

COMPARATIVE STUDY ON SELECTED PHYSICO-CHEMICAL PROPERTIES OF PACKED PALM-BASED COOKING OILS

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ABSTRACT. Cooking oils are used for daily cooking as well as salad dressing, in processed food, and other various uses. The physico-chemical properties of cooking oils can affect the quality of foods and hence must be evaluated. The aim of the present study was to evaluate the physico-chemical properties of palm-based cooking oils (refined, bleached and deodorized (RBD) palm olein). The analyses were conducted on a total of 20 different brands of cooking oil packed in plastic pouches, which were randomly chosen from a local market. The physico-chemical properties of the cooking oils investigated include moisture and impurities (MI), iodine value (IV), peroxide value (PV), slip melting point (SMP), Lovibond colour, and free fatty acid (FFA). The properties were compared with known standards for refined oils such as Malaysian Standard and Codex Alimentarius Standard. Analysis showed that MI, IV, and SMP of all brands were within the requirements set by Malaysian Standard for RBD palm olein. The PV, Lovibond colour, and FFA values of several brands deviated from the Malaysian Standard. Meanwhile, the PV and FFA of all brands of the cooking oil tested were within the value designated by the Codex Standards. The physico-chemical properties of RBD palm olein cooking oils tested in this study were of acceptable and good quality and are considered suitable for consumption. The quality of cooking oil should be regularly monitored to avoid the use of adulterated oil.

KEYWORDS. RBD palm olein, cooking oil, physico-chemical properties, plastic pouch packed

INTRODUCTION

Cooking oil has been widely used in household kitchens, public restaurants and food industries due to its advantages in food processing (Cao et al., 2017). The major constituents of triacylglycerols in cooking oil and other minor components play an important role in providing nutritional support, thus acting as key components of the diet. Furthermore, cooking oils provide characteristic flavour and texture to foods (Lin, 2002; Muneeshwari et al., 2017). There are various types of commonly used cooking oils derived from plant sources, including oil palm, olive, sunflower, corn, soybean, peanut, sesame, etc. (Muneeshwari et al., 2017; Yee et al., 2018). The quality of cooking oil can be evaluated by testing different physico-chemical properties of the oil. To name a few, they include moisture and impurities (MI), iodine value (IV), peroxide value (PV), slip melting point (SMP), Lovibond colour, and free fatty acid (FFA). The poor cooking oil quality can be identified from several indicators such as elevated FFA, change of colour, low IV, high PV, total polar material, and increased viscosity (Kaleem et al., 2015). The evaluation of physico-chemical properties of

cooking oils is important as they are used for daily cooking, as well as salad dressing, in processed food, and for various other industrial uses (Endo, 2018; Muneeshwari et al., 2017).

Monitoring the water content is crucial, as it will affect the hydrolytic stability of the oil (Agbaire, 2012; Chong, 2012). Impurities are defined as substances that remain insoluble and can be filtered off after the oil is dissolved in a specific solvent such as petroleum ether or diethyl ether. Water is regarded as the most common impurities in palm oil (Chong, 2012). It was reported that the moisture content and impurities are directly related to the efficiency of extraction and clarification steps during the extraction of oil (Agbaire, 2012). IV is used to determine the unsaturated fatty acids in the oils which were measured from the iodine absorbed by the oils (Muneeshwari et al., 2017; Ramli et al., 2018). It is an indicator of the purity of the oils and reflects the vulnerability of the oil to oxidation. The oils with higher IV show more unsaturation and increase the susceptibility to oxidation. Determination of PV is commonly used to assess the extent of oxidation of edible oils and fats (Endo, 2018). If oxidation proceeds for too long, the oil will turn rancid and give an unpleasant odour. PV of oil is indicated as the number of milliequivalents of oxygen per kilogram of oil. It is determined by the reaction of peroxides with potassium iodide in a solvent mixture (Chong, 2012).

Slip melting point is defined as the temperature at which the oils or fats becomes sufficiently fluid to slip in an open capillary tube (American Oil Chemists' Society & Mehlenbacher, 2004). The melting point of vegetable oils is correlated to the fatty acid composition. For instance, oils rich in oleic acid (18:1) such as olive and rapeseed oils have melting points ≥ 0 °C, oils rich in linoleic acid (18:2) such as corn and soybean oils have melting points ≤ 0 °C, while oils rich in saturated fatty acids; palmitic acid (16:0) such as palm and coconut oil have higher melting points (Endo, 2018). In general, vegetable oils are transparent and have a yellowish or greenish colour due to the presence of carotenoids and chlorophyll pigments (Endo, 2018). The colour value of the refined oils also provides information on the quality of bleaching processes (Agbaire, 2012). Colour is usually evaluated by the Lovibond spectrophotometric colorimeter. Nevertheless, the measurement of oil colour is subjective and depends on the analyst's judgement and the type of tintometer used (Chong, 2012). Free fatty acids are produced by the hydrolysis of oils and fats, which developed with the presence of moisture (O'Brien, 2004). The refining process helps remove the FFA. Thus lower FFA values are observed in refined oils compared to the crude oils (Muneeshwari et al., 2017).

Different kinds of packaging are used for cooking oils in the market, including glass bottles, PET or HDPE plastic bottles, and plastic pouches (Fuentes et al., 2013; Kucuk & Caner, 2005; Narasimhan et al., 2001; Robertson, 2012). The packaging material of the cooking oils is generally selected based on marketing and economic criteria. Appropriate packaging is essential to assure adequate shelf life of the oils. Many studies have shown that the types of packaging materials, storage conditions, and storage time significantly impact the quality of edible oils (Kucuk & Caner, 2005; Ramli et al., 2018; Sun et al., 2015). In terms of packaging materials, their physical characteristics, such as permeability and light transmittance, may directly affect the quality of oil (Hotchkiss, 1995). It is important to note that light undermines the quality of the oils and affects the performance of packaging materials. For instance, the effect of light on plastics include oxidative degradation, embrittlement, and performance degradation (Sun et al., 2015). It was reported that olive oils exposed to intense artificial light and diffused daylight have shorter shelf life than oils kept in the dark (Piscopo & Poiana, 2012).

