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Chemical Properties of Virgin Coconut Oil

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Abstract A study on the commercial virgin coconut oil (VCO) available in the Malaysian and Indonesian market was conducted. The paper reported the chemical characteristics and fatty acid composition of VCO. There was no significant difference in lauric acid content (46.64–48.03%) among VCO samples. The major triacylglycerols obtained for the oils were LaLaLa, LaLaM, CLaLa, LaMM and CCLa (La, lauric; C, capric; M, myristic). Iodine value ranged from 4.47 to 8.55, indicative of only few unsaturated bond presence. Saponification value ranged from 250.07 to 260.67 mg KOH/g oil. The low peroxide value (0.21–0.57 mequiv oxygen/kg) signified its high oxidative stability, while anisidine value ranged from 0.16 to 0.19. Free fatty acid content of 0.15–0.25 was fairly low, showing that VCO samples were of good quality. All chemical compositions were within the limit of Codex standard for edible coconut oil. Total phenolic contents of VCO samples (7.78–29.18 mg GAE/100 g oil) were significantly higher than refined, bleached and deodorized (RBD) coconut oil (6.14 mg GAE/100 g oil). These results suggest that VCO is as good as RBD coconut oil in chemical properties with the added benefit of being higher in phenolic content.

Keywords Antioxidant · Fatty acids · Iodine value · Lauric oils · Peroxide value · Oxidative rancidity · Saponification value · Triacylglycerol

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Introduction

Coconut oil is commercially derived from copra, which is the dried kernel or 'meat' of coconut. It is colorless to pale brownish yellow. Coconut oil contains a high level of low molecular weight saturated fatty acids, the distinctive characteristic of lauric oil. The chemical composition of coconut oil makes it possible to use in a wide range of edible and non-edible purposes. Coconut oil has unique characteristics such as having bland flavor, pleasant odor, high resistance to rancidity, a narrow temperature range of melting, easy digestibility and absorbability, high gross for spray oil use and superior foam retention capacity for whip-topping use [1].

Most commercial grade coconut oils are made from copra. It can be produced by smoke drying, sun drying or a combination of both. If standard copra is used as starting material, the unrefined coconut oil obtained is not suitable for consumption and must be purified. Unsanitary handling, drastic processing of copra for oil extraction and refining make the product susceptible to aflatoxin contamination and oxidative rancidity [2].

In contrast, virgin coconut oil (VCO), which is extracted by a wet process directly from coconut milk under controlled temperature, may have more beneficial effects than copra oil since it retains most of its beneficial components.

Nevin and Rajamohan [3] reported that VCO reduces total cholesterol, triglycerides, phospholipids, low density lipoprotein (LDL) and very low density lipoprotein (VLDL) cholesterol and increases high density lipoprotein (HDL) cholesterol in serum and tissues compared to copra oil. Moreover, administration of VCO is capable of increasing antioxidant enzymes and reduces lipid peroxidation content [4]. VCO also has a more significant antithrombotic effect over copra oil [5].

Due to its therapeutic value, VCO became popular a few years back. Nowadays, consumers are demanding edible oils that are natural and free from chemical treatment [4]. Thus, the study on VCO chemical composition is of great interest especially to consumers who demand more information on the characteristics and properties of VCO. However, the reports on its chemical properties are limited. Therefore, this study was undertaken to look into the basic components and analyze the quality of VCO available on the market today.

Materials and Methods

Materials

Five commercial VCO samples from different manufacturers were purchased from local markets in Selangor, Malaysia (MAL 1, MAL 2, MAL 3, MAL 4 and MAL 5), while another five commercial VCO samples were obtained from Indonesia (IND 1, IND 2, IND 3, IND 4 and IND 5). The samples were selected based on convenience sampling. Refined, bleached and deodorized coconut oil (RBDCO) was obtained from a local grocery store for comparison. VCO samples were packaged in polyethylene terephthalate (PET) bottles and the dates of manufacturing were not known. All chemicals and solvents used were of analytical grade.

