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The Extraction, Purification, and the Recent Applications of Coconut Oil in Food Products - A Review

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ABSTRACT: Coconut oil has distinctive properties as lauric oil and has been widely used as cooking oil, food processing products, medicines, and cosmetics. This review describes the physicochemical properties, extraction, purification, and various recent applications of coconut oil, especially in food products. Coconut oil has the main fatty acid composition of medium-chain fatty acids (MCFAs) in the form of lauric acid (± 50%). Coconut oil can be extracted through wet extraction and dry extraction methods. Coconut oil refining is usually carried out on dry extracted coconut oil and generally includes the bleaching, deodorizing, and deacidification stages. Coconut oil can be used for a variety of food products, including processed into trans-free margarine, cocoa butter substitutes, structured lipids rich in MCFAs, monoacylglycerols, and bioactive lipids in the form of monolaurin. Coconut oil and its derivative products continue to be researched, especially in relation to its functional properties which are good for health, both in the form of virgin coconut oil (VCO) and monolaurin. Recently monolaurin from coconut oil is claimed to act as an antiviral and boost the immune system.

Keywords: Coconut oil, cocoa butter substitute, lauric acid, structured lipid, trans-free margarine.

I. INTRODUCTION

Coconut oil is the vegetable oil extracted from coconut flesh (*Cocosnucifera*). Fresh coconut fruit contains 30-50% oil; however, when the coconut flesh is dried (in the form of copra), the oil content increases to 60-65% [1], [2]. The oil content obtained in coconut flesh is affected by the age of the fruit. The oil content increases as the coconut fruit get older. Coconut oil can be obtained through the extraction of coconut fruit, either wet or dry extraction. The extraction method affects the quality of coconut oil. The quality is determined by its stability to oxidation, hydrolysis, and polymerization, which can change the color, flavor, and nutrients in coconut oil [3].

The important characteristics of coconut oil include the content of fatty acids and their distribution in triacylglycerols, free fatty acid, solid fat content (SFC) profile, and melting point [4, 5]. Coconut oil contains triacylglycerols which are composed of various kinds of fatty acids, most of which are saturated fatty acids, such as laurate, myristate, palmitate, and caprate [6]. The breakdown of triacylglycerols in oil will produce free fatty acids which can affect the quality of the oil [7, 8].

The quality and characteristics of coconut oil are determined by the components it contains. Coconut oil contains mostly triacylglycerols and a small number of impurities such as free fatty acids, pigments, sterols, hydrocarbons, phospholipids, lipoproteins, and others. The physicochemical properties of coconut oil include melting point (22-26 °C), density (0.908-0.921 g/mL at 40 °C), soaping number (248-265), iodine number (6-11), the acid number (4 max), and the peroxide number (10 meq/Kg oil max) [9, 10]. Meanwhile, virgin coconut oil has free fatty acids (0.2 max) and a peroxide number (3 meq/kg oil max) [11].

II. PHYSICOCHEMICAL PROPERTIES OF COCONUT OIL

The melting point of coconut oil is in the range of 24.4-25.5˚C. This is mainly because coconut oil has a high content of saturated fatty acids compared to other vegetable oils. The lower the melting point of the oil is concerned when the greater the degree of saturation of fatty acids [5]. Coconut oil will solidify at 21 °C and will melt at 24.4-25.5 C. This change in the form of coconut oil is determined by the accumulated properties of the molecular weight and melting point of each of the constituent fatty acids. Based on this difference in liquid point, coconut oil can be fractionated into an olein fraction and a stearin fraction with different melting properties. Fractionation can be conducted by leaving coconut oil at various levels of cold temperatures [5, 12]. Coconut oil contains about 90% saturated fat, with about 60% being MCFAs [13]. Coconut oil is classified as lauric oil because it has the largest content of lauric acid compared to other fatty acids, which is between 45.4-46.4% [5]. This is in line with research by Abast *et al.*, [14] that the main fatty acids in virgin coconut oil (VCO) is lauric acid (47.79%) and myristic acid (17.17%). The same thing was obtained by Boateng et al. [15] which stated that the main fatty acid content in coconut oil is lauric acid and myristic acid.

