

## Processing, Characteristics, and Potential Application of Red Palm Oil - a review

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### ABSTRACT

Palm oil contains several nutrients such as carotene and vitamin E (in the form of tocopherols and tocotrienols) which are very beneficial for human health. One of the palm oil products that contain high phytonutrient compounds is red palm oil (RPO). The red color of the oil indicates high carotene content. RPO can be produced from refinery process including degumming, neutralization and deodorization of unrefined palm oil (crude palm oil, CPO). The process of refinery at low temperatures aims to reduce levels of free fatty acids (FFA) which are still relatively high and to keep the levels of phytonutrients such as carotene high. RPO has a distinctive red color because it contains high levels of carotene (200-700 ppm) and low FFA levels (<1%). However, carotene levels and FFA levels in RPO are lower when compared to CPO because RPO has undergone heating during the chemical refinery process through the degumming, neutralization, and deodorization process stages. RPO has been used as cooking / stir-frying oil, shortening, margarine, and several other food products. Diversification of RPO-based products is needed so that the nutrients in the oil can be utilized properly. This paper reviews several studies on the processing, characteristics, and potential uses of RPO. The application of RPO in food products, especially margarine, has the potential to be further investigated.

Keywords: applications, characteristics, processes, RPO, and VRPO

### INTRODUCTION

Palm oil (*Elaeis guineensis*) is one of the most important plants in the world because of its high productivity, and the oil produced has excellent functional properties (Mozzon et al. 2013). This plant has

been cultivated in Asia, Central America, and South America (Rutz et al. 2017). Oil palm plantations consist of three types, namely Dura, Psifera, and Tenera (Umerie et al. 2004). Tenera is a hybrid of Dura and Psifera species that are commonly used in commercial plantations (Cheng

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*et al.* 2011). Oval-shaped oil palm fruit is attached to bunches weighing around 10-40 kg, depending on the size and age of plants weighing about 6-20 g per fruit (Ali *et al.* 2014).

Palm fruit produces two types of oil, namely palm oil and palm kernel oil. Palm oil is produced from the pressing and extraction process of palm fruit mesocarp parts while palm kernel oil is produced from pressing and extracting the palm kernel parts (Tan *et al.* 2009, Cheng *et al.* 2011; Ali *et al.* 2014; Rutz *et al.* 2017; Albuquerque *et al.* 2017 2018). Fruit maturity is an essential factor in determining the quantity and quality of oil, especially free fatty acids (FFA) (Saeed *et al.* 2012, Makky and Soni 2014; Hasibuan, 2016a). Ripe fruit has a higher oil content than raw fruit (Hasibuan, 2016a). Also, the condition of palm oil fruits affects the quality of the oil. Bruises tend to produce oil with higher levels of FFA. High FFA levels also cannot be avoided if it involves a wet process because of the presence of water, which causes hydrolysis of oil to become FFA (Cheng *et al.* 2011). Palm oil contains triglycerides as the main component and other minor ones, about 1 % (Mohamad *et al.* 2017). Carotenoids, tocopherols, tocotrienols, sterols, tri-terpenic alcohols, phospholipids, glycolipids, terpenic hydrocarbons, and aliphatics are amongst the minor components found in the palm oil (Umerie *et al.* 2004; Ayustaningwarno 2012; Silva *et al.* 2014; Riyadi *et al.* 2016). Carotene and tocopherol influence the stability and nutrition of palm oil (Umerie *et al.* 2004).

The word "crude" in palm oil does not mean bad, but it merely indicates raw material that is going to be refined for industrial usages in the production of food products, such as cooking oil, shortening, margarine, cocoa butter substitute (CBS), cocoa butter equivalent (CBE) (Elisabeth 2009; Ayustaningwarno 2012) and

non-food products, such as biolubricants, biodiesel, green energy, soap, foaming agent (Cukalovic *et al.* 2013, Tres *et al.* 2013, Mba *et al.* 2015, Albuquerque *et al.* 2018, Hambali *et al.* 2019). Palm oil can also be used in functional and nutritional food because of its high phytonutrient contents, such as carotene, tocopherol, and tocotrienol.

