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Identification of Fatty Acids in Virgin Coconut Oil (VCO), Cocoa Beans, Crude Palm Oil (CPO), and Palm Kernel Beans Using Gas Chromatography

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Abstract. This study aims to identify saturated and unsaturated fatty acids in Crude Palm Oil (CPO), palm kernel seeds, Virgin Coconut Oil (VCO), and cocoa beans using Gas Chromatography (GC-FID). The results of GC-FID analysis showed that VCO contains 90.896% saturated fatty acids, 49.382% CPO, 37.395% palm kernel seeds, and 21.197% cocoa beans. Lauric acid is the highest component in VCO, namely 45.567%, while in CPO the highest component is palmitic acid 43.343%, palm kernel seeds are lauric acid 21.683%, and steric acid 12.120% in cocoa beans. The most unsaturated fatty acids were found in CPO, namely 50.517%, and cocoa beans 11.825%. The unsaturated fatty acids in CPO are oleic acid 39.538% and linoleic acid 10.290%, while in cocoa beans linoleic acid is 11.016%.

Keywords: Virgin Coconut Oil, Crude Palm Oil, palm kernel seeds, cocoa beans, fatty acids.

1. Introduction

One of the main components of food that has a positive and negative impact on health is fat which has multifunctionality, namely as the largest energy contributor (30% or more of the total energy needed by the body) and is a source of essential fatty acids linoleic and linolenic. Apart from being a solvent for vitamins A, D, E, and K, fat provides a specific taste and aroma to foods that cannot be replaced by other food components. Meanwhile, the negative impact of fat consumption related to atherogenic can occur if fat consumption is more than 30% of the total energy requirement [1]. The recommended maximum total fat consumption per day is 30% of total energy, which includes 10% saturated fatty acids, 10% monounsaturated fatty acids, and 10% polyunsaturated fatty acids [2]

Edible fats and oils are one of the basic components of the human diet, along with carbohydrates and proteins. Fats and oils are a source of high energy (9 kcal/g) and essential fatty acids such as linoleic (18:2, linolenic acid (18:3, EPA (20:5, and DHA (22:6) for humans [3]. Vegetable fats and oils are indispensable in the human diet as a provider of essential fatty acids and liposoluble bioactive compounds. The most commercialized vegetable oils in the world are soybean oil, palm oil, sunflower seed oil, and rapeseed oil [4].

Fatty acids (FA) are important components of edible fats and oils where they can be found in the form of esters with a glycerol (triglyceride) backbone. Moreover, the composition of FA differs from one source to another. Fatty acids are a group of hydrocarbon compounds that contain a long chain, a carboxylic group at the end. Based on the type of bond, these acids are grouped into two, namely saturated and unsaturated fatty acids. Saturated fatty acids have a single carbon atom bond, including the fatty acids caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), stearic (C18:0), and arachidic (C20:0). In contrast, unsaturated fatty acids, such as palmitoleic (C16:1), oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) fatty acids, have at least one carbon double bond [5].



Saturated fatty acids are fatty acids that do not have a double bond on the carbon atom which causes fatty acids to be sensitive to oxidation and the formation of free radicals. In general, foods of animal origin (fatty meats, cheese, butter, and milk cream) in addition to containing saturated fatty acids also contain cholesterol. Saturated fatty acids in addition to being found in animal fats, can also be found in coconut oil and palm oil. Palm oil contains a balanced amount of saturated and unsaturated fatty acids. Palm oil is different from some other vegetable oils in that it contains about 44% palmitic acid and about 6% stearic acid of the total fatty acids [1]

Oil palm produces two types of oil with different characteristics, namely crude palm oil (CPO) which is derived from the mesocarp of the oil palm fruit, and palm kernel oil (PKO) which is derived from the kernel of the oil palm fruit. The main fatty acids in CPO are palmitic acid (C16:0) as much as 44.00%, oleic (C18:1) 39.20%, and linoleic (C18:2) as much as 10.10%. PKO is an edible oil that is stable against oxidation because it contains little unsaturated fatty acids. PKO contains lauric acid (C12:0) as much as 48%, myristic acid (C14:0) 16%, and oleic acid (C18:1) 15% [6]

Palm oil is a natural oil that does not contain trans fatty acids (ALT), has high stability, and contains various triacylglycerol components. In terms of composition, palm oil consists of 50% saturated fatty acids, 40% monounsaturated fatty acids, 10% polyunsaturated fatty acids. In addition to being ALT free, the palm oil fraction also has excellent oxidative stability. This will increase the service life and longer shelf life. In addition, palm oil is rich in bioactive components such as carotenoids, tocopherols, and tocotrienols so it provides a significant additional functional value [7]

Oil derived from palm oil is a semi-solid fatty oil having an unchanged composition. Palm oil is composed of liquid and solid fractions. the composition of the solid-state with a saturated fatty acid structure, such as Palmitic Acid, Stearic Acid, and Myristic Acid. For the patterned liquid form with unsaturated fatty acids, it is composed of Linoleic Acid and Oleic Acid [8].