Coconut oil can be damaged during processing and storage, especially as a result of hydrolysis that produces free fatty acids. Fat/oil damage due to hydrolysis occurs as a result of the breakdown of triacylglycerol molecules in ester bonds followed by the formation of free fatty acids. This is characterized by changes in the smell and flavor of the oil and other characteristics. The flavor that arises due to an increase in free fatty acids depends on the fatty acid composition of the constituents. The release of short-chain fatty acids such as butyric, caproic, and capric acid will produce unpleasant odors and flavor, whereas long-chain fatty acids produce a waxy mass or produce a soap-like odor at alkaline pH [5].

The physical, chemical, and functional properties of oil or fat are determined by the triacylglycerol profile and fatty acid composition. Therefore, the type and amount of triacylglycerol in oil greatly affect the properties of the oil. There are changes in the physical and chemical properties of coconut oil if it has been used several times in the frying process. This has been reported by Nodjeng *et al.,* [16] by examining the quality of virgin coconut oil after three frying times. The water content of coconut oil increased by about 4.87%. The high water content in the oil makes it easier to hydrolyze the oil. The levels of free fatty acids in coconut oil increased after three frying times, from 0.065% to 0.078%. The density and peroxide number of coconut oil increase during frying from 1.042 g/mL to 1.0496 g/mL.

III. COCONUT OIL EXTRACTION

Coconut oil is generally produced through crushing copra (dried coconut kernel), which contains 60-65% oil [1]. However, coconut oil extraction can be conducted by two main methods, namely the dry method and the wet method. In the wet extraction process, the coconut flesh does not go through a drying process, in contrast to dry extraction, where the coconut fruit goes through a drying process under several conditions. Drying in dry extraction aims to remove moisture in coconut fruit and reduce microbial contamination [13].

Extraction by the wet method can be conducted by heating, fermentation, cream centrifuge, pH adjustment, and cooling. Wet extraction can use one or a combination of several methods with the main principle being to break down the emulsion from coconut milk [17]. Each extraction method produces different yields, depending on the type of coconut, age of coconut, and processing. Coconut oil extracted from middle age coconut (intermediate) produces the most yield when compared to young coconut or old coconut. The extraction of young coconut produces the highest unsaturated fat, as well as the high content of α-tocopherol and phenolic compounds [18].

Oil extraction using dry extraction with copra processing is generally carried out by large industries. The result of this dry extraction is crude coconut oil, so it still requires further refining. Purification is mainly carried out by bleaching and deodorizing [19]. This was also revealed by Prapun *et al*., [18] that coconut oil processed using dry extraction requires further oil handling, such as refining, bleaching, and deodorizing. Several types of coconut oil extraction and the results/ characteristics of coconut oil produced can be seen in Table 1.

Tabel 1: Several Types of Coconut Oil Extraction.

S.No.	Extraction types	Results	References
1.	Enzymatic	The yield produced is relatively smaller than other methods such as cooling and dry extraction, relatively greater free fatty acid content, and more environmentally friendly and safer	[13, 17, 19, 20]
2.	Cooling	Produces a large yield (86.62%)	[17]
3.	Centrifugation	Yields between 16.86-21.55%	[19]
4.	Dry extraction	Produces the greatest yield (83.23-88.35%)	[8, 13, 17]

Dry Extraction: The extraction of coconut oil by dry extraction is conducted by drying the kernels of the coconut fruit using controlled heat and then pressing them to obtain the oil [17]. Another way is to heat coconut milk at temper 100 °C- 120 °C for 60 minutes until all the water contained in the coconut milk has evaporated. The heating that is carried out also aims to damage or denaturation the proteins present in the coconut milk emulsion system. Furthermore, to separate the oil, coconut milk is reheated by slow heating from the stove and filtered using a filter cloth [25].