The use of palm oil as a food product material needs to be processed first (refinery) to eliminate undesirable components, such as phospholipids, FFA, oxidation products, odors, and colors (Silva *et al.* 2014; Hasibuan and Siahaan, 2014; Azmi *et al.* 2015, Hambali *et al.* 2019). Palm oil refinery can be done chemically and physically, but what is commonly done in the industry is the physical refinery process. The refinery process aims to prevent high neutral oil (triglyceride) losses. The physical refinery process consists of degumming, bleaching, and deacidification (Silva *et al.* 2014). Degumming and bleaching aim to eliminate phospholipids (through precipitation), and carotenoids (through adsorption). Deacidification removes FFA through volatilization at high temperatures (>200 °C) and low pressure (<5 mbar). During the deacidification, carotenoids are degraded thermally at 240 °C (Ribeiro *et al.* 2018) so that the color and most of tocopherol and tocotrienol will be lost (Zahrina *et al.* 2018).

The refinery process produces a product called refined bleached deodorized palm oil (RBDPO) with FFA levels <0,1% (Tan *et al.* 2009). Refinery products in the industry have characteristics, namely bright yellow color, soft taste, and excellent oxidative stability. This refined palm oil is preferred by the community for food products, such as cooking oil because it is considered a higher quality refined oil compared to reddish-orange oil (Yi *et al.* 2011). This is also caused by the pattern of consumption of cooking oil in Indone-

sia who is accustomed to clear to yellow coconut oil (Sinaga, 2019). The refinery process also prevents the oil from being oxidized excessively (Schex *et al.* 2018). However, the refinery process causes minor compounds, such as carotene, tocopherol, and tocotrienol, to be degraded and lost. Even though these compounds are very beneficial for health, such as carotene as pro-vitamin A, and tocopherol and tocotrienol as vitamin E (Hasibuan, 2012; Hasibuan and Siahaan, 2014). Margarine of the red palm oil is potential for functional food as a source of fat, reddish color, and provitamin A and vitamin E. This paper aims to review the development of information about processing, characteristics, and potential use of red palm oil, especially as margarine products.

## **PRODUCTION AND CHARACTERISTICS OF PALM OIL**

Palm oil processing in several countries in Africa is still carried out conventionally. The basic principles in the production of crude palm oil (CPO) in large industries such as Indonesia and Malaysia is in line with that traditional method but with significant improvement to meet the need of palm oil based downstream industries. CPO production is a complex process with many variables that affect product quality such as natural variations in fruit, interactions between chemicals, processes, and process changes (Rashid *et al.* 2017). High-quality palm oil can be produced by controlling the factors that cause quality changes so that the phytonutrient components (especially carotenoids, tocopherols, and tocotrienols) remain high with low FFA levels. In its processing in Africa, palm oil is packaged in packages of varying sizes, shapes, and colors and labeled with packaging

which is then marketed in traditional markets and supermarkets and even exports. Palm oil in several countries such as Africa, Southeast Asia, and South America is used directly in cooking and making food. Palm oil is used as a major and minor component in several processed foods (Mba *et al.* 2015).

In Africa, oil from palm fruit also known as virgin red palm oil (VRPO). VRPO is extracted directly from the palm fruit through a mechanical process by low temperature heating and without the addition of chemicals in its processing. According to Codex Alimentarius (2001), virgin oil is obtained without changing the properties of the oil, namely through mechanical processes such as expeller, press and heat application, and purification by washing using water, precipitation, filtering, and centrifugation. Virgin oil is not allowed to be given additional food additives to it. In addition, according to BPOM (2019), virgin oil is an oil product that is obtained mechanically (by pressing) without heating or by heating a low heat at a temperature of less than 60 °C and without the use of chemicals. It is important to note that the composition of fatty acids in VRPO is still intact.

### **Palm Oil Production**

The stages of the palm oil processing process including receiving fresh fruit bunches (FFB), sterilization, threshing, pulverizing, clarifying, purifying, removing water, and storing (Badmus *et al.* 2005; Ali *et al.* 2014). In conventional palm oil processing, FFB is sterilized using saturated steam at a pressure of 40 psi (temperature 140°C) for 75-90 minutes (Pootao and Kanjanapongkul 2016). The aim is to deactivate the oil hydrolyzing enzymes and maximize the hydrolysis of carbohydrates in FFB (Loi *et al.* 2011), soften the fruit, and encourage the release of fruit from its bunches (Ariffin *et al.* 2014). In ad-

dition to conventional methods, there are several alternative methods to improve oil quality that can be used as pretreatment for oil palm fruit such as continuous sterilization, dry heating, and microwave heating (Pootao and Kanjanapongkul 2016).

