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The Importance of Research and Development of Virgin Coconut Oil in Food, Pharmaceutical, Nutraceutical and Cosmeceutical Industries

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Abstract: Virgin coconut oil (VCO) is widely known as the purest and least refined form of coconut oil. Many claims the contents in VCO are beneficial for humans' health. VCO is accepted as natural functional food and has mostly been commercialized in the form of liquid or encapsulated in soft gels. VCO is also a popular ingredient used in the cosmeceutical industry, especially in hair and body care products. The percent usage of VCO increases tremendously over the years. The market demands for VCO is forecasted to be increased by 9% for the next five years. Even though many studies have been conducted on VCO, research and development studies in terms of processing, safety, efficacy, and benefits of VCO need to be continued to maximize the utilization of VCO and meet the needs of the market.

Keywords: *Virgin coconut oil, research and development, safety, potential, efficacy*

1. Introduction

Coconut (Cocos nucifera L.: Arecaceae) is acknowledged as a versatile tree because of its diverse function in a wide range of the industry, including food, functional food, pharmaceutical, nutraceutical, and cosmeceutical [1]. Coconut trees are mostly grown in Asian countries such as Indonesia, Thailand, Philippines, and Malaysia. Malaysia is one of the world's top 10 coconut-producing countries. Coconut is the country's fourth most important crop after oil palm, rubber, and rice [1].

VCO is a vegetable oil that can be extracted from a fresh mature kernel of coconut naturally or mechanically, with or without the use of heat [2,3]. There is no alteration to the nature of the oil because no chemical refining, bleaching or deodorizing is involved during the extraction process [3]. It became highly popular in the scientific field because of its usage in the pharmaceutical, nutraceutical, as well as cosmeceutical industry.

Virgin coconut oil is a colorless liquid at or above 30ºC. The color turns white when it is in solid form. The method applied during the extraction of the oil affects the aroma of the oil. If the coconut oil is not refined, bleached or deodorized, the smell of virgin coconut oil is that of coconuts. Its melting point and smoking point are 25ºC and 177 ºC, respectively. The virgin coconut oil is highly insoluble in water at room temperature. The density of virgin coconut oil is 924.27 kg/m3.

VCO is rich in medium-chain fatty acids (59.02% to 62.27%), consisting of caproic acid, capric acid, lauric acid and caprylic acid. These medium-chain fatty acids (MCFAs)

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that made up VCO have demonstrated antibacterial, antifungal, antivirus and antiprotozoal properties [2,4]. The remaining of VCO are made up of long chain fatty acids (myristic acid, stearic acid and palmitic acid), mono-unsaturated fatty acids and di-unsaturated fatty acids [5]. The concentration of long chain fatty acids in VCO is from 28% to 31%. Meanwhile, 6.73% to 8.13% is made up of unsaturated fatty acids. VCO is well-known for its high antioxidant properties with maximum scavenging activities ranging from 52.54% to 79.87%.

Copra used to be a primary product of the coconut trees. Worldwide demands of copra have resulted in the harvesting of 61.5 million tons of fruit per year for 30 years; however, the yields of copra production have slightly changed between 1980 and 2014, specifically in Asia [6]. Copra production started to decline because of the issues of substitutability, low productivity and price volatility. Non-food products dominate a significant share of international trade in coconut. Activated carbon, produced from coconut shell, is a highly sought-after product in the international market due to its physical properties. Philippines exports 38 different coconut-based products (including by-products) evaluated at almost 1 billion US dollars per year [6].

VCO has many high-value co-products, such as coconut water, coco flour, charcoal and coconut coir. Originally, coconut water entered the market in Brazil in the early 2000s. Then, a global campaign results in a rapidly growing demand for coconut water worldwide. According to a new Global Info Research (GIR) study, the worldwide market for coconut water will increase at a CAGR of roughly 14.4% for 5 years; from 6150 million US$ in 2017 to 13800 million US$ in 2023 [7]. Coconut water is enriched with nutrients because coconut trees are usually planted in coastal regions. The seawater supplied enough amounts of minerals, such as potassium, calcium and magnesium to the coconut trees.

