# Physical and chemical properties of palm oil and its derivatives compared to butter oil

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**ABSTRACT**

The compatibility of palm oil, its fractions and their blends corresponding with butter oil was investigated for some physical and chemical properties. The results revealed that most of the studied parameters showed significant differences between palm oil products and butter oil. The fractions and blends showed great differences in their physical and chemical properties from those of the original palm oil. The colour of palm oil and its fractions or their blends ranged from light yellow to golden yellow, while the colour butter oil was reddish yellow. Density values of palm oil and its derivatives were significantly lower than the density of butter oil. Different fats showed statistically significant differences in their melting points. The melting point of PO was close to the melting point of BO. However, POo showed the lowest melting point and POs showed the highest melting point, while PO blends showed intermediate melting points. Free fatty acids (FFA%) and peroxide values (PVs) of palm oil and its fractions were significantly lower than those specified by the Malaysian standards, demonstrating good oxidative stability, excellent quality and long shelf life. The varied properties of palm oil products make them a good choice for replacement of butter oil. Therefore, the utilization of these modified products provides other functional benefits in a wide variety of food systems.

## INTRODUCTION

Fats and oils are very important raw materials and functional ingredients for several food products such as confectionery, bakery, ice creams, emulsions, and sauces, shortenings, margarines, and other specially tailored products. Butter oil is one of the highest economic sources of dietary fat. It imparts organoleptic properties such as creamy mouth feel, buttery aroma, palatability and desirable texture to the food (**Augustin and Versteeg, 2006**). Physically, poor spreadability is a major disadvantage of butter compared to margarine at refrigerator temperature (**Wright et al., 2000**). Nutritionally, butter oil has the highest saturated and *trans* fatty acids. It has also highest cholesterol and hyper cholesterolemic fatty acid percentage such as myristic and palmetic acids (**Rousseau and et al., 1996**). As part of a healthy diet, avoid saturated and *trans* fats. These fats can raise LDL cholesterol (known as "LDL cholesterol") and triglyceride levels in the blood and also reduce the proportion of high-density lipoprotein (HDL) or "good" cholesterol. High total cholesterol or high cholesterol LDL is a major risk factor for diabetes, high cholesterol and heart disease. It is recommended that the amount of saturated fat should be less than 10% and *trans* fat is less than 1% of total energy intake. The development of new products using fat substitutes can be a good option for companies that are always trying to reduce costs or substitute *trans*-fat or saturated fat. Palm oil is now the most widely used vegetable oil in the world, a key component of foods ranging from baked goods to salad dressings to ice cream (**Mancini et al., 2015**). Unlike other oils, PO contains almost equal amounts of saturated and unsaturated fatty acids, making it naturally semi-solid at room temperature and therefore does not require hydrogenation, a process that produces *trans* fatty acids. In addition, PO, like all vegetable oils, is virtually cholesterol-free; less saturated than milk fat and does not contain *trans* fatty acids. However, it contains a sufficient amount of linoleic acid, an unsaturated omega-6 fatty acid, which is one of two essential fatty acids for humans. In addition, palm oil is nature's richest source of β-carotene and lycopene. It is also very rich in vitamin E. Carotenoids and the vitamins E work synergistically as powerful natural antioxidants, provide oxidative stability to palm oil in most food applications (**Tan et al., 2009; Mba et al., 2015**).

Although, some studies have suggested that palm oil may increase some risk factors for heart disease in some individuals, many studies have found that palm oil has a protective effect against heart disease, including lowering “bad” LDL cholesterol and increasing "good" HDL cholesterol. Palm oil has a unique fatty acid profile which makes it suitable for many food applications. This property is unique among vegetable oils and fats for many food applications (**Choo, 2013**). Palm oil contains 50% saturated, 40% monounsaturated and 10% polyunsaturated fatty acids. It contains a high level of palmitic acid (C16:0) which represents about 44% of fatty acids. Other major fatty acids are oleic acid (C18:1), linoleic acid (C18:2) and stearic acid (C18:0) representing 40%, 10% and 5%, respectively (**Tan and Man, 2000; Sundram et al., 2003; Wahid et al. 2011**). Moreover, palm oil stabilizes in β' polymorphic form, which is required for good creaming performance (**Koushki et al., 2015; Omar et al., 2015)**. In addition, palm oil can also be modified by fractionation and blending. Fractionation and blending of PO further enhances the usage of PO in many food formulations. It can be fractionated to a liquid palm olein and a solid palm stearin. These fractions have distinct physical and chemical properties. Further blending process of PO and its fractions, may then be carried out to produce different fat blends, which have properties somewhere between olein and stearin. This further diversifies the utility of oil. Palm oil and its fractions, or their blends, can be used in multiple application in convenience food preparation (**Kellens et al., 2007; Dian et al., 2017**). Therefore, the aim of this study was to evaluate some physical and chemical properties of palm oil and its fractions to assess the compatibility of these fats with butter oil and compliance with legal standards as well as the effect of blending palm oil with its fractions on the properties of these blends.