Palm fruit is separated from bunches and then softened in a digester and pressed (Tan *et al.* 2009). During pressing, palm oil extraction from mesocarp leaves about 5-6 % oil in the fiber material (Wenten *et al.* 2019). The main pressing tools commonly used are press screw digester, digester with a separate hydraulic press, and digester with press spindle (Azmi *et al.* 2015). Palm oil is mechanically extracted from palm fruit mesocarp (Makky and Soni 2013). There are two types of palm oil extraction methods, namely wet and dry extraction. In the wet-extraction mode, water is used to extract oil from palm fruit. Hot water or steam is used to release oil from palm fruit cells and to hydrolyze resins, starches, and coagulate proteins. Hydrolyzed and coagulated products are removed during oil clarification. In dry extraction, hydraulic pressure or centrifugation is used (Wenten *et al.* 2019). Oil from the press is clarified to remove impurities, fibrous material, and non-greasy solids. Hot water is added during clarification so that solids and those that dissolve in water can be separated due to differences in density (Cheng *et al.* 2011). The oil is then separated and evaporated to reduce the water content.

### **Palm Oil Characteristics**

The quality parameters of commercial palm oil are free fatty acid (FFA), oxidation level, color, peroxide value, iodine value, water content, specific gravity, refractive index, and viscosity (Oseni *et al.* 2002). Based on Codex Alimentarius (2001), virgin oil must have a maximum iron (Fe) content of 5.0 mg/kg, a maxi-

mum copper content (Cu) of 0.4 mg/kg, a maximum acid value of 4.0 mg KOH/g of oil, and a value peroxide maximum of 15 meq/kg of oil. CPO is also known as unrefined red palm oil, because of its high carotene content. Mba *et al.* (2015) have reviewed the physicochemical characteristics of palm oil as presented in Tables 1, 2, and 3.

Table 1 presents physicochemical properties of palm oil, such as water content, FFA levels, viscosity, iodine value, peroxide value, and saponification value; fatty acid compositions (palmitic acid, oleic acid, linoleic acid, linolenic acid); glycerides (saturated and unsaturated fatty acids; and minor components (beta-carotene, tocopherol, and tocotrienol).

The composition of the primary fatty acids consists of palmitic, oleic, linoleic, and stearic acids with a ratio of saturated and unsaturated fatty acids close to one, whereas the glyceride composition, is mono-, di-, tri-saturated, and unsaturated (Table 2). According to Mba *et al.* (2015), palm oil also has minor components in the form of micronutrients, such as carotenoids, tocopherols, and tocotrienols (Table 3). The characteristics of palm oil are relatively different, depending on the variety and quality of the fruit, materials, and equipment as well as the techniques and processing carried out. However, until now there has not been found any reference that states with certainty about the characteristics of virgin red palm oil products.

### **RPO PRODUCTION**

In contrast to West African countries which are countries of origin for oil palm plants, the people prefer direct consumption of oil from the extraction of palm fruit, namely oil without a refinery process, or unrefined palm oil. Meanwhile, some countries such as Southeast Asia do not

like the direct consumption of unrefined palm oil because it is red in color and has a less familiar 'palmy' smell because people are more accustomed to consuming cooking oil with a golden yellow color. For this reason, it is necessary to process palm oil from direct extraction (unrefined palm oil) to produce red palm oil (RPO) that still retains phytonutrient compounds. RPO is obtained through pre-processing, deacidification, and deodorization processes (Lee *et al.* 2018). The production of RPO is generally carried out through a chemical refinery process through the stages of degumming (removing gum and impurities with the addition of phosphoric acid), neutralization, and deacidification (neutralizing FFA by adding NaOH), and deodorization (removing 'palmy' odor with moderate heating).

### Characteristics of RPO

RPO has components that resemble CPO, namely the distinctive red color because it contains quite high carotene levels. The quality of the RPO is slightly different from CPO because of an extensively heated during the refinery process (degumming, neutralization, and deodorization), even though the process is conducted at relatively lower temperatures. The characteristics of RPO include physicochemical properties (in the form of water content, free fatty acid content, iodine value, peroxide value, color, and odor), micronutrient composition (carotenoids, tocopherols, and tocotrienols) and fatty acids (palmitic acid, oleic acid, linoleic, and stearic). The characteristics of RPO products that have been produced by several researchers are presented in Tables 5 and 6.

