The Role of Fat Blends in Improving the Physicochemical Properties of Palm Kernel Oil for Monolaurin Synthesis

Ngatirah Ngatirah[1,2], Chusnul Hidayat[3], Endang Sutriswati Rahayu[3] and Tyas Utami[3],*

[1]Study Program of Food Science, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia
[2]Department of Agricultural Product Technology, Faculty of Agricultural Technology, Institut Pertanian Stiper, Depok, Sleman, Yogyakarta 55282, Indonesia
[3]Department of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

(*Corresponding author's e-mail: tyas_utami@ugm.ac.id)

Abstract

This study aims to analyze the physicochemical properties of fat blends between palm kernel olein and stearin in different ratios. Furthermore, it determines the fat blends, which have more than 50 % lauric acid at the sn-2 position. The liquefied RBDPKOo (refined bleached deodorized palm kernel olein) and RBDPKOs (refined bleached deodorized palm kernel stearin) were mixed in proportions of 100:0; 80:20; 60:40; 40:60; 20:80; and 0:100 (w/w), and homogenized at 70 °C for 15 min. Also, the samples analyzed were fatty acid composition, triglyceride profile and physicochemical properties. The results showed the blending of RBDPKOo with RBDPKOs resulted in a change in melting point, iodine value, and behavior. Increased RBDPKOs resulted to a higher melting point, and a lower iodine value of fat blends. A blending with higher RBDPKOs (more than 60 %) resulted in a sharp endothermic peak. Meanwhile, blending of RBDPKOo with RBDPKOs significantly changes the fatty acid composition and triglycerides profiles. The RBDPKOs in the fat blends increased the trilaurin, and the composition as well as the amount of lauric acid at the position of sn-2. In addition, the 2 fat blends obtained with more than 50 % lauric acid at the position of sn-2 were RBDPKOo: RBDPKOs ratios of 40:60 and 20:80, respectively.

Keywords: Fat blend, Palm kernel olein, Palm kernel stearin, Physicochemical properties, Monolaurin

Introduction

Monolaurin or glycerol monolaurate (2,3-Dihydroxypropyl dodecanoate) is a monoglyceride of lauric acid naturally found in about 5.8 % of milk fat in the breast. It serves as an immune system booster for infants [1]. It acts as a nonionic emulsifier containing a hydrophilic and hydrophobic group in its molecular structure [2]. As an emulsifier, monoacylglycerol (MAG) is used in the food and pharmaceutical industries. Furthermore, it acts as an antimicrobial agent [3,4] that can be applied to various food products [5]. Therefore, the synthesis of monolaurin to be used as an emulsifier and food preservative is very important

Commercially available monolaurin is produced from lauric acid by the process of esterification with glycerin using chemical catalysts. The disadvantage of using lauric acid in producing monolaurin is that the material is not directly available, but comes from the hydrolysis of coconut or palm oil and therefore the price is relatively high. In addition, other raw materials include coconut and palm kernel oil (PKO) through the glycerolysis process. PKO is one of the potential raw materials for monolaurin since Indonesia is one of the largest palm oil producers in the world with a production of 9, 172, 224 tonnes [6]. The global production of palm oil was around 72.27 and 8.77 million metric tons for palm kernel oil in 2020/2021. Indonesia is the leading producer of palm oil, with a recorded 41.5 million thousand metric tons of palm oil in 2018/2019 [7].

PKO is a by-product of palm oil, which is obtained after from pressing the mesocarp of the kernel. Crude PKO (CPKO) is extracted from the kernel using mechanical screw pressing. Every 100 tonnes of

crude palm oil (CPO) production yields 10 to 13 tonnes of CPKO. Furthermore, the CPKO is processed to obtain refined, bleached, and deodorized palm kernel oil (RBDPKO), which can be fractioned into RBDPKO olein (RBDPKOo) and RBDPKO stearin (RBDPKOs) [8]. PKO contains 50 % of lauric acid and the main component is triacylglycerol (TAG) of approximately 95 %. The most extensive composition is LaLaLa (20.46 %), followed by LaLaM (17.77 %), and CaLaLa (16.88 %) [8,9].

The use of PKO as a monolaurin raw material has disadvantage which includes inconsistency of quality affected by the processing and storage condition of the kernel. PKO can be fractionated to 60 - 70 % palm kernel olein (PKOo) and 30 - 40 % Stearin (PKOs) [8] with 39.7 - 48 % and 56 - 59.7 % amount of lauric acid, respectively [10]. In addition, PKOo and PKOs potentially serve as monolaurin synthesis's raw material. The desirable feedstock in this manufacture is the lauric acid content more than 30 % [11]. Even though the availability of PKOo is about twice of PKOs; its lauric acid content is lower. Therefore, it is necessary to blend PKOo and PKOs to increase the amount of lauric acid and produce a more consistent quality of fat blend compared to PKO. Blending can affect the amount of TAG and fatty acids, the iodine value, and the melting point of the fat blends. Previously, it has been used to modify oils and fats into functional products. This is conducted by rearranging the distribution of fatty acids on the glycerol without changing their chemical composition. Blending fats/oils leads to changes in triacylglycerol profile, and the physical properties of oils.