## MATERIALS AND METHODS

## Materials:

### Butter oil (BO):

AL-Haloub Cow pure butter oil (99.8% mik fat) produced in Holand was purchased from the local market, Sohag, Egypt. Butter oil was stored immediately at 4°C until use.

### Palm oil and its fractions:

Typical refined, bleached and deodorized (RBD) plam oil (PO), plam oil olein (POo) and plam oil stearin (POs) were obtained from El-Fares El-Araby for Oil, Soap & Detergent Company (Industrial Zone A, Obour city, Kaliobeya, Egypt), with iodine values (IV) of 52.5, 57.2 and 34.8 g/100g, respectively as informed by the manufacturer. Palm oil and its fractions were stored immediately at 4°C until use.

## Methods:

## Preparation of palm oil blends:

Palm oil and its fractions were melted at 60˚C in a water bath before blending. The liquefied PO was blended with POo or POs in proportions 1:1 (w/w) of each, so two binary blends were prepared: PO + POo and PO + POs. The oil blends were cooled to room temperature and stored at 4°C until further use.

## Analytical Methods:

### Colour:

The colour of the different fatty ingredients was measured using the Lovibond Tintometer Model E (Salisbury, England).

The samples were placed into 1¼ inch cell and the colour was determined at 55°C by achieving the best possible match with the standard colour slides of red and yellow indices.

**Density:**

It was determined by means of pycnometer method described in the **American Oil Chemists Society** (**AOCS, 2000**).

**Melting point:**

The melting point was measured according to the capillary tube method described in the **American Oil Chemists Society** (**AOCS,** C c3-25) (**Mehlenbacher, 2004**).

**Free fatty acids:**

Free fatty acids were determined by the titration with potassium hydroxide in hot ethanol solution, using phenolphthalein as an indicator as described in the **American Oil Chemists Society (AOCS, 2005)**. The result is expressed in mg Na OH g / fat (as oleic acid %).

**Peroxide value:**

Peroxide value was estimated according to the procedure described in the **American Oil Chemists Society** (**AOCS, 2005**). The results were recorded as milliequivalent peroxides per kg of fat.

## Statistical analysis:

All physical and chemical measurements were performed three times for each independent batch. **SAS (2012)** version 9.4 (SAS Institute Inc., Cary, NC) was used to perform the statistical analysis of all data using the ANOVA mixed procedure (proc mixed). Treatments were considered significantly different if $p \leq 0.05$.

## RESULTS AND DISCUSION

Some physical and chemical properties of the different fat ingredients used in this study were estimated. These parameters provide information on the physical and chemical properties (color, density, melting point, free fatty acids and peroxide value) of palm oil, its fractions and their blends compared to the properties of butter oil. The results are given in Tables 1 and 2.

**Colour:**

Lovibond Tintometer was used to measure the color of fats used in this study because it is widely used in the vegetable oil refineries. As shown in Table 1, BO has the highest red reading (4.2) compared to palm oil and its derivatives, possibly due to natural fat-soluble carotenoids, responsible for the reddish-yellow color of BO. The color of PO and its fractions or their blends vary slightly from very light yellow to golden yellow (color range readings from 3 to 3.2). Most consumers prefer light yellow oil, so the color of the PO and its fractions or their blends is acceptable. Similar results were obtained by **Nazaruddin et al. (2008)** who used three types of vegetable fats (palm mid-fraction, palm olein and rice bran oil) in dates ice cream formulations. Crude palm oil (CPO) is rich in carotenoids, such as alpha-carotene, beta carotene and lycopene, giving it a distinctive deep orange red color. CPO is refined to remove impurities such as an undesirable odor, flavor and colour, at the same time as retaining the beneficial components such as antioxidants and vitamins. CPO is processed into refined products, including refined, bleached and deodorized palm oil (RBDPO); refined, bleached and deodorized palm olein (RBDPOo); and refined, bleached and deodorized palm stearin (RBDPOs). Thus, these refined products do not contain carotene because the refining process removes the carotenoids from the oil, where the color is converted to golden yellow **(Nagendran et al., 2000, Sundram et al., 2003; Lai et al., 2012)**. During fractionation, diacylglycerols, tocopherol and carotenoids are preferentially distributed in the palm olein, while, monoacylglycerols, sterols and phospholipids are preferably distributed in the palm stearin (**Gee, 2007**).