The further process of RPO is fractionation to separate the liquid fraction (red palm olein) and the solid fraction (red palm stearin). The main target in the

RPO processing process is low FFA content with high carotene content. Table 4 presents some processing conditions and characteristics of RPO products. In contrast with VRPO, RPO 's fatty acids are primarily composed of oleic acid, linoleic acid, linolenic acid, and arachidic acid.

Table 1 Physicochemical properties of palm oil

Characteristics	Range
Apparent density at 50 °C (g/ml)	0.892-0.899
AOM stability (h)	53.0-60.0
Melting point (°C)	33.0-45.0
Oxidative stability index at 110 °C (h)	16.6-19.0
Refractive index at 50 oC	1.449-1.456
Smoke point (°C)	230.0-235.0
Solidification point (°C)	35.0-42.0
Solid fat content (%)	
10 °C	30.0-39.0
21,1 °C	11.5-17.0
26,7 °C	8.0-14.0
33,3 °C	4.0-11.0
37,8 °C	2.5-9.0
40,0 °C	2.0-7.0
Specific gravity at 50 oC	0.888-0.889
Viscosity (cP)	45.0-49.0
Iodine value (g/100 g)	46.0-56.0
Free fatty acids (% FFA as palmitate)	3.17-5.0
Peroxide value (meqO <sub>2</sub> /kg)	0.1-10
Anisidine value (mgKOH/g)	0.6-4.65
Saponification value (mgKOH/g)	190.0-209.0
Unsaponifiable matter (%)	0.15-0.99
Total Polar Compounds (%)	9.47-19.50
Total polymer materials (%)	0.4-15.0
Saturated fatty acid, SFA (%)	49.9-54.7
Mono-unsaturated fatty acid, MUFA (%)	37.1-39.2
Poly-unsaturated fatty acid, PUFA (%)	8.1-10.5
Crystal habit	-

Source: Mba *et al.* 2015

### NUTRITION OF RPO FOR HEALTH

RPO is a derivative product of palm oil that still contains high amounts of carotene (as provitamin A) (Hasibuan and

ljah 2018a). RPO contains essential micronutrients, including carotenoids (500-700 ppm), tocopherols and tocotrienols (500-1000 ppm), sterols, lycopene, lutein, unsaturated fatty acids, ubiquinone, phytosterols (326-527  $\mu\text{g/g}$ ), and squalene (200-500  $\mu\text{g/g}$ ) (Ayustaningwarno 2012; Phoon et al. 2018; Mustapa et al. 2011; Riyadi et al. 2016; Sulihatimarsyila et al. 2019).

Table 2 Characteristics of palm oil fatty acid and glyceride composition

Characteristics	Range
Lipid acids compositions (%)	
Lauric acid (C12:0)	0.1-1.0
Myristic acid (C14:0)	0.9-1.5
Palmitic acid (C16:0)	41.8-46.8
Palmitoleic acid (C16:1)	0.1-0.3
Stearic acid (C18:0)	4.5-5,1
Oleic acid (C18:1)	37.3-40.8
Linoleic acid (C18:2)	9.1-11.0
Linoleic acid (C18:3)	0.4-0.6
Arachidic acid (C20:0)	0.2-0.7
Triglyceride composition (%)	
Trisaturated (SSS)	0.8-9.0
Disaturated (SUS)	38.5-50.3
Monosaturated (SUU)	31.8-44.4
Triunsaturated (UUU)	4.8-9.8
Diglyserida (%)	3.0-7.6

Source: Mba et al. 2015

Carotene and tocopherol play a role in increasing oil stability (Riyadi et al. 2016). Besides, carotenoids, tocopherols, and tocotrienols, also have antioxidant effects that act as protection against health problems mediated by reactive oxygen, such as cancer, cardiovascular, neurological, and eye diseases (Sathasivam et al. 2018). The minor component also functions as a natural antioxidant (Neo et al. 2010), which can reduce oxidative stress and function to prevent or delay some chronic degenerative diseases (Ayustaningwarno 2012).