Increasing demands for virgin coconut oil for utilization in various industries is another factor that is expected to drive global demands for coconuts. Since VCO has been introduced to local and international markets, the market demands for coconuts increase exponentially. The global market for VCO stood at $2.7 billion in 2018 and is expected to expand at a CAGR of over 9% to reach $4.7 billion by 2024 [7].

According to the statistics of the United Nations Food and Agriculture Organization (FAO), 61 million tons of coconuts were produced in 2014 [1]. Indonesia was reported to be one of the largest producers of coconuts in Asia in 2014. Malaysia also gradually improved coconuts output from 550140 metric tons in 2010 to 624 727 metric tons in 2013 for both the local and global market [1]. However, coconut production in Malaysia showed a declining pattern from 2014 until 2016. Malaysian Agricultural Research and Development Institute (MARDI) suggested that the restriction of acreage of cultivation area for coconut trees was the main constraint to meet the market demand. This declining pattern can also be observed in other countries. In Thailand, coconut palm planting regions have declined steadily from 4000,000 ha in 1997 to 224,000 ha in 2009 [8]. Coconut growers tend to plant more competitive industrial products such as palm oil instead of coconut trees. This issue needs to be adequately addressed to ensure that the increasing demand for coconuts due to the higher than before demand in VCO is satisfactorily met.

Coconut oil has been claimed to be the healthiest on earth [9]; however, some health care professionals or nutritionists are reluctant to suggest the use of VCO because it is rich in saturated fats. Thus, a lot of scientific studies have been conducted on VCO in terms of efficacy, potential, safety, and processing method. These studies are conducted to maximize the utilization of VCO to meet the needs of the food, pharmaceutical, nutraceutical and cosmeceutical industries.

The efficacy, potential and safety of VCO has been studies before but not comprehensive. The medium chain fatty acids (MCFA) of C_6-C_{12} are easily utilized metabolized and exhibited the antimicrobial and antibacterial properties that favor to our health [10]. Table 1 shows the composition of fatty acid in virgin coconut oil.

Table 1. The composition of fatty acid in VCO

Fatty Acid	Content (%)
C6:0 Caproic	nd-0.95
C8:0 Caprylic	4.6-10.44
C10:0 Capric	5.00-7.19
C12:0 Lauric	43.00-53.00
C14:0 Myristic	16.00-21.00
C16:Palmitic	6.38-10.17
C18:0 Stearic	2.00-4.00
C18:1n9C Oleic	5.00-10.00
C18:2n6C Linoleic	nd-2.50
C18:3n6C Linolenic	nd-0.2

Different extraction methods do not result in significantly different ($p>0.05$) fatty acid content in VCO [12,13,14]; provided that the oil smoke point of 171 ºC is not reached [15]. When the oil reaches its smoke point, volatile compounds, such as water, free fatty acids, and short-chain degradation products of oxidation will be released. Decomposition of the oil might result in the formation of possibly toxic relevant compounds [16].

The MCFAs are the most favorable contents in VCO for health treatment. MCFAs help in weight reduction [17] and it can be also applied in the food industry as a natural preservative [17]. Its characteristic as a natural preservative encourages users to consume organic foods without chemical additives.

Lauric acid and myristic acid promote metabolism and possess antibacterial properties [18]. The antibacterial functionality of VCO is highest when VCO is in a simpler form such as mono- and diacylglycerols (MAGs and DAGs). MAGs and DAGs have already been used commercially.

MAGs are used as food emulsifiers in the food industry and as emollients for transdermal slow-release drugs in the pharmaceutical industry. In the cosmeceutical industry, MAGs act as texturizing agents to improve the stability of creams and lotions. A study has proposed that DAGs have anti-obesity activity and can prevent postprandial hypertriacylglycerolemia [18].

Previous works attempted to manufacture industrial-scale MAGs and DAGs through continuous chemical glycerolysis of fats and oils at high temperature (220-250 ºC) using inorganic alkaline catalysts under nitrogen gas [18]. However, this resulted in the disruption of their physical properties. The products were unattractively dark-colored and had a burnt taste due to the high temperature. In addition, the process was energy-intensive resulting in low yields (30%-40%) and requiring product purification by molecular distillation [18].