The results of the comparison of dry and wet extraction to the yield of coconut oil produced are as follows: in a study conducted by Mansor *et al.,* [17] using shredded coconut flesh and drying using an oven at 35°C for 48 hours followed by pressing it produced the maximum oil yield was 88.35 ± 5.96% compared to the wet extraction method. Research conducted by Oseni *et al.,* [13] processed coconut flesh by shredding and drying using an oven at 75°C followed by extraction using a solvent and purifying it using a rotary evaporator to produce the most oil yield higher than the wet extraction method with a yield of 83.23 ± 3.38%. Meanwhile, Nasruddin [8] produced the lowest yield compared to the two studies above, which was 12.21%. However, when comparing the yield between wet and dry extraction, dry extraction gave the highest yield.

Wet Extraction: Oil refining is often carried out to improve quality by removing some unnecessary compounds or impurities found in extracted oil [26]. Purification can be carried out in several steps such as bleached, deodorized, and deacidification. Bleaching is a way of refining oil by removing pigments in the oil by adding compounds that can absorb pigments in oil, such as charcoal, clay, or other chemical reagents. Bleaching is usually conducted using activated carbon or bleaching earth (bentonite) or a combination of both. This adsorbent is mixed with oil that has been neutralized under vacuum and heated at a temperature of 95°C-100°C [27].

Several studies have been conducted on the purification process of coconut oil from copra. Some Coconut Oil Purification Techniques can be seen in Table 2. However, in general, Virgin Coconut Oil (VCO) does not require a complicated refining process like other oils. This is because coconut oil is odorless, colorless, and free from rancidity in the production of VCO. Then coconut oil that has been processed into VCO is rich in medium-chain triacylglycerol, which is relatively stable to oxidation [11].

Fatimah and Sangi [28] purified VCO using zeolite adsorbent, activated charcoal, and rice husk ash to produce oil with low moisture content. The decrease in water content after adding zeolite adsorbent, activated charcoal, and rice husk ash were 71.53%, 67.59%, and

72.29%, respectively. Meanwhile, the peroxide number decreased by 74.55%, 72.65%, and 72.24%, respectively. At the same time, the free fatty acid levels showed a decrease of 16.99%, 28.57% and 39.10%, respectively. The difference in the adsorbent indicates that the characteristics of the particles, polarity, and silica content in each adsorbent affect the refining results of virgin coconut oil.

Tabel 2: Comparison of Several Coconut Oil Purification Techniques.

S.No.	Purification types	Characteristics	References
1.	Addition of adsorbent	Lowering the water content of coconut oil	[28]
		Lowering the coconut oil peroxide number	[27, 29]
		Reducing the yellow pigment in coconut oil	[27]
		Lowering the acid number of coconut oil	[29]
2.	Membrane filtration	Produces minimum oil loss and no free fatty acids were detected	[30]

Poli [27] purified coconut oil from copra using bentonite and activated charcoal as adsorbents; it was reported that activated charcoal absorbs red pigment in oil as much as 59.2-88.9 %, while bentonite absorbs red pigment in oil by 66.7-100 %. Activated charcoal absorbs yellow pigment in oil about 47.4%-92.1%, while bentonite is 48.27% - 97.4%. The use of activated charcoal is more effective in reducing the amount of free fatty acids than bentonite. This is because activated charcoal is easier to absorb compounds from oil hydrolysis. The oil that has been purified by activated charcoal and bentonite shows a decrease in the peroxide number, where activated charcoal is more effective than bentonite. Thus, activated charcoal is more effective at improving the quality of coconut oil than bentonite. The use of zeolites in coconut oil refining has been carried out by Suharmadi and Enjarlis [29] who reported that zeolites were able to reduce acid numbers, peroxide numbers, and water content by 84.34%, 70%, and 42%, respectively. At the same time, the iodine number increased by 42%.

Purification of coconut oil by other methods carried out by Rao *et al.*, [30] reported that the deacidification process of coconut oil using membrane filtration has the advantage of producing minimal oil loss than chemical purification and using a lower temperature than physical purification. The membrane filtration process used two types of solvents, namely ethanol and methanol, both of which were effective in removing free fatty acids in the oil and were easy to separate from the product. The reduction in free fatty acid levels in this process reached 93% for methanol and 94% for ethanol.