The distribution of lauric acid on the position of sn-2 also influences the effectiveness of the antibacterial activity of monolaurin [12]. As an emulsifier, 2-monoglycerides (monoglycerides with fatty acid chains at the positions of sn-2) have only 1 form of β polymorphic [13]. Meanwhile, the β polymorphic has more excellent stability, providing better emulsion capability [5,14,15]. The content of lauric acid at the position of sn-2 in PKO is approximately 48.59 % [16], and it is not yet known in PKOo and PKOs. Therefore, it is essential to study the content of lauric acid at the sn-2 position in PKOo, PKOs, and its blends on various ratios. Also, blending PKOo and PKOs at a specific ratio increases the content of lauric acid at the position of sn-2. Therefore, their desirable criteria as a raw material for monolaurin, especially 2-monolaurin, should have a minimum amount of 30 % lauric acid and the amount in the position of sn2 should be more than 50 %.

This study aims to analyze the physicochemical properties, fatty acid, and triacylglycerol profile of the RBDPKOo-RBDPKOs blends in various ratios. Furthermore, it determines the fat blends, which have more than 50 % lauric acid at the sn-2 position.

Materials and methods

Materials
RBDPKOo, RBDPKOs, and refined glycerin were obtained from PT Wilmar through purification process in refinery and fractionation plants. These procedures were conducted with degumming, bleaching, deodorization process to produce RBDPKO. Furthermore, RBDPKO was fractionated into RBDPKOo (liquid fraction) and RBDPKOs (solid fraction) through the crystallization and filtration process stages. Pancreatic lipase (EC 3.1.1.3-triacylglycerol lipase) and Molecular sieves were purchased from Sigma-Aldrich (St. Louis, MO, USA). Meanwhile, the chloroform, potassium iodide (KI), sodium thiosulfate ($Na_2S_2O_3$) and Wijs (iodine monochloride) reagent were purchased from Merck KGaA (Darmstadt, Germany).

Preparation of fat blends
Preparation of RBDPKOo-RBDPKOs fat blends was conducted according to the modification of Liu *et al*. [21]. Before blending, they were heated at 70 °C for 30 min to homogenize all oil fractions. The liquefied fat blends were mixed in proportions of RBDPKOo: RBDPKOs: 100:0; 80:20; 60:40; 40:60; 20:80; and 0:100 (w/w). The homogenization was conducted at 70 °C for 15 min and then stored in a refrigerator for further analysis. In addition, the experiment was conducted with 3 replications, and the RBDPKOo-RBDPKOs blends were analyzed for physicochemical properties (melting behavior, melting point, iodine value), TAG and fatty acids composition, and lauric content acid at the position of sn-2.

Analysis of melting point and melting behavior
The melting point and behavior of fat blends were determined by differential scanning calorimetry (DSC-60Plus, Shimadzu, Japan). Nitrogen gas was used at a flow rate of 10 mL/min and was calibrated with indium and n-dodecane. Furthermore, the samples (5 - 10 mg) were tightly sealed in an aluminum pan and cooled at 0° C, after been heated to 40 °C. The melting thermograms were recorded at a heating rate of 5 °C/min from 0 to 40 °C.

Iodine value analysis

Iodine value was analyzed using the Wijs method [17] and about 0.25 g of the oil sample was weighted then inserted into the Erlenmeyer. It was dissolved in 15 mL chloroform before adding 25 mL of Wijs reagent. The mixture was Stirred carefully, then the solution was stored in a dark place for 30 min. Furthermore, about 20 mL of KI solution and 100 mL of boiled aquadest were added The mixture was titrated with 0.1 N $Na_2S_2O_3$ solutions, until the yellow color almost disappeared. Also, 2 mL of starch indicator solution was added and titrated (1 g starch in 200 mL H_2O) until the blue color fades. The blank solution was obtained with the procedure but without a sample. The analysis was duplicated and the iodine value calculation was conducted by;

$$\text{Iodine value} = \frac{(B - S) \times N \times 12.69}{\text{wt of fat or oil}}$$

where B = titration of blanks (mL); S = titration of sample (mL), N = $Na_2S_2O_3$ concentration of standardization result.