In the published literature, studies on the quality of palm-based cooking oils packed in plastic pouches and PET bottles and detection of potential markers of recycled cooking oils have been reported, which comprised of various quality parameters such as FFA, FAC, triacylglyceride,

total vitamin E, IV, cloud point, smoke point, colour, polar compound, polymer compound, and oxidative stability (Hassim et al., 2021; Khor et al., 2019). This study aimed to determine the physico-chemical properties of different brands of palm-based cooking oils (RBD palm olein), packed in plastic pouches. The physico-chemical properties include MI, IV, PV, SMP, Lovibond colour, and FFA. The properties of the cooking oils were compared with known standards for refined oils such as Malaysian Standards (MS 816:2007, Palm Olein – Specification) and FAO/WHO Food Standards: Codex Alimentarius Standards for Edible Fats and Oils, and Codex Standards for Named Vegetable Oils.

MATERIALS AND METHODS

Plastic-packed RBD Palm Olein

A total of 20 different brands of cooking oil (RBD palm olein) packed in 1 kg plastic pouch were randomly chosen from the local market. Herein, the 20 cooking oils are labelled as A to T. Upon receipt, prior to analysis, the oil samples were stored as the method described in Ramli et al. (2018). The oil samples were stirred well before being transferred into six clear glass bottles with a screw cap. Afterwards, the oil samples were placed in desiccators and stored at 6 ± 2 °C. The oil samples were analyzed for MI, IV, PV, SMP, Lovibond colour, and FFA (as palmitic) content. The analyses were performed according to the Malaysian Palm Oil Board (MPOB), American Oil Chemists' Society (AOCS), and ISO standard methods. The solvents and chemicals used for the analyses were of analytical grade.

Determination of moisture content

The moisture content in the oil samples was determined according to ISO 662: 1998(E) (International Organization for Standardization, 1998). The method comprised heating the oil sample in an oven at 103 °C, until moisture and volatile substances were completely eliminated. The oil sample was weighed (approximately 5 or 10 g to the nearest 0.001 g) into a vessel that had previously been dried and weighed. The vessel with the oil sample was placed in an oven at 103 °C for 1 h and then allowed to cool to room temperature, followed by weighing to the nearest 0.001 g. This step was repeated at a successive period in the oven for 30 minutes each until the loss in mass between two successive weighings did not exceed 2 mg or 4 mg, according to the mass of the test portion. The moisture content was calculated using equation (1) as follows:

$$\text{Moisture content (\%)} = \frac{m_1 - m_2}{m_1 - m} \times 100\% \quad (1)$$

where m is the mass (g) of the vessel, m_1 is the mass (g) of the vessel and oil, and m_2 is the mass (g) of the vessel and oil after drying.

Determination of impurities

The MPOB p.2.2:2004 test method was applied to determine the impurities in the oil samples (Kuntom, 2005). A test portion was first heated at 60 – 70 °C until completely melted and homogenized. A Gooch crucible, with glass fibre filter paper, was washed with 10 mL petroleum ether under a slight vacuum and was dried for 30 min at 103 °C. The crucible and filter paper were cooled in a desiccator and weighed to the nearest 0.0001 g. Approximately 20 g of the test sample was weighed to the nearest 0.01g into a conical flask, and 100 mL of petroleum ether was added into the flask. The solution was heated and swirled until complete homogenization, then filtered through the Gooch crucible under a slight vacuum. Several portions of 10 mL petroleum ether were

used to transfer all the oil samples and insoluble matter into the Gooch crucible and washed using petroleum ether until all the oil was removed. The crucible was wiped with tissue paper, and the crucible and contents were dried in the oven at 103 °C for 1 h. The crucible was then cooled to room temperature. The Gooch crucible and contents were weighed to the nearest 0.001 g. The insoluble impurity was computed using equation (2):

$$\text{Impurities (\%)} = \frac{m_2 - m_1}{m} \times 100\% \quad (2)$$

where m is the mass of the test portion (g), m_1 is the mass of the Gooch crucible plus filter paper (g), and m_2 is the mass of Gooch crucible plus filter paper and impurities (g).

Determination of iodine value (IV)

The determination of IV was carried out using the procedure specified in AOCS method, AOCS Cd 1d-92 (American Oil Chemists' Society & Mehlenbacher, 2004). The oil sample was melted, homogenized, filtered, heated to a temperature of between 68 – 71 °C, then weighed into a conical flask. Subsequently, 15 mL of cyclohexane: acetic acid (1:1) solution and 25 mL of Wijs solution were added to the flask. The contents were mixed thoroughly and stored in a dark place for one hour at room temperature. Afterwards, 20 mL of 10% potassium iodide (KI) solution was added, followed by 100 mL of distilled water. The mixture was then titrated with 0.1M sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) standard solution until the yellow colour almost disappeared. Starch indicator solution (1 – 2 mL) was added to the mixture, and the titration was continued until the blue colour disappeared. The blank sample was titrated in the same manner as described here. The IV was calculated using equation (3),

$$\text{IV (g/100g oil)} = \frac{12.69 \times C \times (V_1 - V_2)}{M} \quad (3)$$

where C is the molarity (M) of the $\text{Na}_2\text{S}_2\text{O}_3$ solution, V_1 is the volume (mL) of $\text{Na}_2\text{S}_2\text{O}_3$ solution used for the blank test, V_2 is the volume (mL) of $\text{Na}_2\text{S}_2\text{O}_3$ solution used for the sample test, and M is the mass (g) of the oil sample.