Table 3 Minor components and micronutrients of palm oil

Component/micronutrient	Range (ppm)
Carotenoids	
$\alpha$ -carotene	30.0-35.16
$\beta$ -carotene	50.0-56.02
Lycopene	1.0-1.30
Carotenoids total	500-700
<b>Tocopherol</b>	
$\alpha$ -Tocopherol	129-215
$\beta$ -Tocopherol	22-37
$\gamma$ -Tocopherol	19-32
$\delta$ -Tocopherol	10-16
Tocopherol total	500-600
<b>Tocotrienol</b>	
- Tocotrienol	44-73
- Tocotrienol	44-73
- Tocotrienol	262-437
- Tocotrienol	70-117
Tocotrienol total	1000-1200
Phytosterols	326-527
Phospholipids	5-130
Squalene	200-500
Ubiquinon	10-80
Alcohol aliphatic	100-200
Alcohol triterpenes	40-80
Methyl sterols	40-80
Aliphatic hydrocarbons	50

Source : Mba et al. (2015)

Carotenoids are a group of yellow to red pigments. Carotenoids are easily isomerized and oxidized by O<sub>2</sub>, light, and high temperatures resulting in loss of color and reduced antioxidant effects, as well as vitamin A activity (Rutz et al. 2017). The main carotenoids contained in RPO are  $\alpha$ - and  $\beta$ -carotene, which act as provitamin A (Lee et al. 2018) and are 15-30 times higher than carrot and tomato retinol values (Choo et al., 2003). Thus, carotene can also be used to overcome the problem of lack of vitamin A, namely as a natural dye and food supplements

Table 4 RPO processing of CPO

Parameter	Mas'ud et al. 2008	Hasrini et al. 2009	Ayustaningwamo et al. 2012	Azmi et al. 2015	Riyadi et al. 2016	Sumama et al. 2017	Hasibuan and Ijah 2018a
Process	Deacidification	Degumming, neutralization, fraksionation	Degumming, deacidification, deodorization	Deacidification	Deodorization	Wet degumming, Neutralization, fraksionation	Degumming, neutralization, deodorization
Process condition	Temperature 59 °C, 25 minutes, NaOH 11.1 % (16 °Be)	Degumming: H <sub>3</sub> PO <sub>4</sub> 85%/L CPO, 80 °C Neutralization: NaOH (according to FFA content in CPO), 59 °C	Degumming: 80 °C, fosfic acid 85 % (0,15% of CPO weight) Deacidification: NaOH 16 °Be 17.5 % 61 °C, 26 menit Deodorization: 60 °C (vacum), 1 hour.	Membrane fiber technology PVDF crosslinking PVA 100 ppm, 3 hours	Temperature 140 °C, 1 hour	Wet degumming: 80 °C, fosfic acid 85 % (0.09 % of CPO weight, v/w) Neutralization: 60 °C, NaOH 0.1 %	Degumming: fosfic acid 0,05 % of CPO weight, 60-70 °C, 15 minutes Neutralization: NaOH 14 % according to FFA content in CPO, 50 °C, 30 minutes Deodorization: 100 °C, 60 minutes
Yield	95 %	-	90.16 %	-	-	Stearin 35 % and olein 65 %	-
RPO characteristics	FFA content 0.6 % total carotenoid 390 ppm, water content 0.07 % peroxide value 59 meq/1000g, iodine value 46, saponification value 194, colour L = 49.77 a = +30.32; b = +36.95; Yellow (Y) = 10, red (R) = 20	Water content 0.035 % FFA 0.64 % peroxide value 2.32 mg/100g oil, iodine value 52.49 (mg/g), total carotenoid 511.31 ppm	Reduce of FFA 96.35 % and recovery carotene 87.30 %	Reduce of phosphorus content and colour.	Carotene retention 70 % reduction of peroxide value and 'palmy' odor.	Olein fraction with water content 0.08 % FFA 0.17 % iodine value 50.79 g l/100 g, and peroxide value 50.79 mg O/100 g	FFA content 0.71 % water content 0.04 % total carotene 263 ppm, colour 10.2/10,2 (red/yellow, at 1 inch cell), peroxide value 9.45 meq/kg

that are very beneficial for improving health (Rice and Burns, 2010; Manorama, 2014). Red palm olein (RPOI) has been used in various forms of food products as a source of carotene (pro-vitamin A) for children who are deficient in vitamin A (El-Hadad et al. 2011).

Vitamin E plays a role in the body's protection against diseases that are mediated by free radicals and for the prevention of heart attacks (Al-Saqer et al. 2004). Vitamin E is present in eight isomeric forms, namely four tocopherols and four tocotrienols. Tocotrienol is much better as an antioxidant (Musa et al. 2017) than tocopherol. Palm tocotrienol has blood cholesterol-lowering properties and inhibits cancer cell growth (El-Hadad et al. 2011). However further investigation is needed to assess the impact of increasing the pro-

portion of linoleic acid (Omega 6) in RPO do to intentional reduction of saturated for human health.

