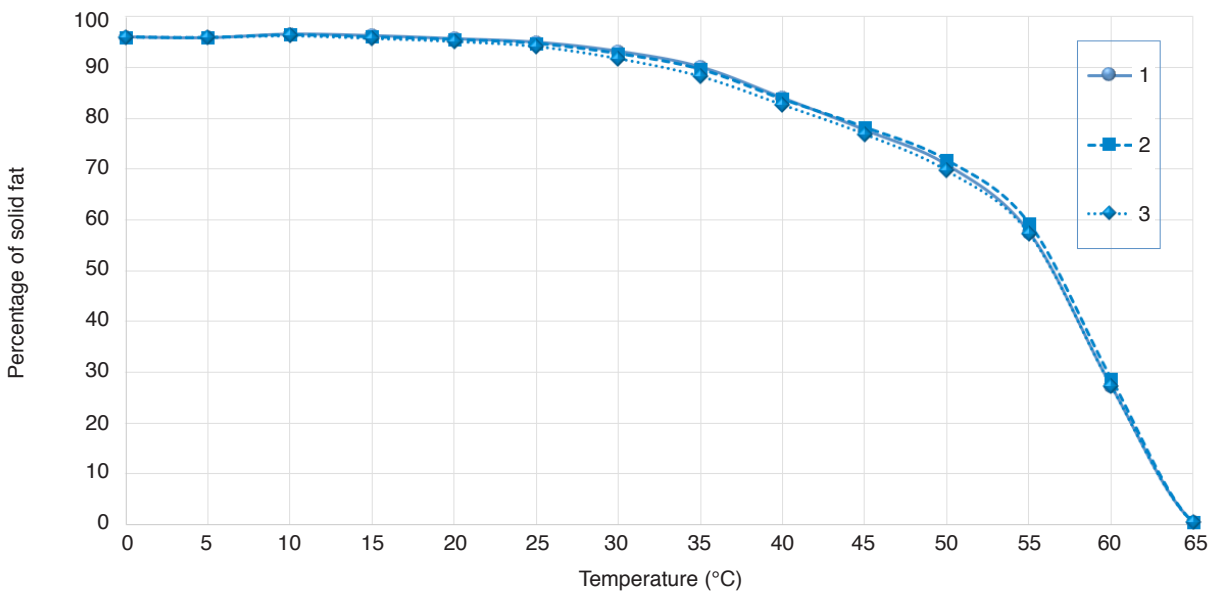
Note: M - myristic, P - Palmitic, S - stearic, O - Oleic, L - linoleic, SSS - trisaturated, SUS - disaturated, SUU - monosaturated, UUU - triunsaturated.
Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

triacylglycerol composition which is reflected in the corresponding fatty acid composition, iodine value, dropping point and SFC. The characteristics of POSF were greatly influenced and dominated by the trisaturated triacylglyceroly namely PPP. The increase of PPP increased the dropping points and exhibited high values of SFC in the evaluated POSF. Hence, fractions were categorised according to the percentage of PPP to provide groupings with specific physical and chemical characteristics to assist food formulators. The percentage of PPP in Group PPP 1 was 20% to 30%, PPP 2 was 40%

TABLE 10. FATTY ACID COMPOSITION, IODINE VALUES AND DROPPING POINTS OF PALM OIL-BASED SOLID FRACTIONS OF PPP 5 WITH 67% TO 68% OF PPP CONTENT

	1	2	3
Fatty Acids			
C 12:0	0.10 ± 0.00	0.10 ± 0.00	0.05 ± 0.00
C 14:0	1.02 ± 0.00	1.00 ± 0.00	0.90 ± 0.00
C16:0	84.65 ± 0.19	84.73 ± 0.21	84.38 ± 0.15
C 16:1	0.20 ± 0.00	0.19 ± 0.00	0.10 ± 0.00
C 18:0	4.51± 0.00	4.50 ± 0.00	4.30 ± 0.00
C 18:1	7.78 ± 0.09	7.78 ± 0.04	8.28 ± 0.00
C 18:2	1.51 ± 0.00	1.49 ± 0.00	1.60 ± 0.00
C 18:3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C 20:0	0.23 ± 0.00	0.20 ± 0.00	0.10 ± 0.00
Saturated	90.51 ± 0.19	90.54 ± 0.21	89.73 ± 0.15
Monounsaturated	7.98 ± 0.09	7.97 ± 0.04	8.38 ± 0.00
Polyunsaturated	1.51 ± 0.00	1.49 ± 0.00	1.60 ± 0.00
Iodine value (I_2/100 g)	9.64 ± 0.12	9.97 ± 0.211	10.1 ± 0.17
Dropping point (°C)	63.70 ± 0.25	63.65 ± 0.30	63.15 ± 0.20

Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).



Note: Each value in the table represents the mean ± standard deviation of triplicate analyses (n=3).

Figure 5. Solid fat content of palm oil-based solid fractions of PPP 5 with 67% to 68% of PPP content.

to 50%, PPP 3 was 55% to 60%, PPP 4 was 62% to 63% and PPP 5 was 67% to 68%. The wide range of commercially available POSF opens great opportunities and diversification of functionality and application of these fractions in high fat food products.

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