Thus, the use of enzymes as a catalyst in the process is beneficial to modify the structure and composition of oils and fats. Hence, a commercially immobilized Candida Antarctica lipase (Novozyme 435) was used in the production of MAGs and DAGs via glycerolysis. A 1:1 molar ratio of glycerolysis between VCO and glycerol was investigated with 3, 5 and 10% w.t. of enzyme concentration at 50 ºC for 24 and 48 hours. The results suggested the possibility of converting VCO in TAG form into simpler compounds (MAG and DAG) is possible via enzymatic glycerolysis. Glycerolysis using 5% of the enzyme for 24 hours gave the highest composition of MAG and DAG**.**

In nutraceutical and pharmaceutical industry, VCO has its benefits and functions on its own**.** R&D is needed to affirm the benefits of VCO for the pharmaceutical and nutraceutical industry. VCO has been claimed to be healthy because some studies have shown that it can aid weight loss; can reduce the risk of atherosclerosis; has anti-diabetic property; can reduce the risk of cancer; can resolve bacterial, viral and fungal infections and improve digestion and absorption of nutrients [9].

VCO may help people lose weight by merely enhancing their satiety [17]. VCO can also stimulate fat loss by increasing thermogenesis, a process that generates body heat directly from fat rather than ATP in brown adipose tissue [17].

Studies have shown that VCO has the potential to improve cardiovascular (CV) risk. Its chemical properties, especially phenol, can reduce the content of lipid peroxidation and normalize lipids through different processes. VCO, which contains a high fraction of polyphenols possessing anti-inflammatory and antioxidants properties, has been shown to arrest the progression of atherosclerosis [5]. Apart from these benefits, VCO also enhances antithrombotic effects that leads to inhibition of platelet coagulation.

VCO has been shown to exhibit anti-diabetic property. VCO can suppress and reduce the severity of hyperglycemia. In one study, 0.8 ml of VCO was injected into diabetic rats on alternate days for ten weeks [19]. The outcome of this study indicated that blood glucose concentrations in diabetic rats were gradually reduced. Lauric acid and capric acid in VCO were shown to affect insulin secretion [19]. Another research concluded that VCO in diet improved insulin activity and binding affinity compared with other oils [20].

VCO also exhibits antibacterial, antivirus, antifungal, and antiprotozoal properties. Increasing the degree of hydrolysis in VCO resulted in the increase in antibacterial activity [21]. The advantage of oral consumption of VCO as an anti-bacterial agent is that VCO does not induce any side effects as it is a food ingredient that will be hydrolyzed in the gastrointestinal tract by lipase [21]. A study shows that 12.5% of VCO could decrease plaque and gingival indexes significantly [22]. Plaque adhesion and bacterial co-aggregation decreased because VCO created an oily layer on the tooth surface.

Apart from nutraceutical and cosmeceutical industries, VCO is vastly use in food industry. Coconut oil is listed as a substance generally known as safe (GRAS) by the United States Food and Drug Administration (FDA) [23]. FDA also states that coconut oil is a food additive that can be used as a substitute of cocoa butter for direct addition to food for human consumption [23]. Infrared spectroscopy has been used widely in the investigations of edible oils. FTIR spectra of VCO and commercially available coconut oil were compared, and the peak profiles were observed to vary [24]. A unique peak at around 2343 cm^{-1} was observed in VCO. This unique peak was absence in commercially available coconut oil. This peak can be used an indicator or a chemical marker for VCO and can be utilized to overcome the issue of VCO adulteration as less costly oils such as palm kernel oil or RBD coconut oil have been introduced to VCO to reduce costs [17].

Meanwhile in cosmeceutical industry. a major portion of cleanser, foaming agent or stabilizer contains coconut oil with concentrations up to 50%. A safety assessment for coconut oil and its derivatives was conducted in 1986 for cosmetics. Cosmetic Ingredient Review (CIR) Expert Panel concluded they were safe to use in cosmetics products [23].

Skin moisturizer is an essential cosmetic care that increases skin moisture and modifies the skin's chemical nature to enhance the structure of the skin to be smoother and softer [25]. In one study, moisturizers with and without virgin coconut oil loaded solid lipid particles (VCO-SLPs) were studied to determine the effects of VCO-SLPs on the skin in terms of its hydration and elasticity. VCO acts as an emollient and occlusive agent in moisturizers. A positive correlation between the application of lotion with VCO-SLPs on the skin and the skin moisture was observed. The usage of VCO-SLP in lotion resulted in the increase in skin moisture compared to blank lotion [25]. Lotion with and without VCO-SLPs increased skin moisture by 24.8% and 12.7%, respectively after 28 days of application [25]. The moisturizer that contained 20% VCO-SLPs resulted in a higher percentage of skin elasticity compared to the one without VCO-SLPs, by a factor of 3.