Virgin Coconut Oil (VCO) is produced from fresh coconut milk obtained from the kernels of fresh and ripe coconuts by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching, or deodorizing, which does not cause a change in oil properties. VCO is in the category of functional food and healthiest oil. VCO can also consume directly [9, 10]. Coconut oil contains 15% of total fatty acids as saturated fatty acids with C6:0, C8:0, and C 10:0 fatty acid chains. Virgin Coconut Oil (VCO) contains short-chain fatty acids and medium (caprylate, caprate, and lauric) which is known to have a function certain biologics for the human body [11]. Almost 50% is medium-chain lauric acid (C 12:0) and coconut oil has only 2% linoleic acid (C18:2), and 6% oleic acid (C18:1), only unsaturated fatty acids in coconut oil. Coconut oil industry applications are mainly: associated with the presence of maximum lauric acid and glycerides, which are not present in other vegetable oils [9].

Cocoa butter (CB) is one of the most valuable and beneficial vegetable fats obtained from cocoa beans. Due to its unique properties such as pale yellow color, neutral taste, and sharp melting profile, equal body temperature, it is widely used in cosmetics and food preparation. The fatty acid (FA) profile of cocoa butter may differ slightly for different species of cocoa plants and different geographical origins. Usually, the closer to the equator the cocoa is grown, the tougher the fat. CB consists mostly of saturated fatty acids such as stearic acid (C18:0) and palmitic acid (C16:0) and about 30-35% unsaturated fatty acids. The fatty acid profile (FA) of cocoa butter may be slightly different for different species of cocoa plants and different geographical origins. Usually, the closer to the equator the cocoa is grown, the harder the fat will get [12].

This fat comes from cocoa butter, which is mainly made of three fatty acids: 34.5% monounsaturated oleic acid (O), 26% palmitic acid (P) (saturated), and 34.5% S stearic acid (saturated). About 85% of total fat is a combination of these three fatty acids in triglyceride fats: POP, POS, and SOS [13]. Quantitative analysis of Fatty Acid composition is very important in food research related to the content of nutritional value and the purity or authenticity of fat. The main objective of the study was to determine the fatty acid composition of several vegetable oils and fats.

2. Materials and Methods

Samples and Materials

The materials used in the research are Crude Palm Oil (CPO), palm kernel seeds obtained from PT. SRL, fermented dry cocoa beans, and Cyber Brand VCO (Virgin Coconut Oil), hexane, methanol, KOH, Isopropanol. The tools used are GC-FID Perkin Elmer x Head Space Turbo Matrix 40.

Implementation Method:

Determination of Fat Content in Sample

BF3-Methanol method [14].

The fat sample was put into a 50 mL falcon tube. For the oil sample, 0.5 M KOH was added, 4 mL isopropanol, then vortexed for 1 minute. After that, 6 mL of hexane was added, then shaken with a 450 rpm mechanical shaker for 5 minutes, then 3 mL of distilled water was added, then centrifuged for 3 minutes, then the organic phase was taken and then put into a 10 mL screw tube. Then 1.5 mL of 0.5 M KOH solution was added in methanol into a 10 mL screw tube that already contained oil/fat extract, then vortexed. Heating at a temperature of $\pm 100^{\circ}\text{C}$ in a water bath for 20 minutes. Cooling was carried out to room temperature, then 1.5 mL of 20% BF₃ was added in methanol, then vortexed. Reheating was carried out at a temperature of $\pm 100^{\circ}\text{C}$ for 20 minutes. Then cooled, then added 3.0 mL of saturated NaCl solution and 2.0 mL of hexane, then vortexed for ± 2 minutes. After two layers were formed, the top layer (organic phase) was transferred to a 2 mL tube containing anhydrous Na₂SO₄ and left for 15 minutes. The solution was allowed to stand at room temperature, then put the solution into a 2 mL vial, then injected into the GC FID system.

Instrument Measurement Condition

Column Supelco SP2560

Inlet

Injection Mode: Split

Injection volume: 1.0 μL

Injection Temperature : 225°C

Column

Capillary column: Supelco SPTM 2560

Carrier gas: Nitrogen (N₂)

Oven

Program oven: Temperature Gradient $100-240^{\circ}\text{C}$

Run Time: 82 min

Detector: FID

Detector temperature: 240°C

3. Results

Fatty acids are a group of hydrocarbon compounds that contain a long chain, a carboxylic group at the end. Based on the type of bond, these acids are grouped into two, namely saturated and unsaturated fatty acids. Saturated fatty acids have a single carbon atom bond, including the fatty acids caprylic (C8:0), capric (C10:0), lauric (C12:0), *myristic* (C14:0), palmitic (C16:0), stearic (C18:0), and arachidic (C20:0). In contrast, unsaturated fatty acids, such as palmitoleic (C16:1), oleic (C18:1), linoleic (C18:2), and linolenic (C18:3) fatty acids, have at least one carbon double bond [5].