Determination of peroxide value (PV)

The AOCS method, AOCS Cd 8b-90, was used to determine PV of the oil samples (American Oil Chemists' Society & Mehlenbacher, 2004). The test portion was weighed according to the expected PV value into a flask with a glass stopper. Then, 50 mL of 3:2 acetic acid-isooctane solution was added, and the flask was swirled to dissolve the test portion. 0.5 mL of saturated potassium iodide solution was added using a suitable volumetric-pipet. The solution was allowed to stand for exactly 1 min, then shaken thoroughly at least three times during 1 min. Subsequently, 30 mL of distilled water was added and titrated at constant and vigorous agitation with 0.1M sodium thiosulfate. The titration was continued until the yellow iodine colour had almost disappeared. After that, 0.5 mL of 10% sodium dodecyl sulfate was added, followed by 0.5 mL of starch indicator solution. The titration was continued with constant agitation, especially near the endpoint, to liberate all of the iodine from the solvent layer. The thiosulfate solution was added dropwise until the blue colour just disappeared. The blank titration was also conducted, where it did not exceed 0.1 mL of 0.1 M sodium thiosulfate solution. The PV of the oil samples was obtained using equation (4) given below:

$$\text{PV (meq O}_2\text{/kg)} = \frac{(S-B) \times M \times 1000}{m} \quad (4)$$

where S is the volume (mL) of titrant of test portion, B is the volume (mL) of titrant of blank, M is the molarity (M) of sodium thiosulfate solution, and m is the mass (g) of test portion.

Determination of slip melting point (SMP)

The SMP of the oil samples was measured according to the AOCS test method, AOCS Cc 3-25, which is the open capillary tube technique (American Oil Chemists' Society & Mehlenbacher, 2004). Initially, the melted and homogenized oil sample was filtered at 60 °C in oven, and left in the oven for 10 min. Three capillary tubes were dipped into the melted oil sample until the oil rose about 10 mm high in the tube. Afterwards, by holding the tubes containing the oil sample against ice, the tubes were chilled until the sample solidified. These tubes were placed in a beaker and held in a refrigerator at 10 ± 1 °C for 16 h. After 16 h, the tubes were removed from the refrigerator and attached to a thermometer using a rubber band. The thermometer was suspended in a 400 mL beaker containing distilled water. The starting bath temperature was adjusted to 8 – 10 °C below the expected SMP of the oil sample. The water bath was stirred with a magnetic stirrer, and heat was then applied to increase the water bath temperature at a rate of 1 °C/min. As the SMP approached, the rate of the heating was then reduced to 0.5 °C/min. The temperature at which each column rises was observed and recorded. The SMP of the oil samples was determined from the average temperature of all capillary tubes.

Determination of Lovibond colour

The Lovibond colour of oil samples was determined using MPOB test method, MPOB p4.1:2004 (Kuntom, 2005). The Lovibond Universal Tintometers Model F was used, and the oil samples were completely liquid, clear, and bright prior to the test. The oil sample was poured into a glass cell (133.35 mm (5¼ in)), and the cell was placed within the lighting cabinet so that it is close to the viewing tube. The lid of the lighting cabinet was closed, and the colour of the sample was immediately determined using the colour racks, initially in the ratio of 10.0 yellow to 1.9 red Lovibond units. The ratio was corrected to obtain an approximate match until an accurate colour match was obtained.

Determination of free fatty acid (FFA) (as palmitic)

The determination of FFA was conducted according to MPOB p2.5:2004 test method (Kuntom, 2005). The FFA content was expressed as the percentage of palmitic acid. As the FFA is frequently expressed as an acid value, the acid value can be obtained by multiplying the percentage FFA (as palmitic) by 2.19. The melted and homogenized oil sample was weighed into a conical flask. 50 mL of the neutralized isopropanol was added to the flask, followed by a few drops of phenolphthalein. Then, the conical flask was placed on a hot plate at 40 °C. The flask was gently swirled while titrated with sodium hydroxide (NaOH) standard solution until the appearance of the first permanent pink colour. The FFA content was calculated as in equation (5),

$$\text{FFA as palmitic acid (\%)} = \frac{25.6 \times M \times V}{m} \quad (5)$$

where M is the molarity (M) of standard NaOH solution, V is the volume (mL) of the standard NaOH solution used, and m is the mass (g) of the oil sample.

Statistical analysis

All analyses were conducted in six replicates. The data obtained from the replicate tests were within the repeatability limit of the respective analysis. The results pertaining to the quality

parameters were given as the mean value and standard deviation. Data were subjected to one-way analysis of variance (ANOVA) and Duncan multiple range test using XLSTAT (Addinsoft, New York, NY, USA) to determine the significant difference between the mean data (Addinsoft, 2019). The significance level was accepted at $P \leq 0.05$.

RESULTS AND DISCUSSION

Quality requirements for cooking oils (RBD palm olein)

The properties of the cooking oils evaluated were compared with known standards for refined oils such as Malaysian Standard (MS 816:2007, Palm Olein – Specification), and Codex Standards for Edible Fats and Oils and Codex Standards for Named Vegetable Oils. Table 1 presents the quality requirements for RBD palm olein set by Malaysian Standard (Department of Standards Malaysia, 2007). The range of quality parameters of the refined oils by Codex Standards is provided in the following sections. According to the Malaysian Standard, RBD palm olein shall comply with the current Malaysian Food Regulations 1985 labelling. Besides, the packaging of palm olein cooking oil should follow a code of practice. For instance, the type of package or plastic for packaging shall adhere to the specific characteristics which include polyethylene terephthalate (PET) and high-density polyethylene. Materials that will detriment the quality or contaminate the packed cooking oil shall not be used, such as plastics that contain polyvinyl chloride, low-density polyethylene, polypropylene, polystyrene, etc. The details on the code of practice for packaging of Malaysian palm olein cooking oil are given in MPOB (2009).

Table 1. Quality requirements for RBD palm olein by Malaysian Standard MS 816:2007.