Fatty Acid Analysis

Fatty acid composition namely caproic, caprylic, capric, lauric, myristic, palmitic, stearic, oleic and linoleic acid were determined. Fatty acid methyl esters (FAMEs) were prepared dissolving the oil sample (50 mg) with hexane (0.8 mL) and sodium methoxide (1 M, 0.2 mL) followed by subsequent analysis using gas chromatography (Agilent Technologies 6890N, Santa Clara, CA) fitted with a FID detector. A polar capillary column RESTEX 2330 (0.25 mm internal diameter, 30 m length and 0.2 μm film thickness; Restek Corp, Bellefonte, PA, USA) was used at a column pressure of 1.03×10^5 Pa. The initial column temperature was 50 °C (held for 2 min), then increased to 180 °C at a rate of 5 °C/min, held for 2 min at 180 °C, then increased at a rate of 8 °C/min to 200 °C and held for 5 min at 200 °C. Standard FAMEs (Sigma Chemicals, St Louis, MO) were used as authentic samples and peak identification was done by comparing relative retention times.

Triacylglycerol Composition

The Triacylglycerol (TAG) composition was obtained by using reversed-phase liquid chromatography Waters (Milford, MA) consisting of a Waters 2695 controller coupled with a Water 2414 RI detector. Samples were eluted isocratically using acetone/acetonitrile (63.5:36.5, v/v) at 1 mL/min flow rate. The column used was Waters Nova Pak C-18 (3.9 × 300 mm, 4 μm). The injection volume was 10 μL of 5% (w/v) oil in acetone. Empower software (Milford, MA) was used for data processing. TAG peaks were identified based on the retention time of a TAG standard (Sigma–Aldrich, St Louis, MO). The TAG data was calculated as percentage areas.

Chemical Analysis

Iodine (Cd 1d-92), saponification (Cd 3-25), peroxide (Cd 8-53), anisidine (Cd 18-90) and free fatty acid (Ca 5a-40) values were determined according to AOCS methods [6].

Total Phenolic Content

The total phenol content was estimated according to the method of Gutfinger [7] with some modifications. Aliquots of test samples (1 mg/mL) were mixed with 1 mL of Folin–Ciocalteu reagent (previously diluted tenfold with deionized water). 0.8 mL of 7.5% of sodium carbonate solution was added and allowed to stand at room temperature for 30 min. The absorbance was read at 725 nm using a UV–VIS spectrophotometer (UV-1610, Shimadzu, Kyoto, Japan). Gallic acid (0.1–0.5 mg/mL) was used as the standard for the calibration curve. Total phenolic content of the extracts was expressed as gallic acid equivalents (GAE) per 100 g oil.

Antioxidant Activity

The antioxidant activity of extract was evaluated by the β-carotene–linoleate assay as described by Amin and Tan [8]. One milliliter of β-carotene solution (0.2 mg/mL in chloroform) was pipetted into a round bottom flask (250 mL) containing 0.02 mL of linoleic acid and 0.2 mL of 100% Tween 20. The mixture was evaporated at 40 °C for 10 min and diluted with 100 mL of distilled water slowly and agitated vigorously to form an emulsion. Five-milliliter aliquots of the emulsion were transferred into

different test tubes containing 0.2 mL of samples in solvents at a final concentration of 1 mg/mL. The mixture was then gently shaken and placed in water bath at 45 °C for 2 h. The absorbance of the samples was measured at 470 nm using a spectrophotometer (UV-1610, Shimadzu, Kyoto, Japan) at initial time ($t = 0$) against a blank, consisting of an emulsion without β-carotene. Standard (α-tocopherol) of the same concentration of samples were used for comparison. A 0.2-mL amount of methanol in 5 mL of the above emulsion was used as the control. Measurements were carried out at 15 min intervals for 120 min. The antioxidant activity (AA) was measured in terms of successful bleaching of β-carotene by using the equation below, where A_0 and A_0° are the absorbance values measured at the initial incubation time for samples and control, respectively, while A_t and A_t° were the absorbance values measured in the samples and control at t = 120 min, respectively.

$$\mathrm{AA}(\%) = [1 - (A_0 - A_t)/(A_0^\circ - A_t^\circ)] \times 100$$

Statistical Analysis

Analysis of variance and least significant difference tests were conducted to identify differences among means using SAS statistical computer package software version 6.12 (SAS Cary, NC). Statistical significance was declared at $P < 0.05$. All analyses were conducted in triplicate.

