

The composition of fatty acids in several vegetable oils from Indonesia

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Abstract. Rahman H, Sitompul JP, Tjokrodiningrat S. 2022. The composition of fatty acids in several vegetable oils from Indonesia. *Biodiversitas* 23: 2167-2176. Fatty acids are generally incorporated into a triglyceride structure in vegetable oils and this indicates vegetable oils are a source of fatty acids. Fatty acids and triglycerides are fatty groups commonly known to have a detrimental effect on health but have an important role in terms of nutrition, health, and are also a source of industrial raw materials. Therefore, this study was conducted to identify the composition of fatty acids in several edible vegetable oils which are quite widely available in Indonesia such as coconut oil, palm kernel oil, palm oil, nutmeg oil, cinnamon oil, and canarium oil. The fatty acids profile of these vegetable oils was determined using high-performance liquid chromatography while the composition was determined by comparing the peaks in each vegetable oil with the standard fatty acids. It was discovered that all the six vegetable oils contain fatty acids with different compositions, and this signifies the availability of a complete variety of fatty acids in Indonesia. Moreover, the highest fatty acid content in coconut oil and palm kernel oil was found to be lauric acid with a concentration of 49.00% and 49.25% respectively while the contents in palm oil include palmitic acid with 44.00% and oleic acid with 41.00%. The nutmeg oil was dominated by myristic acid with 78.00%, cinnamon oil by stearic acid with 50.16%, and canarium oil by oleic acid with 51.71%. Furthermore, the concentration range for all the vegetable oils includes 14.66-91.20% saturated, 6.30-52.31% monounsaturated, and 1.35-33.03% polyunsaturated fatty acids. These results can be used as a source of information in the process of utilizing fatty acids and triglycerides in vegetable oils, and also provide the data required to estimate the nutritional value of the plant biodiversity originating from Indonesia.

Keywords: Edible oil, fatty acids, high-performance liquid chromatography, vegetable oil

Abbreviations: CBO: cinnamon bark oil, CO: coconut oil, CSO: canarium seed oil, FFA: free fatty acids, HPLC: high-performance liquid chromatography, MCFA: medium chain fatty acid, MUFA: monounsaturated fatty acid, NO: nutmeg oil, PKO: palm kernel oil, PO: palm oil, PUFA: polyunsaturated fatty acid, SFA: saturated fatty acid, UFA: unsaturated fatty acid, sn-: stereospecific numbering

INTRODUCTION

Indonesia has a diverse range of habitats and plant species with the potential to serve as a source of food, medicine, and raw materials for the chemical industry (Sutarno and Setyawan 2015). This diversity of plants leads to the existence of different sources of vegetable oils, both edible and non-edible. These vegetable oils, especially edible ones, are rich in triglycerides and fatty acids which are considered useful as a food source. Soybean, sesame, sunflower, and canola produce edible oils that have long been used in the world's food industry (El-Hamidi and Zaher 2018; Górska-Warsewicz et al. 2019). Fatty acids and triglycerides are also useful in making drug formulations to prevent and improve health (Vergallo 2020), and oleochemical industries as bio-based products (Laverdura et al. 2020). Common fatty acids in vegetable oils include caprylic acid, lauric acid, myristic acid, palmitic acid, stearic acid, palmitoleic acid, oleic acid, linoleic acid and linolenic acid. Some of these oils also contain several bioactive compounds such as antioxidants which have a health-promoting effect (Mazzocchi et al. 2021).

The main content of vegetable oil is triglyceride as well as several bioactive compounds such as carotenoids, lecithin, lignans, phytosterols, and tocopherols which have the ability to maintain and improve human health. Moreover, several nutraceuticals product innovations have been made in the form of vegetable oil-based bioactive compounds using nano formulation technology. Palm oil, palm kernel oil, olive oil, coconut oil, and cottonseed oil are edible vegetable oils that have been formulated as nutraceuticals because of their pivotal role in human health and nutrition (Vergallo 2020). These oils are also used in manufacturing structured triglycerides or structured lipids by modifying their natural triglycerides. One of the objectives of modifying triglycerides in vegetable oils is to repair the position of the fatty acids so as to provide benefits both for favorable food consideration and for improving their physicochemical properties. In addition, by inserting essential fatty acids and as well as short-chain and medium-chain fatty acids in triglyceride, a product for structured lipid is produced with benefits for the prevention and cure of disease (Moreira et al. 2017; Shah and Limketkai 2017).