IV. THE RECENT APPLICATIONS OF COCONUT OIL IN FOOD PRODUCTS

Coconut oil can be processed into several food products or modified into structured lipids to be applied to various products. Some food products that have used coconut oil include margarine, butter, cocoa butter substitutes, and several other fat-based products, as shown in Table 3. The application of coconut oil in the food industry is usually based on the type of fatty acid content found in coconut oil. Coconut oil is rich in MCFAs such as lauric, capric, and caprylic acids. These fatty acids are believed to have health benefits, such as preventing obesity, cardiovascular disease, diabetes, and cancer [11]. Based on these things, more and more people are turning to use coconut oil in food processing.

Tabel 3: Various Applications of Coconut Oil in Food Products.

S.No.	Products	Characteristics	References
1.	Trans fat margarine	SFC was 15.5-34.6% at 25℃, but no β'- polymorphic crystals were found.	[31]
		The SFC was 15.9-33.5% at 25℃, and β'- polymorphic crystals were formed.	[32]
		The mixture with a ratio of palm stearin: VCO 3:7 produces the most suitable trans-free margarine, has β´-crystal, and has a low SFC at body temperature (37℃)	[33]
		Interesterification of a mixture of soybean oil: palm stearin: coconut stearin 20:50:30 produces trans-free margarine with an SFC curve similar to commercial margarine and has β´-crystal.	[34]
2.	Cocoa butter replacers/substitutes	The formulation is not more than 60% of the total weight. The melting point of the chocolate bar is lower.	[35]
		The hardness of the chocolate bars decreases, and the chocolate bars look shiny.	[36]
		Krabok seed fat mixture: coconut oil 60:40 produces an SFC curve similar to commercial cocoa butter, has β'-polymorph crystals and has up to 5% compatibility with cocoa butter	[37]
3.	Structured lipids	directed interesterification of coconut oil is effective using acetone as a solvent, resulting in a structured lipid of around 24%	[38]
		Structured lipids have a total SFC that is almost the same as cocoa butter, can reduce cholesterol levels in the blood, lose weight, raise HDL levels, and reduce LDL levels	[39]
4.	Edible film	Structured lipids contain high oleic acid at the sn-2 position in the TAG. Produces an edible film that is clearer, has high tensile strength and low elongation break.	[40]
5.	Human Milk Fat Analog	MCFA levels were 43.86%, of which 39.37% were lauric acid. Palmitic acid which is located in the sn-3 position of TAG is 24.18%, almost the same as human milk fat	[41]
6.	Monoacylglycerol/ Monolaurin	Glycerolysis of coconut oil using *Carica papaya* lipase was optimal at glycerol to oil ratio of 8: 1, lipase concentration of 20%, at 45℃ for 36 hours resulting in 58.35% monoacylglycerol.	[42]
		Glycerolysis of coconut oil using Novozyme 435 was optimal at glycerol to oil ratio of 4: 1, lipase concentration of 8%, at 50℃ for 60 hours resulting in 62.5% monoacylglycerols, and about 29.3% as monolaurin.	[43]

The applications of coconut oil in the food industry include the processing of trans-free margarine. Margarine and shortening generally use the partial hydrogenation method of oils, but this method can lead to the formation of trans-fatty acids. There are several negative health effects when consume margarine containing trans-fats for a long time, namely the increased risk of cardiovascular disease. As an alternative, several studies have been carried out using various methods for avoiding the formation of trans fats, namely by enzymatic interesterification and using physical blending methods using several fractions of fats/oils, including palm stearin and coconut oil [33, 34, 44].

The production of margarine using the enzymatic interesterification method is carried out to form margarine that is free of trans-fats, with the characteristics of the margarine that is formed as expected (spreadable). The enzyme that is usually used as a catalyst for enzymatic interesterification is the lipase, where the use of this enzyme can change the structure and the composition of triacylglycerols, to improve physicochemical characteristics, nutrition, and other functional properties [45, 46].