Results and Discussion

The fatty acid composition of commercial VCO is presented in Table 1. The fatty acid composition was as expected and comparable to the fatty composition of coconut oil according to the Codex standard [9]. Lauric acid (C12:0) was the most dominant fatty acid and ranged from 46 to 48%. The lauric acid values obtained were slightly lower than VCO samples from Philippines as reported by Dia et al. [10], which was from 48 to 53%. This could be due to geographical origin and ecological conditions. There was no significant difference found in the content of lauric acid between VCO and RBDCO despite the difference in the extraction process. This finding was in agreement with Banzon and Resurreccion [11], in which no changes were observed in the fatty acid distribution in samples of coconut oil obtained by heating, fermentation, freeze-thawing and solvent extraction.

The caproic fatty acids (C6:0) in this study ranged from 0.52 to 0.69%. These values were much higher than those reported by Dia et al. [10] which was between 0.35 and 0.60%. Sample MAL 5 contained the highest amount of caprylic acid (C8:0), while sample IND 1 showed the highest percentage of capric acid (C10:0). In this study, medium chain fatty acids ranged from 60.5 to 63.6%. The myristic (C14:0) and stearic (C16:0) acid contents in this study were comparable to the study reported by Laureles et al. [12]. The linoleic fatty acid (C18:2) was found to be higher in VCO samples than reported by Dia et al. [10], but lower than obtained by Laureles et al. [12]. The fatty acid compositions of VCO samples in this study were within the ranges of edible coconut oil as proposed by the Codex standard [9].

Table 2 shows the TAG composition of VCO samples. The major TAG present in VCO samples consisted of 22.78–25.84% of LaLaLa, 14.43–16.54% of CCLa, 19.20–21.38% of CLaLa, 13.62–15.55% of LaLaM and 7.39–9.51% of LaMM with La, C and M are lauric, capric and myristic acids, respectively. These values were in agreement

Table 1 Fatty acid composition of virgin coconut oil (VCO) and refined, bleached and deodorized coconut oil (RBDCO)

Sample	C6:0	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2
RBDCO	0.63^{a}	8.24^{abcd}	6.53^{ab}	47.42^{a}	18.26^{abc}	9.33^{ab}	2.68^{c}	5.25^{d}	1.57^{abc}
MAL 1	0.64^{a}	7.64^{cde}	6.27^{ab}	48.03^{a}	16.23^{d}	8.40^{e}	3.46^{ab}	5.80^{bcd}	0.90 ^{g}
MAL 2	0.69^{a}	7.53^{de}	6.05^{bc}	47.10^{a}	18.51^{ab}	9.52^{ab}	3.53^{a}	6.11^{abc}	1.27^{ef}
MAL 3	0.58^{a}	7.97^{bcd}	6.22^{ab}	47.81^{a}	16.99 ^{cd}	9.11^{bc}	3.15^{abc}	6.36^{ab}	1.38^{def}
MAL 4	0.52^{a}	8.13^{abcd}	6.49^{ab}	47.21^{a}	17.28^{bcd}	8.47^{de}	3.09^{abc}	6.36^{ab}	1.41^{cde}
MAL 5	0.57^{a}	8.81^{a}	6.40^{ab}	47.06^{a}	17.88^{abc}	8.53^{de}	2.81^{bc}	6.65^{a}	1.60^{ab}
IND 1	0.65^{a}	7.89^{bcde}	6.20^{ab}	46.64^{a}	18.85^{a}	9.35^{ab}	3.19^{abc}	5.72 ^{cd}	1.23^{f}
IND 2	0.61^{a}	8.60^{ab}	6.59^{a}	46.89^{a}	17.03 ^{cd}	8.84 ^{cd}	3.23^{abc}	6.36^{ab}	1.43^{bcde}
IND 3	0.57^{a}	8.37^{abc}	6.43^{ab}	47.21^{a}	18.09^{abc}	8.41^{e}	3.00^{abc}	6.70^{a}	1.72^{a}
IND 4	0.68^{a}	8.62^{ab}	6.45^{ab}	47.85^{a}	18.08^{abc}	7.41^{f}	3.38^{ab}	6.38^{ab}	1.46^{bcd}
IND 5	0.62^{a}	7.19^{e}	5.65^{c}	47.12^{a}	18.90^{a}	9.55^{a}	3.57^{a}	6.50^{a}	1.39^{def}