Triglycerides are a group of lipids composed of three fatty acids which are incorporated in the sn-1, sn-2, and sn-

3 positions of the glycerol backbones. This implies the fatty acids composition of the triglycerides need to first be released from the structure before they can be analyzed and this can be achieved through several methods including chemical reaction such as saponification as well as enzymatic reaction using lipase (Lopes et al. 2016; Moreira et al. 2017). In the process of triglycerides metabolism in the human body, the pancreatic lipase enzyme has an important role in converting triglycerides so that they can be absorbed and oxidized to produce a certain amount of energy. The fast or slow fat metabolism process is determined by the presence of fatty acid incorporated in the sn-1 and sn-3 positions in the structure of the triglycerides. Short and medium chain fatty acids in this position will be converted into energy rapidly (Shah and Limketkai 2017).

Each type of oil has different triglycerides composition, fatty acids, and components of bioactive compounds. Olive oil contains triglycerides with 86% unsaturated fatty acids (UFA) and the highest fatty acid composition is oleic acid which has the ability to regulate cholesterol. Olive oil also contains linoleic acid which plays a role in preventing cardiovascular diseases and is considered vital for the growth of children (Hilali et al. 2020). In addition, the dominant fatty acid in cocoa beans oil is stearic acid. The position of stearic acid in the oil is symmetrical which causes the physicochemical properties of cocoa beans oil to be very specific, namely having a sharp melting point and the melting point is close to human body temperature. This attribute is normally exploited in the chocolate-making industry as indicated by the immediate melting of chocolate when in contact with body temperature (Ostrowska-Ligeza et al. 2021). The dominant triglycerides in olive oil are OOO (oleic-oleic-oleic) with oleic acid and linoleic acid occupying the sn-2 position (Hilali et al. 2020). Cocoa bean oil contains triglycerides with oleic acid dominantly occupying at sn-2 position (Ostrowska-Ligeza et al. 2021), while the dominant triglycerides are POP (palmitic-oleic-palmitic), POS (palmitic-oleic-stearic) and SOS (stearic-oleic-stearic) (Hatmi et al. 2021).

Fatty acids are classified into saturated fatty acids (SFA) and unsaturated fatty acids (UFA) with the SFA observed not to have any double bond due to its 4-16 carbon atoms while UFA has one or more double bonds with a terminal of the carboxylic group. The UFA is subdivided into two groups based on the number of double bonds which include the monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). They are also biochemically categorized based on the active site of the fatty acids into omega 3, 6, 7, and 9. Meanwhile, fatty acids are also grouped into essential and non-essential from the nutritional perspective with the essentials defined as those that cannot be synthesized in the human body and need to be obtained from a diet source such as vegetable oils. This essential type includes linoleic and linolenic acid with the metabolism of linoleic acid discovered to have the ability to produce arachidonic acid (ARA) while the linolenic acid produces eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Ivanova et al. 2016; Obboh et al. 2017; Whitmore et al. 2019).

This study was, therefore, conducted to identify the fatty acids contained in edible vegetable oils such as coconut oil (CO), palm kernel oil (PKO), palm oil (PO), nutmeg oil (NO), cinnamon bark oil (CBO), and canarium seed oil (CSO) which are widely available in Indonesia. This is expected to assist in predicting the benefits of these oils as a food source, cosmetic raw material, and their applications in the chemical industry.

MATERIALS AND METHODS

Preparation of oils

Coconut oil (CO) which was produced by the local people was purchased from the local market in Ternate Island, Maluku, while palm kernel oil (PKO) and palm oil (PO) were purchased from locals of South Sumatra, Indonesia. Subsequently, nutmeg oil (NO), cinnamon bark oil (CBO), and canarium seed oil (CSO) were obtained from the extraction of nutmeg seeds, cinnamon barks, and canarium seeds respectively using the soxhlet method. These three materials were obtained from Ternate Island, North Maluku Province, Indonesia.

Oils extraction

Each nutmeg seed, cinnamon barks, and canarium seed were dried and smashed into smaller pieces, after which 100 g of each was weighed, wrapped in filter paper, and loaded into the chamber of the Soxhlet extractor. The extraction was conducted using the extraction solvent, *n*-hexane, and the temperature was set at 70°C for 6 hours after which the extracted liquid was collected and the remaining solvent evaporated using a rotary evaporator. Oil of each seed was stored in a refrigerator in brown glass bottles at 8°C before the analyses.

Preparation and purification of free fatty acids (FFA) by saponification reaction

As much as 100 g of each oil was added 200 mL of NaOH solution and heated at 60°C while stirring at 550 rpm for 1 hour. Next, the solution was added with 40 mL distilled water and 400 mL of *n*-hexane and the mixture was stirred again for 1 hour. The preparation of the solution was based on the description in Chen and Ju (2001) and Sitompul et al. (2018). Further, separatory funnel was used to separate the results of the saponification reaction through solvent extraction. The aqueous phase was added to 160 mL of distilled water and acidified by adding 12 N HCl while shaking vigorously up to the moment the pH of the solution reached 1. Moreover, the free fatty acids in the upper layer were dried with anhydrous sodium sulphate while the remaining solvent was evaporated in a rotary vacuum evaporator at a temperature of 35°C. The result of this process was used to analyze the fatty acid composition using HPLC.