Characteristics	Requirement
Moisture and impurities, % max.	0.1
Iodine value (Wijs), min.	56
Peroxide value, meq O ₂ /kg, max.	2
Slip melting point, °C max.	24
Colour, 133.35 mm (5¼ in) Lovibond, max.	3R
Free fatty acid (as palmitic), % max	0.1

Physico-chemical properties of different cooking oil brands

The physico-chemical properties of different RBD palm olein cooking oil brands packed in 1 kg plastic pouch are summarized in Table 2. The properties were expressed as mean value, and standard deviation from six replicates, where the means within each column with different superscripts are significantly ($P < 0.05$) different. The values of physico-chemical properties obtained from analysis of different cooking oils showed that their values ranged as follows; MI range from 0.047 to 0.098%, IV range from 56.58 to 62.33, PV range from 1.31 to 9.83 meq O₂/kg, SMP range from 15.57 to 23.67 °C, Lovibond colour range from 2.97R to 3.67R, and FFA range from 0.06 to 0.204%. The variations of each property are discussed further below.

Table 2. Physico-chemical properties of different RBD palm olein brands packed in plastic pouch.

RBD palm olein	Properties					
	MI (%)	IV (Wijs)	PV, meq O ₂ /kg	SMP (°C)	Lovibond colour	FFA (%)
A	0.083 ± 0.012 ^{abcd}	57.68 ± 0.147 ^d	9.44 ± 0.211 ^d	23.67 ± 0.103 ^a	3.2 ± 0.041 ^e	0.204 ± 0.004 ^b
B	0.077 ± 0.012 ^{bcde}	56.95 ± 0.226 ^{gh}	3.43 ± 0.066 ⁱ	21.90 ± 0.110 ^{gh}	3.1 ± 0.075 ^f	0.202 ± 0.001 ^a
C	0.073 ± 0.015 ^{cdefg}	57.45 ± 0.138 ^{de}	9.76 ± 0.238 ^c	21.37 ± 0.082 ^{kl}	3.1 ± 0.075 ^f	0.127 ± 0.001 ^h
D	0.087 ± 0.012 ^{abc}	58.68 ± 0.194 ^c	7.31 ± 0.815 ^e	21.43 ± 0.082 ^{jk}	3.0 ± 0.052 ^g	0.148 ± 0.001 ^f
E	0.058 ± 0.008 ^{ghi}	57.55 ± 0.207 ^{de}	9.79 ± 0.218 ^b	20.96 ± 0.082 ^o	3.0 ± 0.001 ^{gh}	0.171 ± 0.001 ^c
F	0.077 ± 0.008 ^{bcde}	57.03 ± 0.266 ^{fg}	9.83 ± 0.280 ^a	21.30 ± 0.110 ^l	3.0 ± 0.001 ^{gh}	0.126 ± 0.001 ^h
G	0.072 ± 0.015 ^{cdefgh}	60.50 ± 0.126 ^b	2.07 ± 0.222 ^m	21.93 ± 0.103 ^{fg}	3.6 ± 0.001 ^a	0.091 ± 0.001 ^m
H	0.075 ± 0.005 ^{cdef}	57.12 ± 0.147 ^{fg}	2.79 ± 0.198 ^k	21.47 ± 0.103 ^j	3.4 ± 0.052 ^c	0.148 ± 0.001 ^f
I	0.092 ± 0.012 ^{ab}	56.67 ± 0.308 ^{hi}	2.81 ± 0.080 ^k	21.80 ± 0.001 ⁱ	3.0 ± 0.052 ^g	0.097 ± 0.001 ^k
J	0.087 ± 0.016 ^{abc}	56.58 ± 0.271 ⁱ	1.56 ± 0.168 ⁿ	21.00 ± 0.001 ^{no}	3.0 ± 0.001 ^{gh}	0.095 ± 0.001 ^l
K	0.087 ± 0.016 ^{abc}	57.30 ± 0.179 ^{ef}	3.21 ± 0.090 ^j	21.83 ± 0.082 ^{hi}	3.1 ± 0.055 ^g	0.085 ± 0.001 ^o
L	0.098 ± 0.018 ^a	58.6 ± 0.268 ^c	5.48 ± 0.144 ^g	22.10 ± 0.110 ^e	2.9 ± 0.052 ^h	0.084 ± 0.001 ^p
M	0.070 ± 0.009 ^{cdefgh}	58.78 ± 0.512 ^c	1.31 ± 0.047 ^o	22.57 ± 0.082 ^c	3.1 ± 0.055 ^g	0.166 ± 0.001 ⁱ
N	0.06 ± 0.009 ^{fghi}	62.33 ± 0.082 ^a	1.087 ± 0.030 ^p	19.57 ± 0.082 ^p	3.0 ± 0.001 ^{gh}	0.056 ± 0.001 ^r
O	0.067 ± 0.005 ^{efgh}	58.60 ± 0.141 ^c	1.37 ± 0.085 ^o	22.80 ± 0.001 ^b	3.2 ± 0.075 ^{de}	0.107 ± 0.001 ^j
P	0.057 ± 0.005 ^{hi}	58.72 ± 0.133 ^c	3.15 ± 0.069 ^j	21.07 ± 0.103 ⁿ	3.3 ± 0.055 ^d	0.06 ± 0.001 ^q
Q	0.047 ± 0.009 ⁱ	56.72 ± 0.214 ^{hi}	2.35 ± 0.090 ^l	22.37 ± 0.082 ^d	3.6 ± 0.052 ^a	0.151 ± 0.001 ^e
R	0.086 ± 0.010 ^{abcd}	57.51 ± 0.248 ^{de}	3.88 ± 0.126 ^h	21.20 ± 0.001 ^m	3.5 ± 0.055 ^b	0.146 ± 0.002 ^g
S	0.072 ± 0.013 ^{cdefgh}	56.83 ± 0.225 ^{ghi}	3.55 ± 0.074 ⁱ	21.80 ± 0.001 ⁱ	3.0 ± 0.001 ^{gh}	0.089 ± 0.001 ⁿ
T	0.066 ± 0.018 ^{efgh}	58.62 ± 0.214 ^c	6.60 ± 0.089 ^f	22.00 ± 0.001 ^f	3.0 ± 0.001 ^{gh}	0.155 ± 0.001 ^d

Means within each column with different superscripts are significantly ($P < 0.05$) different.