Means within each column with different superscript are significantly different at $P < 0.05$. The relative standard deviation was less than 6% for all samples

MAL Malaysian virgin coconut oil, *IND* Indonesian virgin coconut oil

Table 2 TAG composition of virgin coconut oil (VCO) and refined, bleached and deodorized coconut oil (RBDCO)

Sample	RBDCO	MAL 1	MAL 2	MAL 3	MAL 4	MAL 5	IND 1	IND 2	IND 3	IND 4	IND 5
CpCpLa	1.24^{abc}	0.82^{ef}	1.06^{cde}	1.34^{ab}	1.00^{cde}	1.37^{a}	0.87^{def}	1.10^{bcd}	1.32^{ab}	0.71^{f}	0.93^{def}
CpCLa	3.53^{de}	3.97^{abcd}	3.91^{abcd}	4.20^{ab}	4.17^{abc}	4.17^{abc}	3.29^{e}	3.64^{cde}	4.32^{a}	3.66^{bcde}	3.54^{de}
CCLa	13.15^{d}	16.54^{a}	15.12^{bc}	16.41^{a}	15.87^{ab}	16.18^{ab}	14.43^{c}	14.31^{c}	16.71^{a}	14.65^{c}	16.10^{ab}
CLaLa	17.33^{d}	21.38^{a}	19.82^{bc}	19.71^{c}	19.77^{bc}	20.02^{bc}	19.50^{c}	19.20^{c}	21.08^{ab}	19.90^{bc}	20.32^{abc}
LaLaLa	21.95^{c}	25.84^{a}	23.34^{bc}	24.06^{b}	22.78^{bc}	23.62^{bc}	23.50^{bc}	23.55^{bc}	23.51^{bc}	23.64^{bc}	23.91^{b}
LaLaM	17.18^{a}	15.06^{abc}	15.55^{abc}	13.78^{bc}	14.64^{abc}	13.62^{c}	15.43^{abc}	16.50^{ab}	14.21^{bc}	16.17^{abc}	14.82^{abc}
LaLaO	2.29^{a}	1.32^{cd}	1.54^{bcd}	1.94^{ab}	1.42^{cd}	1.64^{bcd}	1.58^{bcd}	1.80^{bc}	1.79^{bc}	1.20^{d}	1.55^{bcd}
LaMM	10.19^{a}	8.57^{bcd}	9.51^{ab}	7.73^{de}	9.07^{bc}	8.20^{cde}	9.07^{bc}	9.35^{ab}	7.39^{e}	9.47^{ab}	8.60^{bcd}
LaMO	2.11^{a}	0.87^{c}	1.44^{bc}	1.59^{b}	1.32^{bc}	1.41^{bc}	1.35^{bc}	1.53^{b}	1.21^{bc}	1.20^{bc}	1.17^{bc}
LaMP	5.80^{a}	4.82^{cd}	4.78^{cd}	4.94^{bcd}	4.91^{cd}	4.80^{cd}	5.67^{a}	5.54^{ab}	4.75^{cd}	5.36^{abc}	4.70^{d}
LaOO	1.39^{a}	0.23^{d}	1.75^{a}	1.07^{bc}	0.98^{c}	1.17^{bc}	0.91^{c}	0.98^{c}	0.95^{c}	0.93^{c}	1.13^{bc}
LaPP	1.59^{ab}	0.41^{c}	1.25^{b}	1.90^{a}	1.98^{a}	1.95^{a}	1.95^{a}	1.87^{a}	1.67^{ab}	1.82^{ab}	1.95^{a}
MOO	0.77^{a}	0.01^{e}	0.58^{abc}	0.40^{cd}	0.60^{ab}	0.62^{ab}	0.63^{ab}	0.30^{d}	0.49^{bcd}	0.48^{bcd}	0.51^{bc}
POO	0.34^{abc}	0.01^{d}	0.34^{abc}	0.33^{abc}	0.43^{abc}	0.44^{abc}	0.46^{ab}	0.15^{cd}	0.20^{bcd}	0.36^{abc}	0.51^{a}