Analysis of the fatty acid composition of VCO, CPO (Crude Palm oil), palm kernel seeds, and cocoa beans was carried out qualitatively and quantitatively using Gas Chromatography (GC FID) instruments. Tables 1 and 2, show the profile of fatty acids and the amount of their content contained in various types of oils and fats.

Tabel 1. Fatty Acid Composition of Crude Palm Oil (CPO), Palm Seeds, Virgin Coconut Oil (VCO), and Cocoa Beans

No	Types of Fatty acids	CPO (%)	Palm kernel seeds (%)	VCO (%)	Cocoa beans (%)
1	C 6:0 (caproic acid)	not detected	0.116	0.7468	not detected
2	C 8:0 (caprylic acid)	not detected	1.628	9.162	not detected
3	C 10:0 (capric acid)	not detected	1.520	6.438	not detected
4	C 12:0 (lauric acid)	0.153	21.683	45.567	0.0246
5	C 14:0 (myristic acid)	0.969	7.433	16.654	0.0344
6	C 16:0 (palmitic acid)	43.343	3.769	8.214	8.321
7	C 18:0 (stearic acid)	4.292	1.061	3.420	12.120
8	C 20:0 (arachidic acid)	0.399	0.0500	0.596	0.4539
9	C 22:0 (behenic acid)	not detected	0.0601	not detected	0.1012
10	C 24:0 (lignoceric acid)	0.112	0.0633	0.5373	0.0715
Total Saturated Fatty Acid		49.382	37.395	90.896	21.197

Based on gas chromatography (GC) analysis (Table 1) of four types of vegetable oil, it shows that the most saturated fatty acid content is in Virgin Coconut Oil (VCO) of 90.896%, then Crude Palm Oil (CPO) 49.382%, palm kernel seeds 37,395 %, and cocoa beans by 21.197%. Types of saturated fatty acids that are mostly found in VCO oil are lauric acid (C12: 0) as much as 45.567%, CPO palmitic acid (C16: 0) which is 43.343%, palm kernel seeds contain lauric acid (C12: 0) 21.683% and Cocoa contains 12.120% stearic acid (C18:0).

VCO is crude oil obtained from fresh coconut meat, which is rich in saturated fatty acids (about 90%), such as lauric acid (C12:0), medium-chain fatty acids [15]. According to research results Suryani *et al.* [16], showed that there are two types of fatty acid content in VCO; 54.06% lauric acid and 12.06% stearic acid, and no (0%) palmitic acid. The absence of palmitic acid because VCO is not made from palm oil. Palmitic acid is found in palm oil. The lauric acid content of VCO is considered high compared to what has been obtained through this study.

The composition of unsaturated fatty acids of CPO, palm kernel seeds, VCO, and cocoa beans can be seen in Table 2.

Table 2. Composition of unsaturated fats in various types of vegetable fats and oils

No	Types of Fatty acids	CPO (%)	Palm kernel seeds (%)	VCO (%)	Cocoa beans (%)
1	C 16:1 (palmitoleic acid)	0.113	0.008	not detected	0.073
2	C 18:1 W9C (c-oleic acid)	39.538	7.016	6.274	11.016
3	C 20:1 (eicocenoic acid)	0.135	0.050	0.207	0.019
Monounsaturated fat		39.807	7.101	6.481	11.108
4	C18:2 W6 (linoleic acid / w6)	10.290	1.104	1.396	0.645
5	C18:3W3 (linolenic acid / w3)	0.269	not detected	not detected	0.060
6	Omega 3 fatty acids	0.388	not detected	0.677	0.060
7	Omega 6 fatty acids	10.322	1.104	1.832	0.657
8.	Omega 9 fatty acids	39.538	7.042	6.274	11.016
Polyunsaturated fat		10.710	1.104	2.544	0.717
Unsaturated fats		50.517	8.205	9.014	11.825

Table 2 shows the highest unsaturated fatty acid component in CPO, namely 50.517%, then cocoa beans 11.825%, VCO 9.014%, and palm kernel seeds 8.205%. Palm oil has a balanced fatty acid composition where the levels of saturated fatty acids (49.382%) and unsaturated fatty acids (50.517%) are almost the same (Tables 2).