Variations of moisture and impurities

Figure 1 shows the variations of MI of RBD palm olein packed in plastic pouches. All brands had MI below the maximum allowable limit (0.10 %) as set by the Malaysian Standard. Besides, the Codex Standards for Named Vegetable Oils specified a maximum of 0.2% for the volatile matter at 105 °C, and a maximum of 0.05% for insoluble impurities (Alimentarius, 1999). It was reported that the variation in moisture content could be attributed to the packaging and processing of the oil (Fuentes et al., 2013). Thus, for this study, as the cooking oils were all packed in plastic pouches, it is suggested that the processing of the oil was the main factor contributing to variation in moisture content.

Low moisture content is crucial for controlling the deterioration of oil samples. Since the presence of moisture promotes hydrolysis, which results in an increase in FFA content (Ramli et al., 2018). Besides, the high moisture content is an indication of its rancidity and short shelf value (Chigbogu et al., 2015). The low moisture content signifies the storage ability and stability of the oil samples. In addition, vegetable oils with low moisture contents implied that they withstand the growth of micro-organisms (Mengistie et al., 2018). The moisture content of the oil is directly dependent on the efficiency of the final extraction and clarification processes, in which the moisture content could be removed by boiling at elevated temperatures (Chigbogu et al., 2015). In addition, the low amount of insoluble impurities revealed the efficiency of clarification during the extraction of oil (Agbaire, 2012).

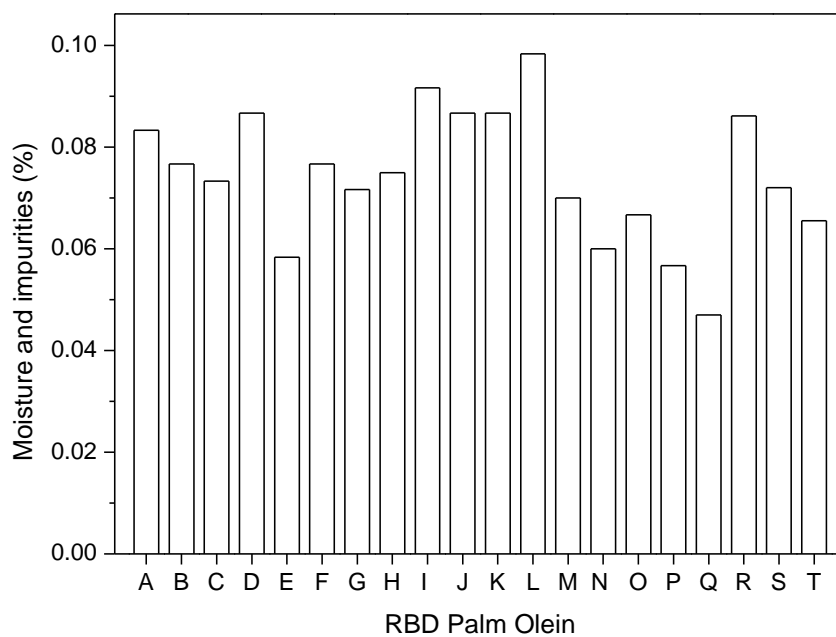


Figure 1. Moisture and impurities variations of different RBD palm olein brands packed in plastic pouches.

Variations of iodine value

The analysis of IV on 20 different brands of cooking oils (Figure 2) indicated that the IV values for all brands are within the requirement (minimum 56) set by the Malaysian Standard. IV is a measure of the degree of unsaturation of an oil. The higher the IV, the more the unsaturation present. Edible oils with high IV are desired by oil processors, while oils having lower IV is suggestive of lower quality (Tesfaye & Abebaw, 2016). Besides, IV reflects the reactivity of the oil and is useful for

detecting adulteration in oils. In a study on physico-chemical characteristics of edible oils, it was deduced that the oils with low IV might have contributed to their greater oxidative storage stability (Tesfaye & Abebaw, 2016). As reported by Chigbogu et al., the IV obtained from the oil samples indicated that the oils were susceptible to oxidation. The study suggested that adding antioxidants may be necessary to prolong the storage stability of the oils (Chigbogu et al., 2015).

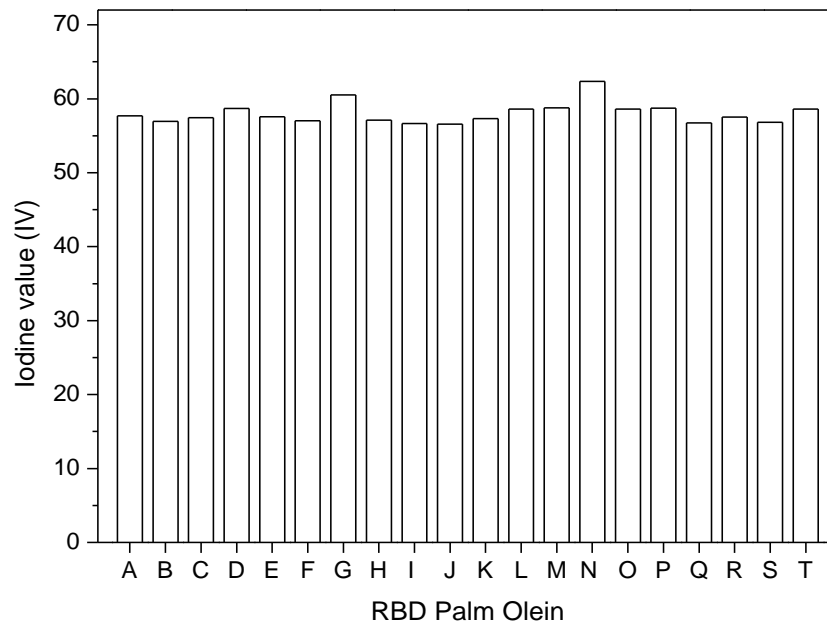


Figure 2. Iodine value variations of different RBD palm olein brands packed in plastic pouches.