Means within each row with different superscript are significantly different at $P < 0.05$. The relative standard deviation was less than 5% for all samples

TAG triacylglycerol, *Cp* caproic, *C* capric, *La* lauric, *M* myristic, *P* palmitic, *O* oleic, *MAL* Malaysian virgin coconut oil, *IND* Indonesian virgin coconut oil

with the value of refined coconut oil reported by Tan and Che Man [13]. The results reflected the high saturation of VCO. Considering the fatty acid composition, a higher content of TAG containing lauric, capric and myristic moieties was expected.

Sample MAL 1 was significantly higher in LaLaLa content compared to other samples. In comparison with VCO samples, RBDCO contained lower medium chain TAG. RBDCO had significantly lower CCLa and CLaLa than VCO samples. However, RBDCO contained the highest LaMP (P, palmitic), but not significant over IND 1, IND 2 and IND 4. RBDCO also had the highest amount of MOO (O, oleic). Generally, MAL samples had relatively higher contents of CpCpLa (Cp caproic), CpCLa and LaOO compared to IND samples, while IND had more of LaMP than MAL samples. According to Reske et al. [14], the proportion of individual fatty acids, the fat source and the product processing history determined the quantity of each type of TAG. In addition, TAG of coconut oils varied significantly among hybrids and parentals [12].

Chemical analyses of commercial VCO samples are presented in Table 3. The iodine value was used to measure the degree of unsaturation of fats and oils. It is expressed as the number of grams of iodine absorbed by 100 g of the fat under the test conditions used. The iodine value of VCO samples ranged from 4.47 to 8.55. The low content of iodine value indicated that VCO has high degree of saturation. The low degree of unsaturation leads to high resistance to oxidative rancidity [15]. There was a significant difference in the iodine values among the commercial VCO samples. The highest iodine value was found in IND 3 and the lowest in IND 1 (Table 3). The values reflected their fatty acid content; with IND 3 containing the highest, while IND 1 contained one of the lowest unsaturated fatty acids among VCO samples (Table 1). Iodine value of RBDCO was not significantly different to MAL samples except for MAL 3 and MAL 5. All iodine values in this study were well within the read limits of Codex standard [9] for edible coconut oil.

The saponification value of VCO is shown in Table 3. The saponification value is a measure of the average molecular weight of all the fatty acids present. The higher the saponification value, the shorter the fatty acids on the glycerol backbone. As compared to other vegetable oils, VCO has very high saponification value, which indicates that VCO contains a higher amount of short chain fatty acids. The result shows that RBDCO contained saponification value of 260.67 mg KOH/g oil higher than VCO samples (250.07–258.26 mg KOH/g oil), but this value was not statistically significant, except for sample MAL 3. According to the Codex standard, specification for saponification value of edible coconut oil should be between 248 and 265 mg KOH/g oil. The saponification values of the studied oils fall within this accepted limit.