Fatty acid composition analysis

The fatty acid composition was determined using gas chromatography (GC-Shimadzu 2010, Japan) with a flame ionization detector and split injector. Furthermore, GC analysis was conducted under the following conditions: Injector temperature was at 300 °C, and samples used injected 1 µL with a split ratio of 1:73. The SH-Rxi-5Sil MS column was used with a film thickness of 0.25 µm and the temperature program of 70 °C rises to 300 °C at a 5 °C/min rate. Also, the carrier gas used was helium at a flow rate of 0.5 mL/min and the detector temperature was at 300 °C.

Triacylglycerol analysis

The profiles of TAG were analyzed using high-performance liquid chromatography with the detector UV-Vis (HPLC series 1,200; Agilent, CA, USA) following the AOCS official methods, Ce 5b-89 [18]. HPLC has an isocratic pump type, and the mobile phase is acetone: Acetonitrile 85:15 (v/v) with a flow rate of 1 mL/min. The column used was 2 columns C-18 with a size of 4.6×250 mm^2.

Lauric acid at the sn-2 position Analysis

The composition of the fatty acids at the position of sn-2 was determined by specific enzymatic hydrolysis (pancreatic lipase) followed by separation of the 2-monoacylglycerol (2-MAG). This was conducted by thin-layer chromatography while their fatty acid methyl esters analysis was by GC [19].

Statistical analysis

The completely randomized design was used as an experimental design and was conducted with 3 replications. The data was analyzed using analysis of variance (ANOVA) and Duncan multiple range test (DMRT), which showed significant difference.

Results and discussion

Fatty acid composition

Table 1 showed that the amount of fatty acid composition in the RBDPKOo-RBDPKOs mixtures differs significantly. Lower RBDPKOo and higher RBDPKOs ratio used in blending increase lauric and myristic acid but significantly decrease oleic and stearic acid. RBDPKOs have higher lauric and myristic acids than RBDPKOo. Therefore, the higher the RBDPKOs ratio in the fat blends, the higher the lauric myristic acid and the lower the oleic and stearic acid composition (**Table 1**). The palmitic acid content does not differ in all proportions, since the content in RBDPKOo and RBDPKOs is almost the same at 5.93 % and 5.74 %, respectively. Therefore, when blended with specific ratios, the palmitic acid in fat blends is not different.

The RBDPKOo-RBDPKOs blends which produce lauric acid almost similar to RBDPKO is 60:40. More than 60 % of RBDPKOs in the fat blends lead to a greater quantity of lauric acid than RBDPKO (**Table 1**). PKO contains fractions of olein and stearin with a ratio of 60 - 70 and 40 - 30 %, respectively. The dry fractionation produces 60 - 70 % PKOo with iodine number 24 - 25 and 30 - 40 % PKOs with iodine number 4 - 7 [23,24]. The lauric acid in RBDPKOo and RBDPKOs and their fat blends are used as monolaurin raw materials since the amount is more than 30 %. Therefore, the lauric acid content of more than 30 % is the desirable feedstock of monolaurin in the manufacture [11].

The results of the lauric acid composition obtained were 2 - 6 % higher than previous studies conducted [10,19,20] because the type of PKO used was different. Some used unfractionated crude PKO, while this study used purified and fractionated PKO (RBDPKOo and RBDPKOs). Ibrahim [8] reported that PKO contains 50 % lauric acid, 17 % myristic acid, 9 % palmitic acid, and 17 % oleic acid. Meanwhile, Gold and Akoh [22] reported that RBDPKO contains 48 % lauric acid, 16% myristic acid, and 17 % oleic acid. Goon *et al*. [20] reported that PKOo contains 48 % lauric acid, 18 % oleic acid, and 14 % myristic acid, while the PKOs contained 56 % lauric acid and 21 % myristic acid. Furthermore, stearin fraction has higher saturated fatty acids than olein fraction. PKOs have 52 - 59.7 % and 20 - 25 % lauric and myristic acids, while the PKOo has 39.7 - 47 % and 11.5 - 15.5 % lauric and myristic acids [10]. The differences in the fatty acid composition are influenced by palm oil plant varieties, processing processes, and storage conditions.

Different results of palm olein-PKO blends were reported by Gold and Akoh [22] with ratios of 40, 30, 20, and 10 %. The result showed decreased lauric and myristic acid while palmitic, oleic, and linoleic acid increase with the addition of palm oil oleins. Furthermore, Srivastava *et al*. [25] reported that blending VCO with pure soybean oil at different percentages causes a decrease in monounsaturated (MUFA) (oleic) and polyunsaturated fatty acids (PUFA) (linoleic acid and linolenic).

Some literature reported that the PKO can be blended with various oils or fats such as Palm Stearin (POs) [26-28], palm oil olein (POo) [22,29], sunflower oil [27], palm kernel stearin [21,30] and tallow [30]. Blending fats or oil results in modifications within the profiles of fatty acids and triacylglycerols. Meanwhile, blending of PKOo and PKOs fractions affects the composition of TAG and fatty acids, and the melting point changes of the fat blends.