Variations of peroxide value

PV is a measure of active oxygen bound by cooking oils. The variations of PV of different cooking oil brands are presented in Figure 3. As the maximum allowable PV set by Malaysian Standard is 2 meq O₂/kg, the PV of several brands deviated significantly ($P < 0.05$) from the standard value. Analysis of results showed that PV of four samples lies within the range prescribed by Malaysian Standard while 16 samples were not within the range prescribed. Out of the 16 samples, PV of brand G did not deviate significantly ($P > 0.05$) from the standard value, while the remaining brands deviated significantly ($P < 0.05$) from the standard value. According to Codex Standards for Named Vegetable Oils, the maximum level of PV for refined oils is up to 10 meq O₂/kg (Alimentarius, 1999). In this study, the PV of the tested samples was in the range of 1.31 to 9.83 meq O₂/kg. From the analyses, all brands were within the PV designated by the Codex Standards.

The oxidation of cooking oils can be suppressed by the addition of antioxidants. For instance, polyphenolic compounds that are naturally present or intentionally added in the cooking oils can act as antioxidants to lower the PV (Abdullah et al., 2018; Mehmood et al., 2012). As reported by Mehmood et al., the quality of cooking oils was categorized into several groups based on the PV values (2012). The oils exhibited excellent, good, acceptable, and low qualities for PV values in the range of <3.33, 3.33 to 6.67, 6.68 to 10, and 10 to 13.33, respectively, while the remaining with PV values >13.33 lie in a very low-quality range (Mehmood et al., 2012). According to this category, 15 out of 20 brands of cooking oils tested in this study are considered as excellent and good qualities.

High PV could be resulted from a high degree of unsaturation and was found to increase with the storage time, temperature, light and contact with air of the oil samples (Mengistie et al., 2018; Okparanta et al., 2018; Tesfaye & Abebaw, 2016). It was found that during storage and handling processes, the quality of RBD palm olein deteriorated. The oil quality showed that the PV is usually on the higher side of the range between 1 to 10 meq O₂/kg (Chong, 2012). A study on the effect of canola oil packaging films revealed that PV increased rapidly under light conditions (Sun et al., 2015). A similar trend was reported on the properties of sunflower oil (Kucuk & Caner, 2005). The findings from previous studies indicated that oils in a tin packed resist rancidity due to blockage of light (Mehmood et al., 2012; Méndez & Falqué, 2007). Meanwhile, cooking oils packed in poly pouches are more susceptible to rancidity. Therefore, it is presumed that the effect of packaging materials on the physico-chemical properties of vegetable oils could be explained by the absorption of light into the packaging materials. This statement is in agreement with findings reported elsewhere (Kucuk & Caner, 2005).

The initial oxygen concentration and permeability of oxygen through the packaging materials also contributed to the degradation of oil (Kucuk & Caner, 2005). The combined factors of higher permeability of oxygen and transmittance of light resulted in high PV (Kucuk & Caner, 2005), which was suggested to be profoundly affected by the oils packed in the transparent plastic pouch. The initial PV of sunflower oils purchased from a local market, which was directly measured after procurement of samples, revealed a high value (19 meq O₂/kg) (Abdellah & Ishag, 2012). This indicates that the oil has already undergone previous oxidation after industrial processing or while being stored. It is important to note that as soon as the food, feed, or product is manufactured, it begins to go through various chemical and physical changes, including autoxidation determined as PV (Kaleem et al., 2015). A previously reported study also presumed that the high PV was attributed to climatic conditions that characterized arid and semi-arid regions (Abdellah & Ishag, 2012).

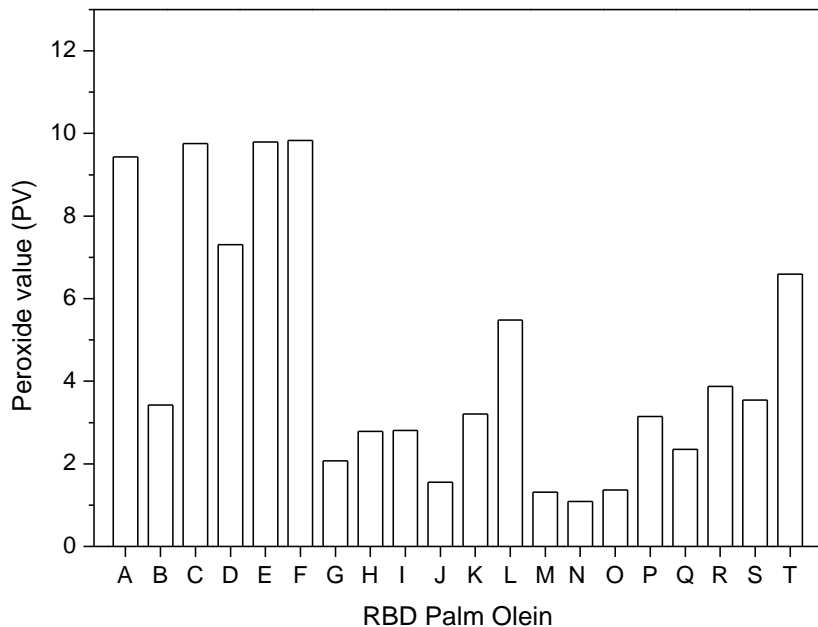


Figure 3. Peroxide value variations of different RBD palm olein brands packed in plastic pouches.