The peroxide value is a measure of the concentration of peroxides and hydroperoxide forms in the initial stage of lipid oxidation. The number of peroxides present in vegetable oils reflects its oxidative level and thus its tendency to become rancid. Theoretically, VCO should exhibit a low rate of oxidation due to its low content of unsaturated fatty

Table 3 Chemical composition of virgin coconut oil (VCO) and refined, bleached and deodorized coconut oil (RBDCO)

Sample	Iodine value	Saponification value (mg KOH/g oil)	Peroxide value (mequiv oxygen/kg)	Anisidine value	Free fatty acid
RBDCO	4.71^{c}	260.67^{a}	0.27^{g}	0.23^{c}	0.13^{b}
MAL 1	4.81^{c}	256.29^{ab}	0.21^{h}	0.18^{c}	0.15^{b}
MAL 2	4.63^{c}	256.08^{ab}	0.63^{a}	0.49^{a}	0.24^{a}
MAL 3	5.89^{b}	250.07^{b}	0.45^{d}	0.46^{a}	0.24^{a}
MAL 4	4.95^{c}	252.45^{ab}	0.44^{d}	0.36^{b}	0.16^{b}
MAL 5	6.76^{b}	256.07^{ab}	0.22^{h}	0.16^{c}	0.16^{b}
IND 1	4.47^{c}	258.26^{ab}	0.34^{f}	0.19^{c}	0.15^{b}
IND 2	6.20^{b}	256.09^{ab}	0.56^{b}	0.43^{ab}	0.25^{a}
IND 3	8.55^{a}	252.45^{ab}	0.57^{b}	0.43^{ab}	0.16^{b}
IND 4	6.67^{b}	260.27^{a}	0.37^{e}	0.19^{c}	0.17^{b}
IND 5	6.73^{b}	258.23^{ab}	0.49^{c}	0.41^{ab}	0.22^{a}

Means within each column with different superscript are significantly different at $P < 0.05$. The relative standard deviation was less than 7% for all samples

MAL Malaysian virgin coconut oil, *IND* Indonesian virgin coconut oil

acids. Unsaturated fatty acids easily react with oxygen to form peroxides. Oils with high peroxide values are unstable and easily become rancid [16].

Table 3 shows the peroxide value of VCO samples. There was significant difference ($P < 0.05$) between RBDCO and VCO samples. The peroxide values obtained were relatively low, indicating that the samples were highly stable against oxidation. Sample MAL 3 contained the highest, while sample MAL 1 had the lowest peroxide value. Since the age of the oils was unknown, it was not reasonable to compare the quality of the oils based just on peroxide value. However, according to the Codex standard [9], the maximum peroxide value for virgin oils was 15 mequiv oxygen/kg oil, while the maximum peroxide value for RBDCO was 10 mequiv oxygen/kg oil. The peroxide values of the studied oils were ranged from 0.21 to 0.63 mequiv oxygen/kg oil, which was far below the maximum limits. This implied that the samples were relatively fresh. Even if the samples had been sitting on shelves for a long time, its high saturated content ensure its stability against oxidative rancidity. The significant difference ($P < 0.05$) in peroxide values among the samples could arrive from the different processing method. Samples that had undergone heating process would have a higher peroxide value because heating accelerates the oxidation process [10].

In the second phase of oxidation, the primary product of oxidation, peroxides decompose and develop substances such as aldehydes, which are responsible for the rancid smell and taste. Anisidine value test measures this secondary oxidation. The anisidine value for VCO samples ranged from 0.18 to 0.49 (Table 3). There were significant differences in the anisidine value among the samples. Sample MAL 1, MAL 5, IND 1 and IND 4 were not significantly different from RBDCO, but other samples were significantly higher in anisidine value than RBDCO. According to Rossell [17], oils with an anisidine value below 10 were considered as good quality, while Subramaniam et al. [18] considered good quality oils as having an anisidine value of less than two. Since VCO samples acquired in this study had anisidine values of less than 1, it indicated that the quality of the oils was relatively good.