Derivation reaction for the formation of *p*-bromophenacyl esters

The structure of fatty acids does not have a chromophore group, and this indicates it is necessary to conduct a

derivatization reaction to form the p-bromophenacyl esters using p-bromoacetophenone bromide (PBPB) and an 18-crown-6-ether catalyst based on the method used in Arcos et al. (2000). A sample of 1 mg/mL of FFA produced from the saponification reaction was prepared in chloroform and 300 μ L of the mixture was added to the 100 μ L of 18-crown-6-ether 0.5 mg/mL solution in acetonitrile after which 200 mg potassium carbonate was added. Subsequently, the mixture was heated in a water bath at 80°C in a closed vial for 30 minutes, cooled in an ice bath for 15 minutes, filtered using a 0.45 μ m membrane filter, and the product was prepared to be analyzed using HPLC.

Measurement of fatty acids composition using HPLC

The fatty acids were measured using HPLC based on the working procedure of Arcos et al. (2000) and Sitompul et al. (2018). This involved injecting 20 μ L of the free fatty acids sample derivatized into the HPLC equipped with a UV detector at a wavelength $\lambda=254$ nm. The mobile phase used was acetonitrile with water (87:13 v/v) at a flow rate of 1.5 mL/min while the fatty acids were separated using Luna column 5 μ m C8(2) 100 Å 0.15 m x 4.6 mm.

Data analysis

The fatty acids composition contained in each vegetable oil was determined by comparing the chromatogram peaks of the content in each oil to the standard. Moreover, the identification process was based on the similarity of the fatty acid retention time tested against standards while the value of the fatty acid content was calculated based on the normalization of the area expressed in mol %.

RESULTS AND DISCUSSION

The current advancement in science and technology has allowed several countries to be using vegetable oils as a source of nutritious food (Kumar et al. 2016; Gorska-Warsewicz et al. 2019; Zhao et al. 2021), fuel for energy known as biodiesel (Demirbas et al. 2016; Silalahi et al. 2020), pharmaceutical products such as medicines (Górecki

et al. 2016; Vergallo 2020), cosmetics (Burnett et al. 2017; Yang et al. 2020) and in other chemical industries (Biermann et al. 2021). There are also currently several studies and innovations being conducted to produce structured triglycerides also known as structured lipids using vegetable oils as the main raw material (Ract et al. 2015; Moreira et al. 2017; Nicholson and Marangoni 2021; Temkov and Muresan 2021). Basically, vegetable oils contain triglycerides and fatty acids are the basic building blocks of triglycerides. Fatty acids are generally incorporated into a triglyceride and occupy the sn-1, sn-2, and sn-3 positions in the glycerol backbone as shown in Figure 1.

Fatty acids first need to be liberated from triglycerides through a saponification reaction to form free fatty acids to analyze the fatty acids composition in the triglycerides of the six vegetable oils studied. Moreover, a derivatization reaction was also conducted to form a p-bromo-phenacyl ester compound which can be measured on a UV detector due to the absence of a chromophore group in the structure of the fatty acids. This further allowed the measurement of the free fatty acids using the HPLC equipped with a UV detector at $\lambda=254$ nm. The results obtained from the measurement procedures of each type of vegetable oil used in this study are presented as follows.

Determination of fatty acids in coconut oil

The analysis showed that there are ten fatty acids in CO as indicated in Table 1 and Figure 2, and those observed to be most abundant include lauric acid with 49.00%, myristic acid with 15.50%, and palmitic acid with 9.35%. Lauric acid, myristic acid, and palmitic acid are a group of saturated fatty acids because they do not have double bonds in their chemical structure. It is also important to note that the oil also contains significant amounts of MUFA such as oleic acid 6.30% and PUFA such as linoleic acid 2.50%. These findings were discovered to have similarities with those reported by Azevedo et al. (2020) that the fatty acid in CO include lauric acid at 38.40%, myristic acid at 20.20%, and palmitic acid at 13.50%, and the same trend was also recorded by other studies (Silalahi et al. 2018).