Blending is a simple method to modify and expand the use of oils and fats [31]. The triacylglycerol profile influences the amount and composition of fatty acids. Furthermore, the composition of fatty acids and TAG is essential to study Fats' physicochemical characteristics [32]. The blending of palm oil with unsaturated or monounsaturated oils improves and enhances the commercial attributes, functional properties and nutrients of palm oil [25,33].

Table 1 The fatty acids composition in the RBDPKOo-RBDPKOs blends.

Fatty acids	% area of fatty acids in the RBDPKOo: RBDPKOs blends*						RBDPKO
	100:0	80:20	60:40	40:60	20:80	0:100	
Caprylic acid	5.49 ± 0.22a	4.63 ± 0.03b	3.77 ± 0.02c	3.02 ± 0.01d	2.79 ± 0.01e	2.37 ± 0.02f	3.90
Capric acid	5.08 ± 0.08a	4.88 ± 0.22a	4.39 ± 0.04b	4.10 ± 0.02c	4.20 ± 0.02c	4.10 ± 0.03c	4.52
Lauric acid	50.42 ± 0.52f	53.88 ± 0.10e	55.33 ± 0.41d	57.01 ± 0.15c	59.92 ± 0.09b	61.52 ± 0.19a	56.35
Myristic acid	11.63 ± 0.05f	13.38 ± 0.05e	14.93 ± 0.12d	16.43 ± 0.06c	17.47 ± 0.02b	18.04 ± 0.05a	15.20
Palmitic acid	5.93 ± 0.31ns	5.80 ± 0.11ns	5.77 ± 0.11ns	5.79 ± 0.13ns	5.50 ± 0.04ns	5.50 ± 0.24ns	5.74
Oleic acid	13.73 ± 0.38a	12.18 ± 0.08b	10.23 ± 0.11c	8.42 ± 0.10d	6.32 ± 0.06e	4.70 ± 0.05f	9.50
Linoleic acid	1.52 ± 0.17a	1.34 ± 0.02ab	1.31 ± 0.05ab	1.25 ± 0.15b	1.07 ± 0.02c	1.01 ± 0.01c	1.41
Stearic acid	6.21 ± 0.28a	3.90 ± 0.34b	4.28 ± 0.76b	3.97 ± 0.59b	2.73 ± 0.08c	2.77 ± 0.03c	3.40

*value is average ± SD (n = 3). A row's average, followed by a different letter, indicates a significant difference in the Duncan Multiple Range Test (DMRT) 5%.

Melting behavior of RBDPKOo-RBDPKOs blends

Figure 1 showed that the melting behavior of RBDPKOo-RBDPKOs blends (onset melting temperature (Tom), peak melting temperature (Tp), endset melting temperature (Tem), and enthalpy of melting (DH)) was obtained from enthalpy-temperature data. The results showed that the melting behavior was significantly influenced by the percentage. The melting behavior of RBDPKOo (100:0) showed that there was only 1 broad endothermic peak. It ended at a melting point of about 20 °C, while RBDPKOs (0:100) showed a sharp endothermic peak with a final temperature of about 34.4 °C. This is because the RBDPKOs has a higher composition of TAG LaLaLa, LaLaM/LaMLa, and LaMM/MLaM. The fat blends starting from 80:20, 60:40, and 40:60 ratio has only 1 peak for all the RBDPKOo: RBDPKOs blends. The blending of RBDPKOo with RBDPKOs resulted in an increasingly sharp endothermic peak. Meanwhile, the blending with higher RBDPKOs results to a sharp melting curve. A

new trend was discovered after adding more than 60 % of RBDPKOs. The broad endothermic peak became sharp with a higher melting point (**Figure 1**).

Melting behavior and crystallization are essential for understanding the interaction of components and complex structures as well as the basis for explaining their physical-chemical properties [21]. When blending is performed, the TAG interacts with each other, resulting in complex phase behavior [21]. The sharp endothermic peak showed a relatively higher hardness at room temperature and immediately melts when at body temperature [34].