Free fatty acids are responsible for undesirable flavor and aromas in fats. Free fatty acids are formed by hydrolytic rancidity, which is the hydrolysis of an ester by lipase or moisture [19]. The free fatty acid values for VCO samples ranged from 0.15 to 0.25 (Table 3). The RBDCO had the lowest free fatty acid value, which was significantly lower than sample MAL 2, MAL 3, IND 2 and IND 5. Since RBDCO had gone through the refining process, it was expected that its free fatty acid would be low. The difference in the free fatty acid value among VCO samples could arise from the different methods of processing. Che Man et al. [20] found free fatty acids amounts were high in coconut oils having a high moisture content. According to Lawson [21], hydrolysis was accelerated by high temperatures and excessive amounts of water. Thus, VCO produced through the fermentation method would have high free fatty acid amounts due to the action of lipolytic enzymes, which was enhanced by the addition of water [22]. Nevertheless, the free fatty acid values obtained in this study were relatively low, indicating that the oils were of good quality.

Table 4 shows the total phenolic contents of VCO samples. Sample IND 3 had the lowest total phenol content (7.78 mg GAE/100 g oil), while MAL 3 had the highest total phenol content (29.18 mg GAE/100 g oil). All VCO samples were significantly higher in total phenol contents than RBDCO, except for IND 3. This was in accordance with the study done by Dia et al. [10] and Nevin and Rajamohan [3]. The refining process that had been gone through by RBDCO practically removed some of the phenolic contents. The different production methods of VCO samples could be a major factor contributing to the

Table 4 Total phenolic content and total antioxidant activity of virgin coconut oil (VCO) and refined, bleached and deodorized coconut oil (RBDCO)

Sample	Total phenolic content (mg GAE/100 g oil)	Total antioxidant activity (%)
Tocopherol	–	94.28^{a}
BHA	–	84.53^{b}
RBDCO	6.14^{f}	49.58^{h}
MAL 1	17.04^{d}	71.19^{d}
MAL 2	11.82^{c}	52.54^{gh}
MAL 3	29.18^{a}	66.73^{e}
MAL 4	12.25^{e}	76.69^{c}
MAL 5	23.14^{c}	70.97^{d}
IND 1	12.20^{e}	55.30^{fg}
IND 2	18.74^{d}	57.20^{f}
IND 3	7.78^{f}	49.79^{h}
IND 4	25.09^{b}	79.87^{c}
IND 5	13.06^{e}	56.36^{f}

Means within each column with different superscript are significantly different at $P < 0.05$. The relative standard deviation was less than 6% for all samples

MAL Malaysian virgin coconut oil, *IND* Indonesian virgin coconut oil

variation in the phenolic contents. It was possible that some phenolics might be diminished if heat was used in the production of VCO. Differences in the phenolic contents among VCO samples in this study could also be explained by the variety differences in the coconuts used.

Table 4 shows the antioxidant activity of VCO samples. Tocopherol and BHA were used as standards. Standards were significantly higher in antioxidant activity than all samples. The antioxidant activity of VCO samples ranged from 52 to 80%. The highest antioxidant activity was observed in IND 4. The observed antioxidant activity of the studied samples correlated significantly with the total phenolic content ($r = 0.67$, $P < 0.05$). Thus, phenolic content might be attributed to the high antioxidant activity in VCO. RBDCO had significantly lower antioxidant activity than other studied VCO except for MAL 2. The lower antioxidant activity of RBDCO compared to VCO was expected since oil loses its natural antioxidant during refining [23]. The difference in antioxidant activity among VCO samples could be due to the differences in processing methods used. Antioxidant activity can also be affected by thermal treatment [24]. Thus, introduction of heat during production or extraction of VCO could therefore decrease the antioxidant activity.

The present study demonstrated that MAL and IND samples showed only marginal differences in all of the analyses studied. The studied VCO were well within the limit of the Codex standard for edible coconut oil. This indicated that VCO obtained through a wet process were as good as refined coconut oil. In fact, VCO samples contained a higher phenolic content and antioxidant activity than RBDCO. Variation in the chemical composition among VCO studied could also be due to different in geographical origins, processing methods and duration of storage.

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