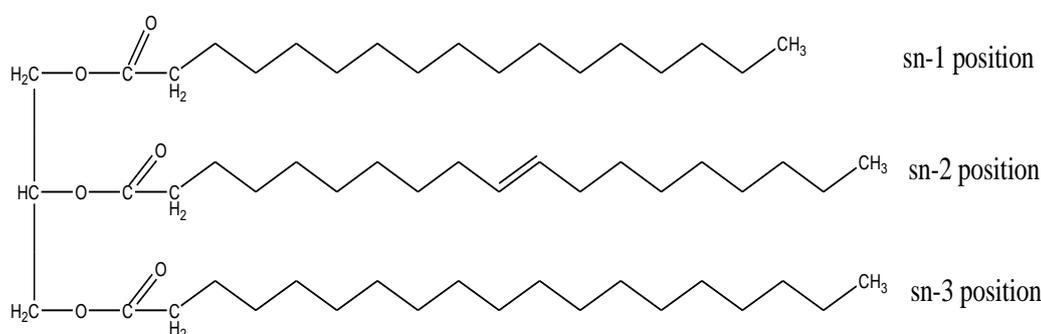


Figure 1. The relative positions of fatty acid in the sn-1, sn-2 and sn-3 in structure triglyceride

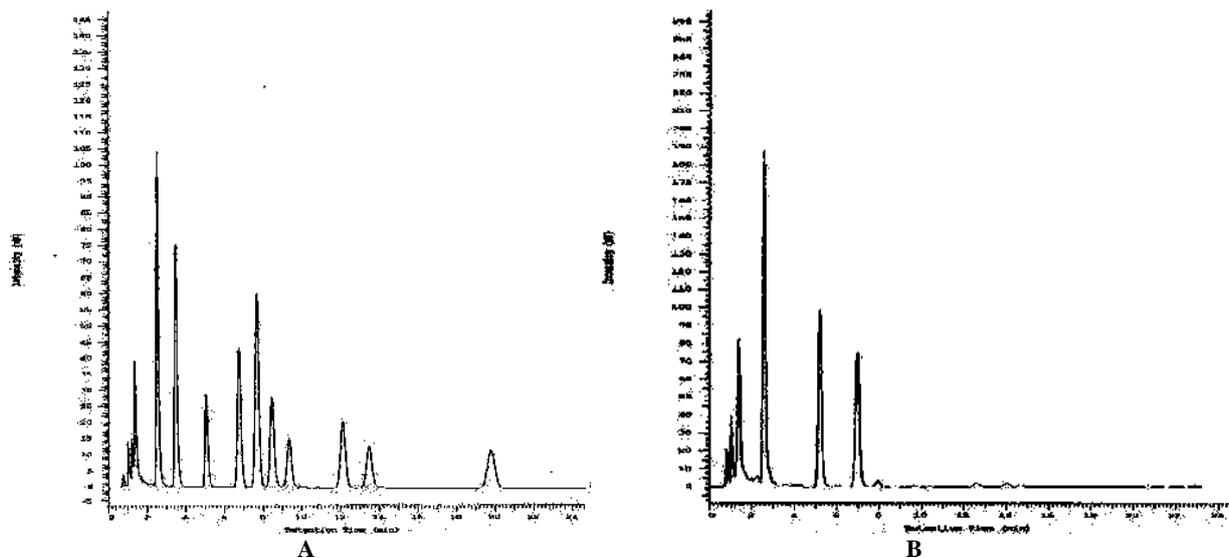


Figure 2. A. Chromatogram of several fatty acid standards. B. Chromatogram of fatty acids in CO

It was interesting to see that the CO contains MCFAs in significant quantities as indicated by caprylic acid at 6.94%, capric acid at 6.36%, caproic acid at 0.50%, and lauric acid at 49.00%. This is due to the fact that the intake of MCFAs is an advantage considering the fact that they can be quickly converted into energy and this means the fatty acids will not accumulate in the body as fat reserves (Schönfeld and Wojtczak 2016). MCFAs also have a shorter number of carbon atoms (C6-C12) compared to LCFAs (C14-C24) and this shows they can be transported directly from the portal vein to the liver during the process of metabolism while the LCFAs predominantly enter the lymphatic system. This means the absorption of MCFAs causes faster digestion and absorption and also makes energy available rapidly (Deen et al. 2021; Ramesh et al. 2021). The innovation of making structured triglycerides by placing MCFAs at the sn-1 and sn-3 positions is based on the ability of lipase enzymes to easily cut fatty acids at these positions during the fat metabolism process (Moreira et al. 2017).

The dominance of lauric acid makes CO different from other vegetable oils (Deen et al. 2021) because the SFA in the oil is 92.00% with 62.00% having a carbon chain of 8 to 12. It is pertinent to restate that lauric acid is the dominant medium chain fatty acid in CO (Perera et al. 2020) and has several benefits with those contained in the form of monolaurin reported to have antiviral activity based on their ability to increase human immune system (Subroto and Indiarito 2020; Ramesh et al. 2021) and also has antibacterial activity against gram-positive and gram-negative bacteria (Nitbani et al. 2016; Anzaku et al. 2017; Silalahi et al. 2018). Some of the other bioactive compounds found in CO include phenolic compounds, flavonoids, and phytosterols (Ghani et al. 2018; Perera et al. 2020). This oil is widely used in the cosmetic industry (Ghani et al. 2018; Boisa et al. 2020), infant foods, and functional food (Ghani et al. 2018).