The peak of the melting point of RBDPKOo (ratio 100:0) is 20 °C. The fat blends with less RBDPKOo and higher RBDPKOs have an increased melting point and the peak was shifted towards the right (**Figure 1**). Furthermore, the fat blend RBDPKOo: RBDPKOs of 20:80 has a melting peak at 33 °C, and that of RBDPKOo: RBDPKOs blend (0:100) at 34.4 °C. The peak of the melting curve at RBDPKOo: RBDPKOs blend 60:40 (about 27.75 °C) was similar with the peak of the melting curve on RBDPKO at a temperature range of 27.38 °C. In addition, a melting behavior in refined PKO showed only 1 broad endothermic peak at the beginning of the temperature (Tom). This was approximately 20 °C and ended at a melting temperature (Tem) of around 31 °C [21]. Also, PKO is a semi-solid fat at room temperature with a melting point of about 26 - 28 °C [21]. It contains many lauric acids with coconut oil, resulting in a sharp melting curve that can be applied in food containing structured lipids such as margarine, CBS, and ice cream [9].
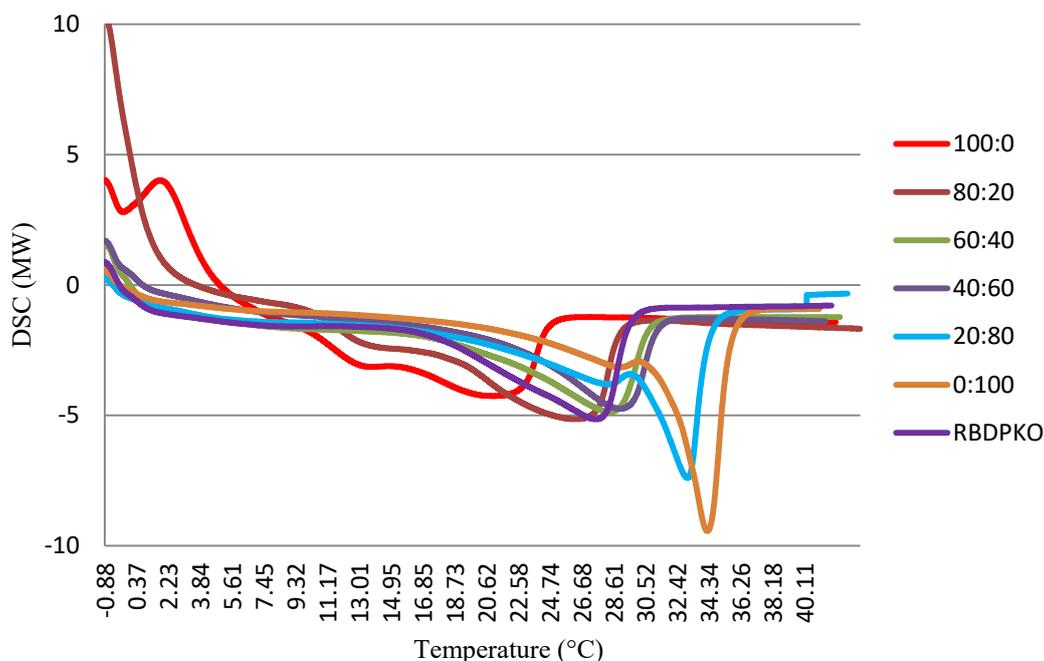

Figure 1 Melting behavior of RBDPKOo-RBDPKOs blends as measured by differential scanning calorimetry (DSC).

The melting point of RBDPKOo-RBDPKOs blends

The appearance of RBDPKOo-RBDPKOs blends in various ratios at room temperature was different. RBDPKOo: RBDPKOs appeared on the ratios of 100:0 and 80:20 as liquid. When the ratio was 60:40, the appearance changed to solid and liquid mixture appearance. Fat blends of RBDPKOo-RBDPKOs with RBDPKOs (more than 60 %) appeared as solid. When the fat blends were melted at a temperature of 40 °C, there was a small stearin fraction that has not melted in the RBDPKOo: RBDPKOs 20:80 and 0:100 ratios. However, when the temperature was higher than 40 °C, all of the oil fractions were melted perfectly in all ratios. This variation results from the differences in the melting point of each fat blend (**Table 2**), which is influenced by the composition and amount of triacylglycerol and fatty acids. During fat blending, the TAG attaches with each other, forming a complex phase behavior that affects the melting and crystallization of fats [35]. At room temperature (25 - 28 °C), the RBDPKOo-RBDPKOo

blends 80:20 ratio is in liquid. This is because both fats have a melting point of 20.96 ± 0.10 and 24.56 ± 0.10 °C, respectively. Meanwhile, the appearance of 60:40 ratio is solid with the melting point 27.24 ± 0.44 °C. The fat blends of RBDPKOo: RBDPKOs 40:60; 20:80 and 0:100 ratios have a solid form due to the melting point of 28.88 ± 0.38, 33.53 ± 0.48 and 34.43 ± 0.15 °C for each (**Table 2**). The RBDPKOs used in fat blending increased the melting point of the RBDPKOo-RBDPKOs blends. This is due to the higher amount of saturated fatty acids, especially lauric and myristic on RBDPKOs compared to the RBDPKOo. In addition, RBDPKOs contained 61.52 and 18.04 % lauric and myristic acids, while the RBDPKOo contained 50.42 and 11.63 % lauric and myristic acids (**Table 1**). Based on the melting point, RBDPKOs and its fat blends are needed in the synthesis of monolaurin. This is because the glycerolysis is conducted at a temperature above the melting point for the reaction to occur.