4. Discussion

Saturated Fatty Acids

Fatty acids consist of two parts: saturated fatty acids and unsaturated fatty acids. Saturated fatty acids are fatty acids whose carbon atoms have saturated bonds (single bonds) and unsaturated fatty acids are fatty acids whose carbon atoms have double bonds [17].

Virgin coconut oil or VCO is one of the coconut oil products that is known for its many benefits and is used as a raw material for various industries. In the processing, VCO is produced from fresh coconut flesh (non-copra) without going through a chemical process and does not use high heating so that the characteristics of the oil produced are clear (clear) and have a distinctive coconut aroma [18]. VCO also contains high lauric acid, namely 45.567% (Table 1).

According to Kusuma and Putri [19], most of the VCO contains lauric acid which ranges from 48.40% to 52.84% of the fatty acid content. The saturated fatty acid content in VCO dominates at 85% of the total fatty acid content. VCO contains medium-chain fatty acids (MCFA) which are easily broken down in the body. Some medium-chain fatty acids contained in VCO are caprylic acid (C:8) 9.162%, capric acid (C:10) 6.438% (Table 1). VCO is included in the category of functional food and the healthiest oil, in contrast to cooking oil which contains long-chain fatty acids.

Palmitic acid content is the largest component in CPO at 43.34%, then cocoa beans at 8.321%, VCO at 8.214%, and palm seeds at 3.769% (Table 1). According to Barcelos [20], crude palm oil contains on average 44% palmitic acid (C16:0), 5% stearic acid (C18:0), and residual myristic acid (C14:0), which together constitute half of FA (Fatty acid) which is found in triacylglycerol (TAG) synthesized by the mesocarp of the fruit of *E. guineensis*. Palm oil has a chemical composition stable i.e. elements C, H, and O consist of solids and liquids. The solid phase consists of Saturated Fatty (saturated fat), while the phase liquid consists of Unsaturated Fatty (unsaturated fat). Saturated fat in coconut oil palm is myristic acid (1%), palmitic acid (45%), and stearic acid. While the liquid phase consists of oleic acid (39%) and linoleic acid (11%) [21],

Unsaturated Fatty acid

Unsaturated fatty acids are fatty acids that have a carbon-carbon double bond, whereas Saturated fats are fatty acids that do not contain a double bond in the bond between carbon atoms that make up fatty acids. The degree of unsaturation of the fat depends on the double bonds in fatty acids and can be seen from the amount of iodine. The more double bonds contained in fat then the iodine number will be bigger. Unsaturated fatty acids which have 18 carbon atoms per molecule, i.e. oleic acid, linoleic acid, and linolenic acid. These fats have 1, 2, and 3 double bonds two per molecule [22].

Table 2 shows the components of monounsaturated fatty acids reached 39.807% including oleic acid (C18:1), palmitoleic acid and eicosanoid acid, and polyunsaturated fatty acids namely linoleic acid (C18:2) 10.290%. In addition, CPO contains 39.538% omega 9 fatty acids, 10.322% omega 6 fatty acids, and 0.388% Omega 3 fatty acids.

The oleic acid component is the most abundant unsaturated fatty acid in CPO (39.538%), palm kernel seeds (0.016%), VCO (6.274%), and cocoa beans (11.016%). Oleic acid (C18:1) ($C_{18}H_{34}O_2$) is an unsaturated fatty acid that contains omega-9 and can be obtained from animals or plants. Oleic acid is a compound with a molecular weight of 310.28. Oleic acid or commonly known as omega-9 is a type of MUFA fatty acid. GC-MS test results on research samples contain abundant amounts of omega-9 39.538%. Omega-9 has great benefits very big for health that are helping lower bad cholesterol, lower triglycerides in the blood, increase HDL (high-density lipoprotein) cholesterol [23].

The high content of monounsaturated fatty acids, especially oleic acid (C 18:1), was associated with a decrease in the incidence of coronary heart disease due to oleic acid can lower total cholesterol and low-density cholesterol. Long-chain unsaturated fatty acids are more susceptible to oxidation. On the other hand, unsaturated fatty acids in particular conjugated linoleic and fat-soluble antioxidants (α -tocopherol, carotenoids) are very good for health [24].

5. Conclusion

The results of the GC-FID analysis on several vegetable fats showed that VCO contained 90.896% saturated fatty acids, 49.382% CPO, 37.395% palm kernel seeds, and 21.197% cocoa beans. The most

saturated fatty acids in VCO and palm kernel seeds were lauric acid at 45.567% and 21.683%, respectively, while in CPO the most saturated fatty acids were palmitic acid 43.343%, and steric acid 12.120% in cocoa beans. The most unsaturated fatty acids were found in CPO, namely 50.517% including oleic acid 39.538% and linoleic acid 10.290%, while cocoa beans contained 11.825% unsaturated fatty acids, namely linoleic acid, namely 11.016%.

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