CO is obtained from coconut (*Cocos nucifera* L.) which is a fruit considered to have economic value due to its several benefits such as its use in traditional foods and cooking oil in different countries, especially Asia and the Pacific. The global need for coconut is mostly met by Asian countries due to its cultivation in Indonesia, the Philippines, India, Sri Lanka, and Thailand (Patil and Benjakul 2019; Perera et al. 2020). *Cocos nucifera* is also used to produce VCO (virgin coconut oil) which has many health benefits, including as an antiviral (Ramesh et al. 2021). The product of coconut processing, namely crude coconut oil (CCO) is one of the mainstay products for Indonesian exports along with increasing world demand for vegetable oils as a source of alternative energy raw materials (Yulhar and Darwanto 2019).

Determination of fatty acids in palm kernel oil

Palm kernel oil (PKO) is derived from the kernel of the oil palm fruit through the pressing method. The analysis showed that it has nine fatty acids with the highest being lauric acid with 49.25% followed by myristic acid with 16.30%, and palmitic acid with 8.00%. The lauric acid is a MCFAs with 12 carbons atom as indicated in the structure presented in Figure 3.

Another fatty acid observed in this oil includes oleic acid with 16.35% which is a MUFA group. Meanwhile, the fatty acid composition in PKO is presented in Table 2. Fatty acids level in PKO measured using gas chromatography by Nainggolan and Sinaga (2021) showed that lauric acid was the highest with 45.61% followed by myristic acid with 16.26%, and palmitic acid with 9.70%. A similar trend was also observed in the findings of Paulin and Irene (2019) and Tambun et al. (2019) that lauric acid is the most abundant fatty acid in PKO. The results of the present study are in line with the findings of these previous studies.

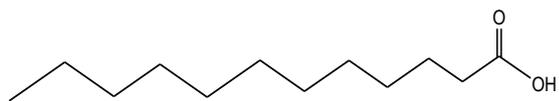


Figure 3. The structure of lauric acid

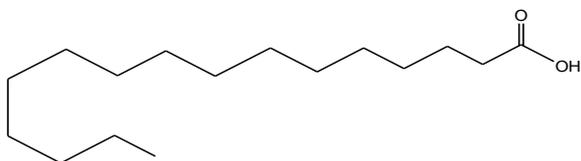


Figure 4. The structure of palmitic acid

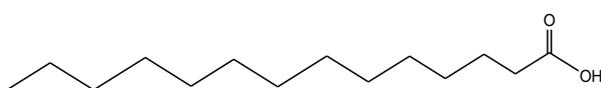


Figure 5. The structure of myristic acid

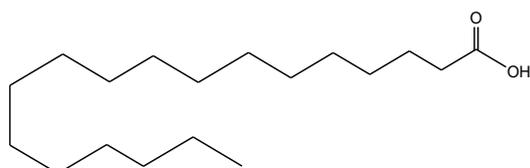


Figure 6. The structure of stearic acid

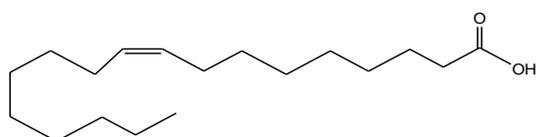


Figure 7. The structure of oleic acid

The description of the fatty acid composition in PKO is similar to CO as indicated by the presence of MCFAs which are dominated by the lauric acid. An important physical property of PKO is its sharp melting point which makes it suitable for use as raw material in certain food products such as margarine and different types of chocolate (Dian et al. 2017). Moreover, fatty acids and their derivatives produced from PKO are used in the chemical industry to produce tires, cosmetics, pharmaceuticals, plastics, paints, soaps, detergents, and others (Tambun et al. 2019). This oil also has bioactive compounds with antimicrobial and antioxidant activities that the antimicrobial and antiviral activities are due to the large composition of lauric acid it contains while the antioxidant activity is associated with the presence of polyphenols, α -tocopherol, carotenoids, and β -sitosterol (Paulin 2020; Nainggolan and Sinaga 2021).

There are two different oils that can be produced from oil palms (*Elaeis guineensis*) and they include PKO and PO. Moreover, Indonesia and Malaysia are the largest producers of crude palm oil globally (Sequino and Avenido 2015; Ayompe et al. 2021) and the PKO is observed to be widely applied throughout Indonesia as part of products used daily in the form of biofuels, agri-food, and personal care products (Ayompe et al. 2021).