The melting point of fat blends reflects the composition of their fatty acids, and it is affected by chain length and degree of unsaturation. Increase in chain length increases the melting point. Furthermore, unsaturated fatty acids have a lower melting point than saturated with the same carbon atoms. This is because the cis configurations produce bends in the structure and reduce possible van der Waals interactions between molecules. The number of double bonds also affects the melting point. Increased number of double bonds in fatty acids with the same carbon atoms decreases the melting point [36].

The solid fat content (SFC) of PKO and PKOo is reduced by 50 % when the temperature is raised from 20 to 25 °C and becomes completely melted at 30 °C [8]. PKOs have the highest SFC because the amount of lauric and myristic acids is higher than PKO and PKOo. They have the highest SFC at temperatures lower than 25 °C. Furthermore, they melt sharply above 30 °C and are completely melted at 35 °C [8]. The physical and chemical properties of fats and oils depend on their fatty acid composition and position in the triacylglycerol (TAG) molecule [36]. Also, the physical properties of lipids depend on the characteristic of saturated or unsaturated alkyl chains, the configuration of cis or trans, and the short length of fatty acid chains. The melting point increases with the length of the fatty acid chain. Meanwhile, it decreases when there is an increase in unsaturated fatty acids. This is because the presence of a cis-double bond lowers the melting point [14].

Table 2 The melting point, iodine value and composition of lauric acid at the sn-2 position of RBDPKOo: RBDPKOs blends.

RBDPKOo:RBDPKOs blends	Melting point (°C)*	Iodine Value (Wijs)*	% composition of lauric acid at the sn-2*
100:0	20.96 ± 0.10f	20.60 ± 0.09a	39.84 ± 2.04b
80:20	24.56 ± 0.55e	19.34 ± 0.36b	39.86 ± 2.15b
60:40	27.24 ± 0.44d	15.66 ± 0.21c	42.29 ± 3.92b
40:60	28.88 ± 0.38c	12.84 ± 0.41d	50.71 ± 2.53a
20:80	33.53 ± 0.48b	9.62 ± 0.67e	51.84 ± 2.17a
0:100	34.43 ± 0.15a	6.85 ± 0.29f	53.50 ± 2.90a
RBDPKO	27.38	16.14 ± 0.09	

*value is average ± SD (n = 3). The average, followed by a different letter, indicates a significant difference in the Duncan Multiple Range Test (DMRT) 5 %.

Iodine value (IV)

The iodine value is one of the parameters used in analysing the number of double bonds contained in the fat and it is indicated by the presence of oleic and linoleic acids. **Table 2** showed the iodine value of RBDPKOo-RBDPKOs blends in different ratios. The blending changes the iodine value due to the change in fatty acids and triglycerides in the fat blend. Higher RBDPKOs ratio decreases the iodine value because the long-chain fatty acids contain double bonds such as oleic and linoleic acids. The fat blend of RBDPKOo: RBDPKOs 60:40 has an iodine value similar to RBDPKO because the amount of oleic and linoleic acids is almost the same. In addition, RBDPKOo contains several long-chain fatty acids with double bonds such as oleic and linoleic acids higher than RBDPKOs (**Table 1**). During the fractionation process, oleic and linoleic acids from PKO was distributed into liquid fractions. Meanwhile, the saturated fatty acids (lauric and meristic acid) were in solid fractions. This resulted in many unsaturated fatty acids in PKOo, causing a higher and lower iodine value of PKOo and PKOs respectively [8]. The one-stage dry

fractionation process produced 60 % PKOo IV-25 and 40 % PKOs IV-7. The 2-stage dry fractionation resulted in 70 % PKOo IV-24 and 30 % PKOs IV-4 [23]. In addition, the dry fractionation of CPKO produced PKOo 63.4 % and 36.6 % PKOs IV-7 or 75.85 % PKOo and 24.15 % PKOs IV-5 [24].