## RPO STABILITY

The stability of RPO, especially carotene, is relatively low during storage. At room temperature, RPO can last for up to 8 months with a reduction in carotene from 500 ppm to 370.1 ppm (Albuquerque et al. 2018). Increasing the stability of RPO can be done through encapsulation. The encapsulation of RPO in polymers or microcapsules can protect the nutritional benefits as well as increase oil stability (Sathasivam et al. 2018). The encapsulation of RPO without heat makes it possible to increase stability and protect its active components from damage

Table 5 Physicochemical characteristics of RPO

Component	Hasibuan and Ijah 2018a	Hasibuan and Meilano 2018b	Sumama <i>et al.</i> 2017	Riyadi <i>et al.</i> 2016	Andarwulan <i>et al.</i> 2014	Azlan <i>et al.</i> 2010	Hasrini <i>et al.</i> 2009	Oseri <i>et al.</i> 2002
Water content (%)	0.71	0.24±0.07	0.08-0.14	0	0.06	-	0.035	1.2
FFA content (%)	-	0.22±0.03	0.17-0.22	0.490±0.15	0.15	-	0.64	3.7
Iodine value (g I <sub>2</sub> /100g)	-	-	37.48-52.94	-	57.5	60.27±0.89	52.49 (mg/g)	52
Saponification value (mg KOH/g)	-	-	-	-	-	200,05±0,42	-	197
Peroxide value (meq/kg)	-	0	0.03-0.04 (mg O/100g)	0.12±0.03	4.2	7.98±0.01	2.32 (mg/100 g oil)	0.5
Acid value (mg KOH/g)	-	-	-	-	-	0.84±0.00	-	-
Colour, Lovibond	-	-	-	30 Y±9.6 R (5 % <sup>a</sup> )	11.8R (3/8 <sup>a</sup> )	L: 85.77±0.01 a: -7.43±0.01 b: 0.84±0.00	-	Red
Odor, intensity	-	-	-	3.3	-	-	-	-
Density (g/L)	-	-	-	-	-	-	-	0.9007
Carotenoid (ppm)	263	519±4.24	-	375.33±22.87	290.7 (β-carotene)	-	511.31	-
Solid fat content (%)								
10	52,1	-	-	-	-	-	-	-
20	27,1	-	-	-	-	-	-	-
25	20,1	-	-	-	-	-	-	-
30	10,0	-	-	-	-	-	-	-
35	5,1	-	-	-	-	-	-	-
40	1,8	-	-	-	-	-	-	-

TL, lightness on scale 0-100 (dari hitam ke putih); a, (+) redness atau (-) greenness; b, yellowness or (-) blueness, C12:0 laurat, C14:0 miristat, C16:0 palmitat, C16:1 palmitoleat, C18:0 stearat, C18:1 oleat, C18:1 elaidat, C18:1 cis-Vaccenat, C18:2 linoleat, C18:3 linolenat, C20:0 arachidat, C20:1 cis-11-eikosanoat, C22:0 behenat, C24:1 lignoserat

during storage and processing (Lee *et al.* 2018). Yuliasari *et al.* (2016) encapsulated RPO using a capsule in the form of a mixture of maltodextrin and xanthan gum resulting in encapsulation with β-carotene content of 3.13226 mg/kg, β-carotene retention 72.65 %, encapsulation efficiency 72.05 %, no oil 1.03 % encapsulated and 92.40% oil retention.

## USE OF RPO IN FOOD PRODUCTS

RPO has been widely used for food products, including low-temperature cooking oil, margarine, shortening, pow-

dered fats, spreads, emulsions in the form of drinks and encapsulation, and other products such as bread, sponge, and biscuits as well as chili. Also, RPO can be used as sachet oil for instant noodles, and salad dressing (Ayustaningwarno 2012, Azlan *et al.* 2010). A mixture of red palm oil and its fractions or with other vegetable oils is used in various food products such as margarine to soup mixes and infant formulas (Mba *et al.* 2015). RPO contains beneficial phytonutrients, especially carotene. The carotene is produced without a fortification; therefore, it becomes more cost-effective for the food industry. While