The production of trans-free margarine was carried out by Adikari *et al.,* [31] who used a mixture of coconut oil, rice bran oil, and palm stearin by enzymatic interesterification. Coconut oil was added to improve the nutritional value because coconut oil contains high MCFAs. This research was conducted by several treatments with a ratio between rice bran oil and palm stearin of 1:1, 1:2, and 1:3 with the addition of coconut oil as much as 40%. The results of this study indicate that margarine processed using enzymatic interesterification has a solid fat content (SFC) of 15.5-34.6% at 25℃, while margarine processed using physical blending shows the SFC about 30.0-46.5% at 25℃. SFC is closely related to margarine and shortening properties, in terms of spreadability, ease of packaging, appearance, and organoleptic properties of margarine and shortening [32].

A good type of margarine for easy application should have an SFC at room temperature of about 15-35%. Based on these criteria, the margarine made by the interesterification process is very compatible with the properties of margarine spread. However, in terms of polymorphic crystals, there is no β'-form crystals, in which β' crystals are polymorphic forms that are expected to appear on margarine, which indicates small polymorphic crystals, and spreadable margarine [31].

A similar study was also conducted by Ruan *et al.*, [32] through the enzymatic interesterification of a mixture of coconut oil, camellia seed oil, and palm stearin at the camellia seed oil: palm stearin ratio of 50:50, 40:60, and 30:70. Meanwhile, the coconut oil used is 10% of the total oil weight. The results of the interesterification were then tested for SFC and its polymorphic form. The results showed that the SFC in the interesterified margarine was 25.5-45.8% at 20℃ and 15.9-33.5% at 25˚C. The SFC in the interesterified margarine was lower than the SFC for margarine resulting from physical blending, which ranged from 38.1-44.6% at 25℃. This is due to changes in the composition and structure of triacylglycerols which affect the melting profile and the SFC percentage of margarine. The margarine obtained shows crystals of shape β´ which are suitable for the expected margarine characteristics.

The production of trans-free margarine using the blending method was also studied by Sonwai and Luangsaipong [33] by mixing virgin coconut oil, palm oil and palm stearin. The results of this study indicate that the mixing treatment of 30% palm stearin and 70% virgin coconut oil produces margarine that matches the characteristics of trans-free margarine. The crystalline form found was β', and the percentage of SFC was low at room temperature.

Coconut oil is also used as a substitute for cocoa butter in the production of chocolate bars. Research conducted by Halim *et al*., [36] and Limbardo *et al.,* [35] shows that coconut oil can be used as a raw material for the production of cocoa butter substitutes. This substitution is mostly conducted by several chocolate industries due to the high price of cocoa butter. It is hoped that with this substitution, the characteristics of chocolate bars remain the same as when cocoa butter is used, namely a stable crystal structure and increases the melting point so that it does not melt at room temperature but melt at 37℃.

Limbardo *et al.,* [35] reported that the substitution of cocoa butter with coconut oil produces different characteristics of chocolate bars with the use of cocoa butter. This is affected by the total amount of fat, the physical and chemical characteristics of the oil used, and the crystal changes during cooling and heating processes. The higher the oil formulation used, the lower the melting point of the chocolate bar compared to those using cocoa butter. This is due to the higher the oil substituted formulation, the higher the unsaturated fat content in the chocolate, which can reduce the hardness of the chocolate bar. The maximum amount of substituted oil for a stable chocolate bar is not more than 60% of the total weight. The use of coconut oil as a substitute fat in chocolate bars must be followed by a longer cooling process so that the crystal form in the chocolate bars becomes stable. Similar results were reported by Halim *et al*., [36], namely the use of coconut oil as a substitute fat in the manufacture of chocolate bars lowering the melting point and reducing the rheological properties of chocolate bars, but still within the limitations of the characteristics of chocolate bars. On the positive side, the use of coconut oil in chocolate bars improves the appearance of chocolate bars based on sensory assessments, by producing shiny chocolate bars.