Lauric acid composition of the position of sn-2

The amount of lauric acid at the sn-2 position increases with the increase of RBDPKOs in the fat blends of RBDPKOo and RBDPKOs (**Table 2**). This is because RBDPKOs contains higher lauric acid 61.52 ± 0.19 % than RBDPKOo 50.42 ± 0.52 %. The types of triacylglycerols containing lauric acid at sn-2 positions such as trilaurin (LaLaLa), LaLaM, and LaLaP on RBDPKOs are higher RBDPKOo. Therefore, fat blends with Increased RBDPKOs cause the higher amount of lauric acid at the sn-2 position. The 2 fat blends that produce the amount of lauric acid at the position of sn-2 more than 50 % are RBDPKOo: RBDPKOs 40:60 and 20:80. The amount of lauric acid obtained was 2.38 - 3.25 % higher than the value reported by Silalahi *et al*. [16] on virgin coconut oil (VCO) and PKO due to ratios of 40:60 and 20:80 (**Table 1**). In both ratios, the number of TAGS containing lauric acid in sn-2 positions such as LaLaLa, LaLaM, LaLaP, CaLaLa, and CLaLa is higher than RBDPKO (**Table 3**). Furthermore, the lauric acid distribution at the position of sn-2 in VCO and PKO is no different. VCO and PKO have a lauric acid at the position of sn-2 48.33 and 48.59 %, respectively [16]. The fat blend at a ratio of 40:60 and 20:80 are the promising raw material for 2-monolaurin synthesis. This is because the number of lauric acid at the sn-2 position was more than 50 %.

Fats and oils consist of a TAG mixture consisting of glycerol's backbone with 3min esterified fatty acids and the attachment positions are sn-1, sn-2, and sn-3. They are positioned to affect the properties of fats/oils [37] and the composition of saturated fatty acids at PKO is 80 %. Furthermore, palm olein contains about 87 % unsaturated fatty acids (oleic acid and linoleic acid) and 7 - 11 % palmitic acid at the position of sn-2 [37]. The distribution of lauric acid on the position of sn-2 influences the effectiveness of the antibacterial activity and capability emulsion of monolaurin [12,13].

TAG composition of RBDPKOo-RBDPKOs blends

The composition of Triacylglycerol of RBDPKOo-RBDPKOs blends is shown in **Table 3** and the dominant presence in the RBDPKOo fraction is LaLaLa (trilaurin), followed by CaLaLa, LaLaM, and CLaLa. Furthermore, the RBDPKOs fraction was also dominated by LaLaLa, followed by LaLaM and LaLaP/LaMM. RBDPKOo contains a TAG with unsaturated fatty acids (oleic acid), such as triolein (OOO), POO, POP, MOP, and MOO. Besides trilaurin, CLaLa, CaLaLa, LaLaM, LaLaO, and LaLaP/LaMM are TAGs that contribute to lauric acid RBDPKO has 22.51 ± 0.27 % triacylglycerol LaLaLa and 15.66 ± 0.17 % triacylglycerol LaLaM. The composition of TAG LaLaLa and LaLaM is higher than the value reported by Fauzi *et al*. [38] and similar to the report of Chai *et al*. [9].

The amount of trilaurin in RBDPKOo (21.14 ± 0.20 %) is lower than RBDPKOs (28.04 ± 0.27 %) and this was similar to the study by Ibrahim's research in 2013 [8]. The blending of RBDPKOo with RBDPKOs caused a change in the triacylglycerol compositions of fat blends. Furthermore, the RBDPKOs fraction in the fat blends decrease the TAG containing the oleic acids and the Triacylglycerol of OOO (triolein), POO, and POP is not detected in the RBDPKOs. The higher the RBDPKOs in the fat blend, the lower of the triacylglycerol OOO, POO, and POP, even at RBDPKOo: RBDPKOs blend 20:80 the triacylglycerol POP is not detected.

The blending of RBDPKOo with RBDPKOs alters the composition of triacylglycerol. Meanwhile, blending with a lower RBDPKOo and higher RBDPKOs ratios significantly increase the composition of LaLaLa, LaLaM, LaLaP/LaLaM, MMM/LaPM, and LaPP/MMP. However, it decreases the composition of CLaLa, CaLaLa/CLaM, LMM/LaOM, LMO/LaOO, MPL/LaOP/MMO, MOO, MOP, OOO, POO and POP. During the fractionation process, oleic and linoleic acid from PKO were distributed into liquid fractions, Meanwhile, saturated fatty acids (lauric and meristic acid) go into solid fractions and it causes a high number in PKOo. It affects the iodine value of the higher PKOo and the lower value in the PKOs [8]. The iodine value for the RBDPKOo 20.60 ± 0.09 and RBDPKOs 6.85 ± 0.29. The composition of triacylglycerol determines the physical properties affecting fats and oils' structure and stability, flavors, sensory characteristics, and food visuals [14].

Table 3 The composition of triacylglycerol on the RBDPKOo-RBDPKOs blends.