Determination of fatty acids in palm oil

Palm oil (PO) is derived from the extraction or compression process of the mesocarp of the oil palm tree (*Elaeis guineensis*) and its fatty acid composition as measured using HPLC is presented in Table 3.

PO and PKO are derived from the same plant species but their SFAs composition differs (Dian et al. 2017; Gesteiro et al. 2019). This is indicated by the findings of this study that the three most abundant fatty acids in PO include palmitic acid with 44.00%, oleic acid with 41.20%, and linolenic acid with 8.00%, and these were observed to be in line with the results of Gesteiro et al. (2019) that reported palmitic acid at 39.30-47.50%, oleic acid at 36.00-44.00%, and linoleic acid at 9.00-12.00%. A similar trend was also recorded in another study that showed that the PO from Indonesia mostly contains palmitic acid at 44.00%, oleic acid at 39.20%, and linoleic acid at 10.10% (Hariyadi 2020).

Palmitic acid is a saturated fatty acid with 16 carbon chains as shown in Figure 4 and is categorized as LCFA. It is the predominant SFA found in breast milk in the form of beta-palmitate which indicates it is at the sn-2 position of the triglyceride structure and provides several physiological functions for infants such as an increase in calcium absorption, improvement in bone matrix quality, enhancement of bowel consistency, and a positive effect on the digestive system (Havlicekova et al. 2016). The technology used in manufacturing structured lipid and formula milk mimics the composition of triglycerides in breast milk and this means the palmitic acid in PO triglyceride can be used to produce formula milk through chemical or enzymatic reactions.

PO also contains a composition of omega 6 fatty acids such as linoleic acid at 8.00% and omega 3 such as linolenic acid at 0.50% which are a group of essential fatty acids that cannot be synthesized in the human body and needs to be obtained from food such as vegetable oils. The enzymatic reaction in the body allows these essential fatty acids to experience elongation and desaturation reactions in order to form fatty acids with longer chains and more double bonds such as EPA, DHA, and ARA (Obloh et al. 2017; Whitmore et al. 2019). There are some other bioactive compounds in PO such as vitamin E which functions as an antioxidant, anti-aging, anticancer, and carotenoids with heart-protective and anticancer activities as well as phytosterol compounds which have cholesterol-lowering and cardioprotective properties, squalene, and others (Mancini et al. 2015; Gesteiro et al. 2019; Hariyadi 2020). Moreover, approximately 90% of the world's PO oil products are normally used to manufacture food products such as margarine and cooking oil (Absalome et al. 2020).

Table 1. Fatty acid composition in coconut oil

Fatty acids			Composition of fatty acids (mol %)
Groups	Trivial names	Symbol	
SFA	Caproic acid	C6:0	0.50
	Caprylic acid	C8:0	6.94
	Capric acid	C10:0	6.36
	Lauric acid	C12:0	49.00
	Myristic acid	C14:0	15.50
	Palmitic acid	C16:0	9.35
	Stearic acid	C18:0	3.45
	Arachidic acid	C20:0	0.10
MUFA	Palmitoleic acid	C16:1n9	nd
	Oleic acid	C18:1n9	6.30
PUFA	Linolenic acid	C18:3n3	nd
	Linoleic acid	C18:2n6	2.50

Note: 'nd' means not detected

Table 2. Fatty acid composition in PKO

Fatty acids			Composition of fatty acids (mol %)
Groups	Trivial names	Symbol	
SFA	Caproic acid	C6:0	0.20
	Caprylic acid	C8:0	2.65
	Capric acid	C10:0	3.50
	Lauric acid	C12:0	49.25
	Myristic acid	C14:0	16.30
	Palmitic acid	C16:0	8.00
	Stearic acid	C18:0	2.10
	Arachidic acid	C20:0	nd
MUFA	Palmitoleic acid	C16:1n9	nd
	Oleic acid	C18:1n9	16.35
PUFA	Linolenic acid	C18:3n3	nd
	Linoleic acid	C18:2n6	1.65

Note: 'nd' means not detected

Table 3. Fatty acid composition in palm oil.

Fatty acids			Composition of fatty acids (mol %)
Groups	Trivial names	Symbol	
SFA	Caproic acid	C6:0	nd
	Caprylic acid	C8:0	nd
	Capric acid	C10:0	nd
	Lauric acid	C12:0	0.10
	Myristic acid	C14:0	1.00
	Palmitic acid	C16:0	44.00
	Stearic acid	C18:0	5.00
	Arachidic acid	C20:0	0.10
MUFA	Palmitoleic acid	C16:1n9	0.10
	Oleic acid	C18:1n9	41.20
PUFA	Linolenic acid	C18:3n3	0.50
	Linoleic acid	C18:2n6	8.00

Note: 'nd' means not detected

Determination of fatty acids in nutmeg seed oil

The nutmeg oil was derived from the seeds of nutmeg fruit (*Myristica fragrans* Houtt) using a Soxhlet apparatus and hexane as the solvent. The fatty acids composition observed in this oil is presented in Table 4.