Table 6 Composition of RPO fatty acids

Fatty acid (%)	Hasibuan and Ijah 2018a	Ribeiro <i>et al.</i> 2018	Mba <i>et al.</i> 2017	Azian <i>et al.</i> 2010	Bahurmiz <i>et al.</i> 2007	Ng <i>et al.</i> 2003
C12:0	0.2	-	-	-	0.2	0.2
C14:0	0.9	1.83	0.51±0.04	9.19±0.03	1.4	1.1
C15:0	-	-	-	0.91±0.00	-	42.8
C16:0	44.7	35.43	44.32±0.21	33.84±0.00	35.8	-
C17:0	-	-	-	-	-	-
C18:0	3.9	11.62	2.85±0.16	3.68±0.00	3.9	3.8
C20:0	0.3	0.37	0.09±0.03	-	-	0.3
C21:0	0.1	-	-	-	-	-
C24:0	-	-	-	0.32±0.01	-	-
Total saturated fatty acid (SFA)	50.1	49.25	47.77±0.44	47.94±0.02	41.2	48.2
C15:1	-	-	-	-	-	-
C16:1	0.1	0.80	0.12±0.03	0.17±0.00	1.8 (n7)	0.1
C17:1	-	-	-	-	-	-
C18:1	40.4	37.70 0.87 0.69	42.16±0.19	39.65±0.03	32.6	41.1
C19:1	-	-	-	-	-	-
C20:1	-	-	-	0.18±0.02 (n9)	0.6 (n9)	-
C22:1	-	-	-	-	0.7 (n11)	-
C24:1	-	-	-	0.14±0.01	-	-
Total monounsaturated fatty acid (MUFA)	40.5	40.06	48.28±0.22	40.14±0.01	35.7	41.2
C18:2	9.3	10.10	7.76±0.11	0.73±0.01 10.92±0.00 (n6)	13.2 (n6)	10.3 (n6)
C18:3	0.2	0.61	0.34±0.07	0.27±0.02	-(n6) 0.8 (n3)	0.3 (n3)
C18:4	-	-	-	-	0.3 (n3)	-(n3)
C20:3	-	-	-	-	-	-
C20:4	-	-	-	-	0.1 (n6) 0.1 (n3)	-
C20:5	-	-	0.88±0.16	-	1.6 (n3)	-(n3)
C22:5	-	-	-	-	-(n6) 0.4 (n3)	-
C22:6	-	-	-	-	3.0 (n3)	-
Total polyunsaturated fatty acid (PUFA)	9.5	10.71	8.98±0.34	11.92±0.02	19.5	10.6

the drawbacks are the reddish color and odor of 'palmy,' which is less liked by consumers, and if used in high-temperature frying can cause the degradation of micro-nutrient components such as carotene.

### Cooking Oil

Palm cooking oil rich in pro-vitamin A can be obtained by changing the processing conditions to produce oil that still contains pro-vitamin A without having to be fortified with synthetic vitamin A (Hasibuan and Siahaan, 2013). Albuquerque *et al.* (2018) report that RPO can be used as a cooking oil. Budiyanto *et al.* (2010) also

state that RPO can be used to saute/fry at temperatures less than 150 °C with short heating. Hasibuan and Meilano (2018b) also used RPO and its olein fraction for stirring media, as a substitute for cooking oil in the cooking of red chili sauce.

Mixing of RPO with coconut oil (80:20) and RPO with a flavor of 0.5 % for frying have been reported by Hasibuan and Ijah (2018a). The mixture of RPO has high-quality stability during repeated frying (Hasibuan and Ijah, 2018a). Mba *et al.* (2017) also mixed palm oil with canola oil, which is used as cooking oil. The use of palm oil can be used as a frying media

with products that do not absorb oil, rich in carotene, and vitamin E. Besides, carotenoids and vitamins contained in palm oil function as natural antioxidants and provide oxidative stability to palm oil during the frying process (Mba *et al.* 2015).

### Shortening

Hasibuan *et al.* (2018c) use RPO and unrefined palm oil in making baking shortening as an ingredient for making sweet bread, donuts, and roll cakes. Sweetbread with baking shortening made from RPO and unrefined palm oil has characteristics including water content, fat content, FFA content, peroxide value, and the development of dough resembling commercial products but high carotene content. Julita and Damayanti (2002) used RPO as a substitute for shortening in making cookies with the best composition of rice flour cookies (with 80% RPO substitution and  $\alpha$ -carotene content of 29408  $\mu\text{g}$  per 100 g) and cornstarch cookies (with palm oil substitution red 60 %  $\alpha$ -carotene levels 12360.35  $\mu\text{g}$  per 100 g). Robiyansyah *et al.* (2017) also used a mixture of RPO and cooking oil in making peanut biscuit products with a normal flavorfull, crispy texture, distinctive nutty flavor, and a yellowish color with beta carotene levels of 347.15 ppm.