Variations of slip melting point

Melting point is widely used to measure the consistency of oils and fats and can be used as a criterion of purity. Figure 4 displays the variations of SMP of 20 different brands of RBD palm olein cooking oils. As the maximum SMP set by Malaysian Standards for RBD palm olein is 24 °C, all brands possessed SMP below the maximum allowable limit. Thus, all oil samples remained liquid at room temperature. There were generally no major differences between the SMP of the oils from different brands. The SMP of cooking oil brand A was the highest among all the oils tested, while cooking oil brand N possessed the lowest SMP. The SMP is affected by the content of FFA and triacylglycerols (Endo, 2018; Lin, 2002). Thus, crude oils have higher SMP than refined oils.

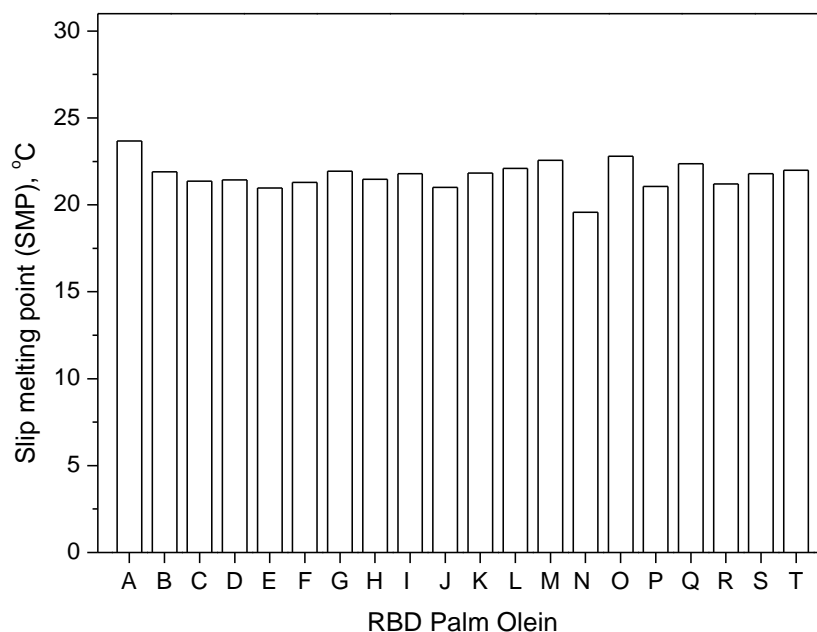


Figure 4. Slip melting point variations of different RBD palm olein brands packed in plastic pouches.

Variations of Lovibond colour

Colour of the vegetable oil is attributed to tocopherol, carotenoids and some other pigments (Abdellah & Ishag, 2012; Mengistie et al., 2018). Generally, refined oils have soft tastes, clear and transparent appearance (Mengistie et al., 2018). As shown in Figure 5, out of 20 brands of RBD palm olein cooking oils evaluated, colour R of seven brands were within the maximum allowable limit set by the Malaysian Standard (3R). The colour R values of several brands did not deviate significantly ($P > 0.05$) from the standard value, which were brands B, C, D, E, I, K, and M. The measurement of colour by tintometer involves matching the redness intensity by the naked eye. Thus the measurement is rather subjective (Narasimhan et al., 2001).

As reported elsewhere, the high colour R is probably due to insufficient colour reduction during the bleaching process, or the oil was exposed to a higher temperature for a long time (Mehmood et al., 2012; Mengistie et al., 2018). Exposure to high heat during the deodorization process leads to polymerization and consequently increases the colour. Besides, other factors such as the presence of dissolved impurities and other unfinished products could give colour to oils (Mengistie et al., 2018; Nangbes et al., 2013). It was implied that the slight changes and darkening

in colour might be ascribed to storage conditions and oxidative effects during storage (Imran & Nadeem, 2015). The effect of oxidation was also reported in a previous study, where the formation of tertiary oxidation products resulting from the polymerization of secondary oxidation products caused darkening of the oil colour (Kaleem et al., 2015). As in this study, the cooking oil samples were randomly selected off from the shelf. Thus the duration of storage and storage conditions (such as light) were not controlled. Thus, this might be one of the factors that affect the physico-chemical properties of the oils. Furthermore, it was observed that during storage and handling processes, the quality of RBD palm olein declined, as the colour could range from 0.27R to nearly 5R (Chong, 2012).

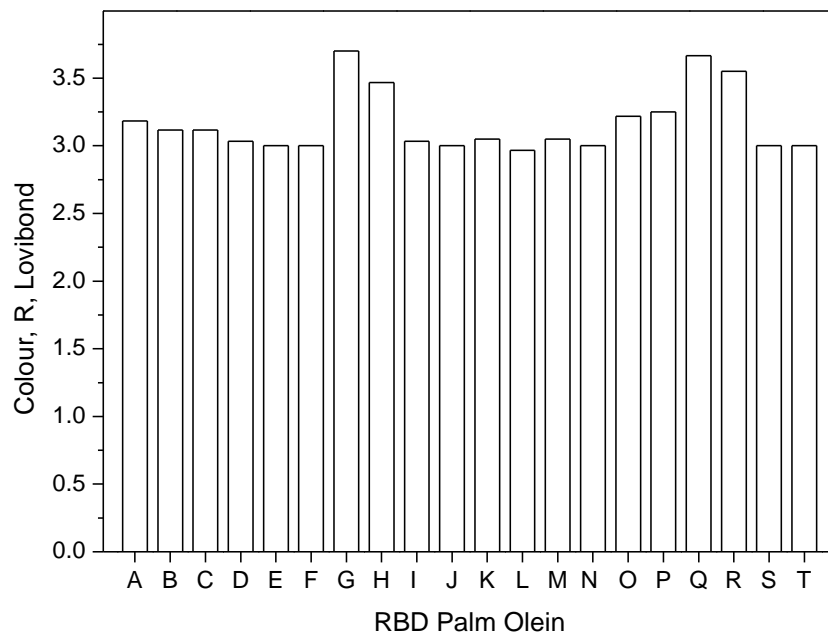


Figure 5. Colour R variations of different RBD palm olein brands packed in plastic pouches.