**Density:**

According to the data in Table 1, BO showed the highest density (0.9291), while palm oil product densities ranged from 0.8828 to 0.8974, where POo showed the highest density while the POs showed the lowest density. For blends, the density of PO + POs and PO + POo showed medium density values (0.8857 and 0.8931, respectively). Oil density varies depending on the nature of the fatty acids that make up it. Unsaturated oils have higher densities than saturated oils. However the effect of unsaturation level seems to outweigh the effect of chain length, so, the density of short chain oils is not necessarily higher than the density of longer chain oils for the same level of unsaturation (**Koushki et al., 2015**). Therefore, the density of POo, which is highly unsaturated, is higher than the density of PO, which is less unsaturated, although the length of the chain is shorter than the other (Table 1).

**Melting Point:**

The melting point is widely used to describe the melting and hardening properties of oils and fats. It increases with increasing chain length and decrease, as the acids become more unsaturated (**Karabulut et al., 2004**). Significant differences in melting points were observed for different fats as shown in Table 1. The melting point of PO was almost identical to BO (36.8 vs. 37.6 ° C, respectively) (Table 1). Although PO closely matches the melting point of BO, it has a slightly higher solid fat content at 35°C, which may convey some waxiness. Milk fat is high in saturated fat: about 65% of saturated fatty acids (C16: 0, C18: 0, C14: 0) (**Lopez et al., 2006**). Several studies and articles agreed that the dominant fatty acids in palm oil are palmitic acid (**Pande et al., 2012; Tan & Nehdi, 2012; Fattore & Fanelli, 2013**). The melting points of the palm oil and its fractions differed significantly ($P \leq 0.05$). Melting points of low melting fraction (POo) and high melting fraction (POs) were 21.3 and 48.7˚C, respectively (Table 1). The lowest melting point of POo compared to other palm oil products is due to the high content of unsaturated fatty acids in this fraction. POo contains a mixture of polyunsaturated, mono-unsaturated and saturated fatty acids. It is highly mono-unsaturated and rich in oleic acids. By contrast, the highest melting point of POs is due to its high content of saturated fatty acids (**O'Brien, 2004; Fauzi et al. 2013**).

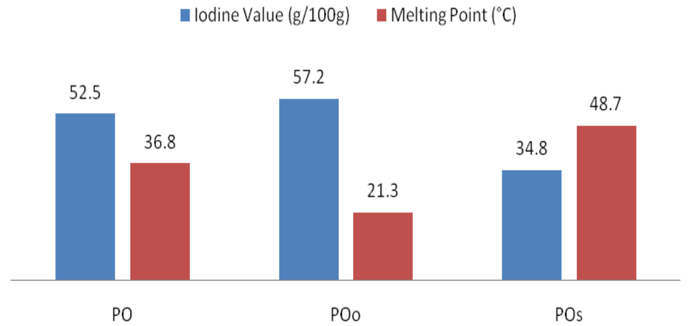
**Table 1:** Physical properties of palm oil, its fractions and their blends compared with butter oil

| Fat ingredients | Physical properties | | |
|---|---|---|---|
| | **Colour* (R/Y/B)** | **Density (g/ml at 50°C)** | **M.P (°C)** |
| BO | 4.2/35/- [a] | 0.9291 [a] | 37.6[d] |
| PO | 3.1/35/- [b] | 0.8892[d] | 36.8[c] |
| POo | 3.2/35/- [b] | 0.8974 [b] | 21.3[f] |
| POs | 3.0/35/- [c] | 0.8828 [f] | 48.7[a] |
| PO + POo | 3.1/35/- [b] | 0.8931 [c] | 30.4[e] |
| PO + POs | 3.1/35/- [b] | 0.8857 [e] | 41.8[b] |

*Colour: (Red/Yellow/Blue) measured using a Lovibond Tintometer (cell 5 ¼ inch).
[a, b, c] Means within the same column with different superscripts are significantly different ($p \leq 0.05$).