Coconut oil can also be used for the production of structured lipids (SLs). Structured lipids from coconut oil are chemically or enzymatically modified oils containing MCFAs, where these MCFAs are claimed to be hydrolyzed and absorbed by the body faster than long-chain fatty acids [40]. Structured lipids are also claimed to have health benefits, namely reducing calories and controlling body weight [38]. Some products of structured lipids are human milk fat substitutes, trans-free margarine/butter, low-calorie fats, and others. The structured lipid production from coconut oil containing MCFA and USFA can be carried out through the direct interesterification method as reported by Nuhrahini and Soerawidjaja [38]. The results showed that the structured lipid synthesis method from oil with direct interesterification was effective when using acetone as a solvent than 2-ethoxyethanol.

The use of coconut oil as a structured lipid (low-calorie cocoa butter substitutes) was studied by Bakar *et al*., [39]. Structured lipids made from a mixture of fractions of palm oil, canola oil, and MCFA-rich virgin coconut oil. The cocoa butter substitute has almost the same SFC as cocoa butter. This low-calorie effect of fat was studied using mice that were divided into six groups and observed their weight and blood plasma for 56 days. Rats treated with a control diet (rat feed + cocoa butter) experienced a significant gain in body weight compared to mice fed a structured lipid mixture rich in MCFA from coconut oil. Cholesterol levels in the blood of rats fed structured lipids decreased when compared to day 0 of observation. For HDL levels in the blood, there was an increase and decreased LDL levels in rats fed structured lipids when compared to the zero-day observation. Thus, a combination of palm oil fraction, canola oil, and virgin coconut oil can be used as a raw material for the production of structured lipids in the form of low-calorie cocoa butter substitute [39].

Structured lipids can also be used in the synthesis of edible films. Moore &Akoh [40] conducted an enzymatic interesterification of a mixture of high oleic sunflower oil with coconut oil which was then used in making edible films. The results showed that structured lipids have high oleic acid content at the sn-2 position in TAG, the resulting film is clearer and has higher tensile strength but has lower elongation break than edible films that do not use structured lipids

Structured lipid applications have also been developed in the production of human milk fat substitutes. Fat in breast milk has a high characteristic of palmitic acid, which is in the sn-2 position in the TAG. Research conducted by Karouw *et al.,* [41] developed a substitute for breast milk fat using palm stearin and coconut oil. The method used was enzymatic interesterification using Lipozyme as a biocatalyst at a temperature of 50 ℃ for 12 hours. The results of the study showed that human milk fat substitutes with MCFA levels of 43.86%, of which 39.37% were lauric acid. Then palmitic acid, which is located in the sn-3 TAG position is 24.18% which is almost similar to human milk fat.

Coconut oil can also be used for the production of monoacylglycerols, especially in the form of monolaurin. Monoacylglycerol has been widely used in the food industry, especially as an emulsifier and structured lipids with desired properties [47, 48]. Meanwhile, monoacylglycerols from coconut oil have advantages because, in the form of monolaurin, it has bioactive properties as an antimicrobial or as a supplement to increase the immune system [49, 50]. Monoacylglycerols can be synthesized effectively, especially through glycerolysis, both chemically and enzymatically [51]. Monoacylglycerols from coconut oil have been investigated by Pinyaphong *et al*., [42] and Zha *et al*., [43] through the enzymatic glycerolysis of coconut oil which was able to produce monoacylglycerols as much as 58.35% and 62.5%, respectively.

V. CONCLUSION

Coconut oil extraction is carried out by crushing copra and can be conducted in two ways, namely the dry method and the wet method. The difference between the dry and wet methods is the use of heat (drying) in the oil extraction process, whereas the wet method does not use heating. Refining coconut oil is often found in copra coconut oil which can be conducted by adding adsorbents and deacidification using membrane filtration, whereas virgin coconut oil usually does not require refining. Coconut oil can be applied to the production of trans-free margarine by physical blending and interesterification methods, cocoa butter substitutes in the chocolate industries, structured lipids rich in MCFA, monoacylglycerol, and bioactive lipid in the form of monolaurin.

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Conflict of Interest. No.

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