### Margarine

Andarwulan *et al.* (2014) used margarine made with the addition of RPO and then used it for pound cake and sweet bread. The pound cake sensory test results show that the texture attribute of the moistness becomes stable, and the sweetbread gives the aroma of fermentation with vigorous intensity and improves the texture (moistness and softness). Hasibuan *et al.* (2018c) also use RPO and unrefined palm oil in the production of margarine. A mixture of RPO or unre-

fined palm oil and RBDPO can be used as an alternative in improving the nutrition of bakery products. Hasibuan and Hardika (2015) made chocolate jam for spread products on white bread) from margarine and chocolate blends made from a mixture of RPO and PKO with organoleptic test results showing that the smear product was acceptable to consumers so that it could be produced as a new innovative product that could fill market opportunities in the bakery industry.

### Other Food Products

RPO has been applied to a variety of food products in addition to palm oil commodity products (cooking oil, shortening, and margarine). Hasrini *et al.* (2009) make product spreads from RPO with product properties in the form of slip melting point (SMP) and solid-fat content (SFC) having the same characteristics as the properties of commercial spreads while maintaining high levels of carotene. Reputra *et al.* (2015) made carotene-rich fat powder using a mixture of RPO fraction olein and stearin, as well as fully hydrogenated oil with a product carotene content of 167.71 ppm.

RPO as an emulsion beverage is also very possible to do (Ayustaningwarno 2012). Astuti *et al.* (2010) have used RPO as a functional ingredient in drinks producing products containing  $\beta$ -carotene of 180-360  $\mu\text{g}$  / 250 g. Mursalin *et al.* (2014) applied RPO to emulsion beverage products. Dwiyanti *et al.* (2013) have used RPO as an additive in making coconut sugar to improve nutrition. The use of RPO as a supplement to help the work of oral hyperglycemia drugs has also been reviewed by Sinaga *et al.* (2018).

## POTENTIAL DEVELOPMENT OF RPO AS FOOD PRODUCTS

RPO has the potential to be developed for a variety of food products in Indonesia. Increasing the preference for food products containing RPO can be done through the nutritional approach of RPO to improve health. Health promotion as a result of the consumption of RPO-based products will cause an increase in public use of products made from RPO. Of the several products described above, one of the products that have the opportunity to be developed from RPO is margarine. This is because margarine products have a reddish color and are semi-solid. In the manufacture of commercial margarine, carotene addition is usually done so that the reddish color. The use of RPO is also a coloring agent of carotene (as pro-vitamin A) and vitamin E (from tocopherol and tocotrienol). Natural carotenoids are increasingly used in food technology, especially in maintaining consumer safety with regulations that restrict the use of artificial dyes (Davarnjad *et al.* 2008).

Margarine made from RPO is a product that can provide oxidative stability, texture, and good structure. The use of RPO in the production of margarine is considered beneficial because of its high carotenoid content and gives a natural color to the margarine product produced (Andarwulan *et al.* 2014). Margarine is also commonly used as a spread product on bread or as a filler in food products (sponge, cake, and sweet bread), so it is more protected from high-temperature heating, which can degrade the phytonutrient components.

## CONCLUSION

Red palm oil (RPO) can be produced from unrefined palm oil or crude palm oil (CPO) using refinery process in-

cluding degumming, neutralization, and deodorization at low temperature. The aims of refinery of CPO at low temperatures are reduce the relatively high FFA levels while maintaining phytonutrient levels, through the stages of degumming, neutralization, and deodorization processes. RPO have almost the same characteristics with CPO in terms of physicochemical properties and minor components, but RPO has lower FFA and carotene levels because it has gone through the refinery stage. RPO has low content of saturated fats as a result of fractionation. RPO can be applied to food products such as cooking oil, shortening, spreads, cooking oil, salad dressings, and margarine. One product that has the potential to be developed based on RPO in Indonesia is margarine because it can act as a source of fat and also provides natural coloring (reddish) and high nutrition from phytonutrient components, especially its carotene content. Margarine is generally used as a spread product on white bread or as a filler in food products (such as sponge cake, cake, and sweet bread). This can help maintain product phytonutrient levels such as carotene in margarine because it is not used at high temperatures which can degrade these nutrient components.

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