The three highest fatty acids discovered in this oil using HPLC include myristic acid with 78.00%, oleic acid with 12.50%, and palmitic acid with 6.90%, and these were observed to be similar to the previous findings of Obranović et al. (2021) which showed myristic acid to be the highest in this oil at 75.69%. It is also important to note that this myristic acid has been previously discovered in CO and PKO as reported in Tables 1 and 2 respectively.

Myristic acid is a long chain of saturated fatty acid with 14 carbons atoms as shown in the following Figure 5. Myristic acid is used in industries as a surfactant to maintain foam stability during the process of manufacturing fatty acid-based soaps, detergents, and cosmetics (Arnould et al. 2018) and is also observed to be useful in the pharmacological sector to maintain the cardiovascular health. The consumption of myristic acid increases the levels of omega-3 fatty acids in plasma phospholipids which are considered one of the parameters for cardiovascular health (Verruck et al. 2019).

Nutmeg (*Myristica fragrans*) has been popularly used as a spice throughout the world from ancient times. It is a tropical plant that is available in Malaysia, India, Indonesia, and South East Asia (Morsy 2016; Obranovic et al. 2021). It was also mentioned in some literature to be a native plant from Banda Island in the Moluccas which is one of the regions in Eastern Indonesia and also important to note that almost half of the world's nutmeg is supplied from the country (Ibrahim et al. 2020; Kumari et al. 2021). Moreover, the bioactive compounds in nutmeg seeds including the oil and essential oil have been investigated for their potential application as antidiabetic (Pashapoor et al. 2020), and in medical sciences (Ibrahim et al. 2020; Weerakoon et al. 2021).

Determination of fatty acids in cinnamon bark oil

Cinnamon bark oil (CBO) was obtained as an extract of the crushed bark of *Cinnamomum burmannii* through the soxhletation method. The analysis conducted on this CBO showed that the three most abundant fatty acids it contains are stearic acid with 50.16%, linoleic acid with 21.05%, and palmitic acid with 16.24% as indicated in Table 5.

Stearic acid is a saturated fatty acid with a chain length of 18 carbons as shown in Figure 6. It is neutral to blood lipids and this implies it can be used in food formulations (Garcés et al. 2017) and also has the ability to reduce LDL-cholesterol level thereby preventing atherosclerosis, lowering blood pressure, improving heart function, and reducing the risk of cancer (Senyilmaz-Tiebe et al. 2018). Stearic acid can also be utilized in preparing cosmetics due to its ability to assist in the process of restoring the protective properties of the skin (Mank and Polonska 2016).

Cinnamon belongs to the genus *Cinnamomum* and Lauraceae family and has approximately 250 species worldwide (Muhammad and Dewettinck 2017; Kumar et al. 2019). *C. burmannii* also known as Indonesian cinnamon is an endemic plant in Indonesia (Haddi et al. 2017; Kumar et al. 2019) which is found growing along the Bukit Barisan mountains from Aceh, North Sumatra, Jambi, Bengkulu, to Lampung (Menggala et al. 2019). It is normally used as a spice due to its strong and distinctive

aroma while its stem and bark are also commonly used as a seasoning and for herbal medicine (Kumar et al. 2019; Menggala et al. 2019). This signifies cinnamon is widely used as medicine and functional food due to its phytochemical composition (Muhammad and Dewettinck 2017; Kumar et al. 2019; Błaszczyk et al. 2021). Apart from fatty acids, it also produces essential oil which is reported to have antibacterial potential, thereby, making it suitable as a food preservative material (Al-Fekaiki et al. 2017; Fajar et al. 2019).

Determination of fatty acids in canarium seed oil

Canarium indicum is native to Indonesia, especially in the Eastern part, with approximately 100 species discovered to be existing throughout the world (Bai et al. 2017; Rashid et al. 2021). According to Bai et al. (2019), the global tree nuts trade is dominated by almonds, cashews, hazelnuts, pistachios, and walnuts even though there are others with great commercial potential such as canarium nut. This is important because tree nuts are generally a source of minerals nutrients and beneficial fatty acids (Bai et al. 2019).

The canarium seed oil (CSO) was discovered to have 51.71% oleic acid as the dominant fatty acid while the others include linoleic acid at 32.40% and palmitic acid at 10.30% as presented in Table 6. These were, however, observed to be different from those reported by Bai et al. (2019) but the studies both agreed on the dominance of the oleic acid.