Composition of TAG (% area)	RBDPKOo:RBDPKOs blends*						RBDPKO
	100:0	80:20	60:40	40:60	20:80	0:100	
CLaLa	8.90 ± 0.08a	7.54 ± 0.16b	6.61 ± 0.12c	5.47 ± 0.28d	4.52 ± 0.06e	3.37 ± 0.09f	5.82 ± 0.02
CaLaLa/CLaM	10.31 ± 0.17a	9.52 ± 013b	8.79 ± 0.25c	7.84 ± 0.28d	7.47 ± 0.07d	6.66 ± 0.07e	8.01 ± 0.10
LaLaLa	21.14 ± 0.20e	22.11 ± 0.22d	23.72 ± 0.60c	24.58 ± 0.56c	26.93 ± 0.19b	28.04 ± 0.27a	22.51 ± 0.13
LaLaM	9.94 ± 0.17f	12.63 ± 0.13e	15.96 ± 0.25d	18.56 ± 0.28c	22.65 ± 0.07b	24.95 ± 0.07a	15.66 ± 0.17
LaLaO	5.89 ± 0.06a	5.64 ± 0.28a	4.89 ± 0.05b	3.97 ± 0.19c	3.11 ± 0.10d	2.36 ± 0.12e	4.89 ± 0.02
LaLaP/LaMM	4.15 ± 0.07f	6.82 ± 0.39e	8.97 ± 0.20d	10.81 ± 0.12c	13.21 ± 0.14b	14.84 ± 0.41a	8.84 ± 0.13
LMM/LaOM	5.32 ± 0.07a	4.63 ± 0.11b	3.95 ± 0.03c	3.22 ± 0.22d	2.64 ± 0.10e	2.02 ± 0.15f	3.89 ± 0.12
MMM/LaPM	2.62 ± 0.04f	3.53 ± 0.17e	4.51 ± 0.01d	5.31 ± 0.10c	6.61 ± 0.19b	7.32 ± 0.25a	4.63 ± 0.53
LMO/LaOO	5.00 ± 0.04a	4.20 ± 0.10b	3.25 ± 0.07c	2.75 ± 0.16d	1.94 ± 0.02e	1.18 ± 0.02f	4.02 ± 0.24
MPL/LaOP/MMO	5.90 ± 0.05a	4.93 ± 0.11b	4.40 ± 0.08c	3.60 ± 0.31d	2.79 ± 0.17e	2.10 ± 0.10f	4.56 ± 0.01
LaPP/MMP	0.72 ± 0.01e	1.13 ± 0.10d	1.77 ± 0.12c	2.59 ± 0.34b	3.19 ± 0.16a	3.40 ± 0.16a	1.74 ± 0.02
MOO	1.82 ± 0.03a	1.68 ± 0.14a	1.47 ± 0.35a	1.32 ± 0.17a	1.18 ± 0.83a	0.86 ± 0.68a	1.40 ± 0.00
MOP	2.71 ± 0.02a	2.66 ± 0.27a	1.95 ± 0.16ab	1.80 ± 0.13ab	0.94 ± 0.66b	1.08 ± 0.79b	2.13 ± 0.30
OOO	2.04 ± 0.00a	1.98 ± 0.24a	1.46 ± 0.06ab	1.26 ± 0.02b	0.39 ± 0,55c	ND	1.70 ± 0.20
POO	2.59 ± 0.02a	2.41± 0.22a	1.83 ± 0.08b	1.56 ± 0.21b	0.35 ± 0.50c	ND	2.13 ± 0.15
POP	1.42 ± 0.03a	1.58± 0.20a	0.76 ± 0.55a	1.33 ± 1.04a	ND	ND	1.54 ± 0.33
Other triglycerides	9.51 ± 0.85a	7.00± 0.87b	5.52 ± 1.10bc	4.07 ± 0.96cd	2.08 ± 0.76d	1.85 ± 0.92e	6.56 ± 0.45

*value is average ± SD (n = 3). A row's average, followed by a different letter, indicates a significant difference in the Duncan Multiple Range Test (DMRT) 5 %.
ND: not detected.
C: Capric, Ca: Caprylic, La: Lauric, M: Myristic, P: Palmitic, O: Oleic,

Conclusions

The blending of RBDPKOo with RBDPKOs resulted in the change of melting point, iodine value, and behavior. Also, the higher the RBDPKOs, the higher the melting point, and the lower the iodine value of fat blends. A blending with higher RBDPKOs (more than 60 %) results in a sharp endothermic peak. Meanwhile, blending of RBDPKOo with RBDPKOs causes a significant change of fatty acid composition and triglycerides profiles. The higher RBDPKOs in the fat blends increased the trilaurin, the composition and amount of lauric acid at the position of sn-2. Furthermore, the 2 fat blends obtained with more than 50 % lauric acid at the position of sn-2 were RBDPKOo: RBDPKOs ratios of 40:60 and 20:80. Moreover, RBDPKOo-RBDPKOs fat blend of 40:60 may be better raw material for monolaurin synthesis. These results create possibility of synthesizing monolaurin as emulsifiers and food preservatives using enzymatic glycerolysis.

Acknowledgements

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