2. Materials and Methods

A number of methods have been implemented in producing VCO. The selection of the technology is based on the production's scale, machineries needed, investment and prospective buyers. The general practice of processing can be divided into dry method, wet method and solvent extraction method [26].

The dry method is a term used when VCO is obtained from fresh coconut kernels. The kernel, being either grated, shredded, grounded or milled is then dried until it reaches a moisture content of about 10-12%. The dried meat would be extracted to obtain VCO [15].

The wet method starts with fresh coconut milk. The wet method includes the fermentation technique, enzymatic approach, "cooking technique" and centrifuge method. Each technique uses coconut milk produced by pressing out the milk from fresh coconut meat. The oil is then extracted from the coconut milk emulsion. The drawbacks of the wet process are low oil recovery of only 30-40% in general, high moisture and a short shelf life [26].

Fermentation method results in VCO with a high phenolic content. VCO obtained through fermentation has been reported to exhibit substantial scavenging effect on 1,1-diphenyl-2-picrylhydrazyl (DPPH) and high antioxidant activity based on β-carotene-linoleate bleaching method [8,25]. The fermentation process can be improved by the addition of enzymes such as cellulase and pectinase. The purpose of the fermentation and enzymatic processes is to separate the oil phase on the upper layer from the water-soluble components including carbohydrate and protein on the bottom layer [24].

A different combination of enzymes and yeast result in various amounts of VCO extracted. Yeast inoculation facilitated oil yield 8 times than the control and the introduction of cellulase and pectinase, facilitated oil yield 7.5 and 7.3 times, respectively [24]. In the combination of cellulase and pectinase, the oil yield was 14 times higher than the control and 1.69 times higher than the endosperm fermentation process supported with yeast [24].

Integrated wet process is a combination of chilling, churning, thawing and centrifugation steps. The chilling process is aimed to destabilize coconut milk emulsions. When an emulsion is cooled to a temperature where part of the fat phase become crystalline, the fat crystals from one droplet may penetrate into another droplet leading to emulsion destabilization by partial coalescence [27]. This chilling temperature gives significant effect on the coconut oil yield during processing. The solidification state after chilling process at a low temperature will result in destabilization of emulsion during thawing at 29^{o}C±2; and will produce higher oil yield. In one study, the coconut milk was first cooled to below 12^{O}C (Hamid *et.al.*, 2011) before thawing. The higher oil yield of 92% from 65% was obtained upon thawing and centrifugation [28,29].

An alternative method for extracting VCO using green technology has been proposed. Supercritical carbon dioxide (SC-CO2) has been used as an alternative technique to enhance the properties of the extracted VCO [30]. SC-CO2 has low viscosity and high diffusivity that causes mass transfer to be more favorable. Other than that, it has a relatively low critical temperature (31.1 ºC) and critical pressure (7.3 MPa) which allows the extraction process to operate near ambient temperature. Furthermore, carbon dioxide (CO2) leaves no residue in the extracted VCO and this solvent is also non-toxic. The effect of temperature and pressure on the total phenolic content in VCO, oil yield and potential of its antioxidant activity have also been studied. The optimum operating pressure and temperature to obtain VCO with acceptable yield and quality were at 20MPa and 47 ºC [30].

3. Conclusion

R&D is important because it uncovers many usage potentials of VCO in food, nutraceutical, pharmaceutical and cosmeceutical industry. This open many business opportunities in products based on VCO. After the safety assessment on VCO had been conducted in 1986, a significant increase in total uses of coconut oil and coconut acid had been recorded. FDA reported that total uses of coconut oil and coconut acid increased by a factor of 5 in 2007 [23]. Nowadays, the market demand of VCO has increased even more.

R&D in the processing of VCO is important to produce VCO at a commercially scalable level. The addition of enzymes in the fermentation process, employing an integrated wet process or using inert substances in the extraction process improve oil yield significantly making the processing method highly economical and attractive to manufacturers of VCO.

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