This oleic acid belongs to the MUFA group and has 18 carbons atom with one double bond as shown in Figure 7. Oleic acid has several uses associated with nutrition due to its ability to regulate human physiological functions toward preventing disease disorders. An experimental study conducted on rats showed that a high oleic acid diet derived from olive oil was able to increase the levels of omega 3 PUFA such as EPA and DHA and this was further positively correlated with the reduction in the risk of cardiovascular diseases, increase in HDL-cholesterol level, as well as a decrease in triglyceride level and body weight (Nogoy et al. 2020). Oleic acid was also utilized as a raw material to produce biodegradable surfactants which are to be used in the petrochemical industry to ensure the process is environmentally friendly (Bhadani et al. 2017).

Table 7 shows the six samples of vegetable oil derived from Indonesian plants presented in Figure 8 have different compositions of SFA, MUFA, and PUFA. It was discovered that CO, PKO, and NO contain the highest SFAs with 91.20%, 82.00%, and 86.00% respectively, PO has a balanced fatty acids composition between SFA and MUFA while CBO contains a high PUFA composition in the form of linoleic acid which was recorded to be 21.05%. It is also important to note that oleic acid which is categorized as a MUFA group is dominant in CSO but there is also 33.03% of linoleic acid which is a PUFA group in this oil. Besides differences in fatty acid composition, several other studies have also noted some differences in the bioactive chemical compounds and essential oils of these vegetable oils.

In conclusion, there are several sources of vegetable oils in Indonesia each with its fatty acid composition, thereby, leading to significant benefits considering the fact that the country has different types of fatty acids and triglycerides. It is shown that from the measurement results of six vegetable oils, lauric acid was found to be dominant in coconut oil and palm kernel oil, palmitic acid and oleic acid were found in abundance in palm oil and canarium oil. Myristic acid was abundant in nutmeg oil, while stearic acid was found abundance in cinnamon bark oil.

Table 4. Fatty acids composition in nutmeg seed oil

Groups	Fatty acids		Composition of fatty acids (mol %)
	Trivial names	Symbol	
SFA	Caproic acid	C6:0	nd
	Caprylic acid	C8:0	nd
	Capric acid	C10:0	nd
	Lauric acid	C12:0	nd
	Myristic acid	C14:0	78.00
	Palmitic acid	C16:0	6.90
	Stearic acid	C18:0	1.00
	Arachidic acid	C20:0	0.10
MUFA	Palmitoleic acid	C16:1n9	0.15
	Oleic acid	C18:1n9	12.50
PUFA	Linolenic acid	C18:3n3	1.15
	Linoleic acid	C18:2n6	0.20

Note: 'nd' means not detected

Table 5. Fatty acid composition in cinnamon bark oil.

Groups	Fatty acids		Composition of fatty acids (mol %)
	Trivial names	Symbol	
SFA	Caproic acid	C6:0	nd
	Caprylic acid	C8:0	nd
	Capric acid	C10:0	2.50
	Lauric acid	C12:0	1.25
	Myristic acid	C14:0	0.05
	Palmitic acid	C16:0	16.24
	Stearic acid	C18:0	50.16
	Arachidic acid	C20:0	nd
MUFA	Palmitoleic acid	C16:1n9	nd
	Oleic acid	C18:1n9	8.75
PUFA	Linolenic acid	C18:3n3	nd
	Linoleic acid	C18:2n6	21.05

Note: 'nd' means not detected

Table 6. Fatty acid composition in canarium seed oil

Groups	Fatty acids		Composition of fatty acids (mol %)
	Trivial names	Symbol	
SFA	Caproic acid	C6:0	nd
	Caprylic acid	C8:0	nd
	Capric acid	C10:0	nd
	Lauric acid	C12:0	nd
	Myristic acid	C14:0	0.06
	Palmitic acid	C16:0	10.30
	Stearic acid	C18:0	4.30
	Arachidic acid	C20:0	nd
MUFA	Palmitoleic acid	C16:1n9	0.60
	Oleic acid	C18:1n9	51.71
PUFA	Linolenic acid	C18:3n3	0.63
	Linoleic acid	C18:2n6	32.40

Note: 'nd' means not detected

Table 7. The content of SFA, MUFA, and PUFA in several edible oils from Indonesia

Sample of edible oils	Fatty acids composition (%)		
	SFA	MUFA	PUFA
Coconut oil	91.20	6.30	2.50
Palm Kernel oil	82.00	16.35	1.65
Palm oil	50.20	41.30	8.50
Nutmeg oil	86.00	12.65	1.35
Cinnamon oil	70.20	8.75	21.05
Canarium oil	14.66	52.31	33.03

**Figure 8.** The sources of vegetable oils. A. Palm was used to produce PKO and PO. B. Coconut for CO. C. Nutmeg for NO. D. Cinnamon for CBO. E. Canarium for CSO

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