Variations of free fatty acid

Figure 6 displays the variations of FFA for different brands of RBD palm olein in 1 kg plastic pouch. The FFA analysis showed that the RBD palm olein cooking oils with FFA values higher than 0.1% were significantly deviated ($P < 0.05$) from the standard value set by the Malaysian Standard. Out of 20 brands, the FFA value of only eight brands met the Malaysian Standard. According to Codex Standards for Edible Fats and Oils, the maximum level of acid value for refined oils is 0.6 mg KOH/g oil (Alimentarius, 1999). In this study, the acid value of the tested samples was in the range of 0.12 to 0.45 mg KOH/g oil. From the analysis, the acid value of all cooking oil brands tested was within the acid value designated by the Codex Standards.

In a previous study on the evaluation of different cooking oils, the quality of the cooking oils was categorized based on the FFA values (Mehmood et al., 2012). The cooking oils with FFA values less than 0.068 indicated excellent quality, FFA values in the range 0.068 to 0.13 indicated good quality, and FFA values from 0.14 to 0.20 indicated acceptable quality. In addition, cooking oils with higher FFA values, 0.21 to 0.27 was characterized as low-quality oil and FFA values more than 0.27 was considered as very low-quality cooking oil (Mehmood et al., 2012). Based on these categories, the cooking oils tested in this study were mostly considered as excellent, good, and acceptable qualities.

A high level of FFA is undesirable in finished oils as they can cause off-flavours and shorten the shelf life of the oils (Mengistie et al., 2018). It was suggested that the variation of acid value in vegetable oil samples could be due to differences in moisture contents and differences in the refining and deodorization technologies (Mengistie et al., 2018). Herein, the moisture content of all samples was lower than 0.1% (Table 1); thus, the variation of the FFA values was possibly due to the refining and deodorization processes. In addition, hydrolysis of triglycerides and oil deterioration also caused the increase of FFA (Mehmood et al., 2012). Other factors include exposure to light, lipase enzyme and high temperature, which commonly exist in certain country's climate. The effect of climatic conditions on the physico-chemical properties of cooking oils has been discussed in previous studies (Abdellah & Ishag, 2012; Mehmood et al., 2012).

As mentioned before, it was found that the quality of RBD palm olein deteriorated during storage and handling processes. The oil quality showed that FFA could range from 0.06% to 0.6% (Chong, 2012). It was implied that partial hydrolysis of oils took place during storage, thus increasing the FFA content (Kucuk & Caner, 2005). As all samples were randomly selected off from the shelf, the storage time before the procurement of oils is unknown. Therefore, the high FFA content in the cooking oils samples was possibly due to the partial hydrolysis that occurred during the storage at the shelf. It was found that vegetable oil samples stored under light showed a very significant difference in FFA content compared to those stored in the dark (Kucuk & Caner, 2005). As it is well aware that the cooking oil samples tested in this study were randomly selected and that the storage time and condition of the oil samples before analysis was unknown, the high FFA content of several brands was potentially due to this factor. This factor also possibly caused the high measurement of PV for the oil samples.

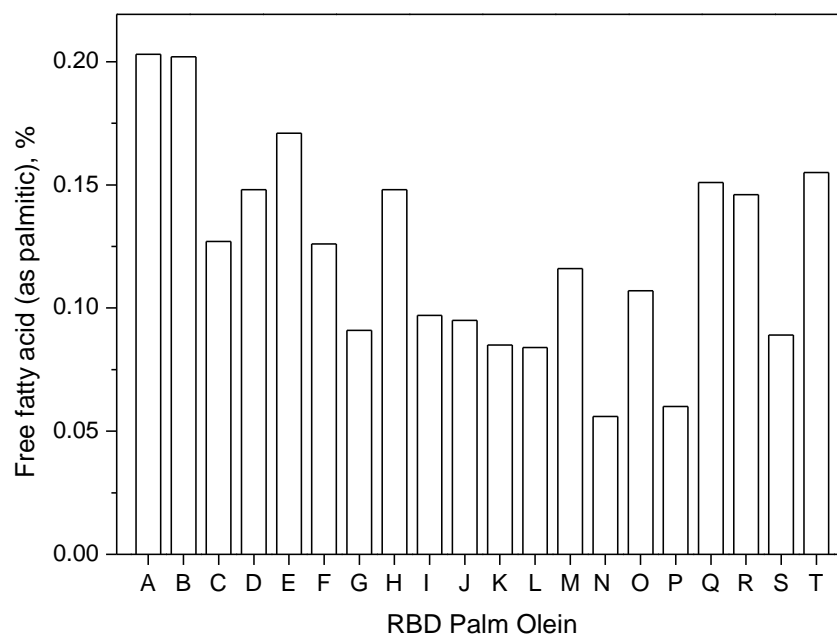


Figure 6. Free fatty acid (as palmitic) variations of different RBD palm olein brands packed in plastic pouches.

CONCLUSIONS

The physico-chemical properties of 20 different brands of RBD palm olein cooking oils packed in plastic pouches were investigated. The properties of all brands were within the Malaysian Standard of RBD palm olein for MI, IV and SMP. For several brands, PV, Lovibond colour, and FFA values deviated from the Malaysian Standard. Compared to Codex Alimentarius Standards, MI, PV and FFA of all brands were within the values assigned. The physico-chemical properties of cooking oils tested in this study were of acceptable and good quality and were considered suitable for consumption. The quality of cooking oil should be regularly monitored to avoid the use of adulterated oil. All samples were randomly selected off from the shelf, and the storage time before the procurement of oils was not controlled. As vegetable oil samples stored under light showed a significant difference in PV and FFA values compared to those stored in the dark, the off-value of several physico-chemical properties were potentially due to this factor. Nevertheless, the cooking oil samples tested in this study were randomly chosen. The sampling method applied in this study could not represent the entire samples available in the market. Further studies should be conducted by investigating other types of packaging materials and should include more physico-chemical properties of the cooking oils. The effect of storage duration on the shelf on the quality of the cooking oils should also be considered.

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