The fractionation process separates palm oil into two fractions with different melting properties. The fatty acid compositions of palm olein and palm stearin differ from palm oil composition. During fractionation, unsaturated fatty acids are preferentially distributed in the palm olein whereas saturated fatty acids are preferentially distributed in the palm stearin **(Gee, 2007; Miskandar et al., 2011)**. Palm oil is 50% unsaturated and contains mainly oleic (C18:1) and palmitic (C16:0) acids (**Wahid et al., 2011**). Palm olein contains higher amounts of oleic (39–45%) and linoleic acids (10–13%) compared to palm oil. It has a melting point of 18–20°C and therefore is a liquid at room temperature (25°C) (**Siew, 2002**). The melting point results obtained in this study meet the standard specifications of PORAM (2012); 33-39°C for PO, a maximum of 24°C for POo and at least 44°C for POs. PO Blends with its fractions showed intermediate melting point values (30.4 and 41.8ºC), depending on the type of palm oil fraction in the blend. The addition of PO to POo significantly increased the melting point of the PO / POo blend ($P \leq 0.05$), while the addition of PO to POs significantly reduced the melting point ($P \leq 0.05$) in the PO / POs blend (Table 1). Both melting point (MP) and iodine value (IV) are important physical properties of fats that are useful in identification and have an impact on many technological applications of fatty ingredients. MP is related to the unsaturation of oils and fats; the higher the unsaturation level, the lower the MP. The IV measures the degree of unsaturation or double bonds of oils and fats. The higher the IV, the more unsaturated level is present. According to the vegetable oil supplier, the iodine values (IV) of plam oil (PO), plam olein (POo) and plam stearin (POs) are 52.5, 57.2 and 34.8 g/100g, respectively. Figure 1 shows a strong relationship between the estimated MPs and the IVs of palm oil and fractions studied. This strong relationship between melting point, saturation rate and iodine value is well consistent with the conclusions of several authors (**Karabulut et al. 2004; Braipson-Danthine and Gibon, 2007; Tarmizi et al., 2008)**.

Fig. 1. The relationship between the iodine value and melting point of palm oil and its fractions



Peroxide value measure specific oxidation values, which represent a specific quality parameter of oils and fats. Table 2 shows slight but significant differences ($P \leq 0.05$) in PVs between the different fatty ingredients used in this study. BO had the highest PV value followed by POo and PO + POo while POs and PO + POs had the lowest PV values. The results were 2.1, 1.5 and 1.4 versus 0.3 and 0.5 meq $O_2$/kg, respectively. In the literature, the PV of refined oils should not exceed 10 meq $O_2$/kg. PVs for PO and its fractions or their blends used in this study were significantly lower, suggesting minimal oxidation. **Gee (2007)** reported that PO and POo have good oxidative stability due to high levels of natural antioxidants (tocopherol) and low levels of polyunsaturated fatty acids (linolenic acid). **Dian et al. (2017)** also reported that the standard POo is rated with a maximum ratio of 0.1% free fatty acids and a peroxide value of 2-4 meq $O_2$/kg.

## Free fatty acids:

The level of fat degradation is best expressed by the FFA%. There were slight but significant differences ($P < 0.05$) in FFA% between different fatty ingredients used in this study (Table 2). POo and PO + POo had the highest ratios while POs and BO had the lowest free fatty acid content. The results were 0.028% and 0.028% versus 0.017% and 0.018%, respectively. PO and PO + POs had moderate FFA ratios of 0.025%. As specified by PORAM, the maximum FFA% for PO, POo and POs are 0.1%, 0.1% and 0.2%, respectively. The FFA% of palm oil and its fractions used in this study are well below the maximum criteria specified by PORAM. The lower FFA% of PO and its fractions is the result of the refining process that removed the FFA, demonstrating the good quality of these fatty ingredients.

## Peroxide value:

In addition to the FFA%, peroxide value (PV) also reveals the extent of oil degradation.

**Table 2:** Chemical properties of palm oil, its fractions and their blends compared with butter oil

| Fat ingredients | Physical properties | |
|---|---|---|
| | FFA (%) | P.V (Meq. $O_2$/Kg) |
| BO | 0. 018 [c] | 2.1 [a] |
| PO | 0. 025 [b] | 0.9 [c] |
| POo | 0. 028 [a] | 1.5 [b] |
| POs | 0. 017 [d] | 0.3 [d] |
| PO + POo | 0.0 28 [a] | 1.4 [b] |
| PO + POs | 0.0 25 [b] | 0.5 [d] |

FFA%: Percent free fatty acids determined (as oleic acid).
[a, b, c] Means within the same column with different superscripts are significantly different ($p \leq 0.05$).

Several studies have been published on the physico-chemical properties of palm oil and its fractions (**Long et al., 2005; Nusantoro, 2009; Akinola et al., 2010; Tan and Nehdi, 2012; Koushki et al., 2015; Japir et al., 2017**).

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