Analysis of Virgin Coconut Oil and Its Potential in Food, Nutrition, and Health

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ABSTRACT

Virgin coconut oil (VCO), renowned for its exceptional nutritional and therapeutic properties, has garnered significant interest as a functional food and health supplement. Coconut trees (Cocos nucifera L.) play a vital role in the livelihoods of millions of farmers in Indonesia and are a source of highly valuable products, including VCO. This study analyzes VCO's composition, quality, and safety to optimize its food, nutrition, and health applications. The research involved processing coconut kernels into oil and conducting a series of tests at an accredited laboratory, including peroxide value analysis, fatty acid profiling, and microbiological assessments. The results demonstrate that the VCO produced in this study has a peroxide value of 0.08 mEq O_2/kg and a moisture content of 0%, indicating high stability and excellent quality. Fatty acid analysis revealed a high content of saturated fatty acids (92.505%), particularly lauric acid, known for its antimicrobial and anti-inflammatory properties. Microbiological tests confirmed the absence of pathogenic microorganisms such as Escherichia coli and Salmonella sp., as well as heavy metals like lead (Pb), mercury (Hg), and cadmium (Cd), ensuring safety for consumption. In conclusion, the findings highlight VCO's superior quality, stability, and safety, underscoring its potential as a functional food ingredient and health supplement. Further research is recommended to explore its applications in nutraceutical formulations and advanced studies on its bioactive compounds.

1. Introduction

Coconut (*Cocos nucifera L.*) is a crop with high economic value that is commonly used in many traditional foods in the Pacific and Asian regions. In Asia, 90% of the world's coconuts are cultivated, and more than half of the harvest is consumed fresh. Most edible coconut products are made of meat (solid endosperm) and water (liquid endosperm) [1]. For many Indonesians, the coconut *(Cocos nucifera L.)* is integral to their social, cultural, and economic lives. It is grown in nearly every province in Indonesia due to its geographic expansion. In that order, the provinces that produce the most coconuts are Riau, North Sulawesi, and East Java. For almost 6.3 million farmers, it is a significant source of revenue [2].

Because coconut is a versatile plant, there is great potential for developing coconut commodities. It is possible to use every portion of the coconut to create processed goods with significant commercial worth [3]. The stems and leaves are frequently used in handicrafts and as building materials for fences and buildings. The fruit's fibrous mesocarp, or shell, is processed to create rope, compressed wood, carpets, and geotextiles. It is also used as a source of nutrient fibers, a sterile plant support medium,

and seat cushions in trucks and trains. The shell, or extremely hard endocarp, is what's used to make activated charcoal. There are liquid and liquid components in the endosperm. Because liquid endosperm contains minerals, sugar, and vitamins, it is much sought after as a freshwater product or sports drink with isotonic qualities [4].

From an economic perspective, the most important product for coconut businesses is virgin coconut oil (VCO). This oil is considered a functional food due to its interesting health benefits [5]. Coconut oil has a high medical value and can be used for therapeutic and aesthetic skin care. Nowadays, coconut is thought to be a good source of complete nutrition that can help fight illness and malnutrition. The notable nutritional and medicinal properties of medium-chain triglycerides and lauric acid present in coconut oil [6]. Virgin coconut oil is more frequently utilized in the food business as a cooking oil, cheese, and ice cream substitute, as well as a buttermilk substitute [7]. Coconut oil, especially VCO, has several characteristics that set it apart from other types of coconut oil. Compared to refined, bleached, and deodorized coconut oil (RBD) and cold-pressed coconut oil (CPO), VCO contains more short-chain fatty acids [8].

The low moisture content in producing VCO of 0.1% can prevent oxidation and rancidity processes and increase shelf life. In general, coconut oil is more resistant to polymerization and oxidation than oils containing unsaturated fatty acids. However, its natural quality and fatty acid composition can be affected by processing [9]. Within the expanding functional food business, VCO is one edible oil that is becoming more and more well-liked [10]. The oil extracted at a low temperature from fresh, mature coconut kernels without processing is known as virgin coconut oil or VCO [11]. Although several methods for producing virgin coconut oil can be broadly divided into wet and dry categories. VCO is extracted directly from the coconut meat or kernel without drying by a wet process, destabilizing the coconut milk emulsion by fermentation, using an enzymatic, cooled, and centrifuged pH approach or any combination of these techniques [12]. The dry method involves physically pressing the kernel to extract the oil after it has been dried by regulated heating [13].

Comparatively, the VCO that is extracted from the coconut milk using a wet processing method at a regulated temperature performs better than the copra oil since it retains the majority of its advantageous qualities [14]. In the 1920s and 1930s, it was discovered that medium-chain triglycerides were the main ingredient in coconut oil, setting it apart from other fats and oils. As components of the fatty acid composition in VCO as determined by gas-liquid chromatography, saturated fats include myristic acid (16% to 21%), palmitic acid (7% to 10%), capric acid (4% to 8%), caprylic acid (5% to 10%), stearic acid (2% to 4%), Lauric acid (45% to 52%), caproic acid (0.5% to 1%) and palmitoleic acid (in traces). as well as unsaturated fats: 1%–3% of oleic acid, 5%–8% of linoleic acid, and up to 0.2% of linoleic acid [15].

VCO is a highly saturated fat rich in short and medium-chain fatty acids, which make up 65% of its composition. Lauric acid is the most abundant medium-chain fatty acid found in VCO as it metabolizes quickly without settling in arteries or fat cells [16]. The antibiotic VCO helps people recover from illness more quickly and increases their resistance to disease. It also aids in the prevention of degenerative diseases, including diabetes, liver, cancer, and bone loss, as well as weight loss, heart health, and blood vessel health [17].

VCO is made naturally or through the use of chemicals or boiling from fresh, ripe coconut kernels. VCO is high in medium-chain fatty acids, such as caprylic, caproic, and capric acids, which have antimicrobial and antiviral properties [5]. VCO contains tocopherols, ferulic acid, p-coumaric acid, and low and medium-molecular-weight saturated fatty acids. Incorporating VCO into food products has been studied for its potential health benefits, such as its role in lipid metabolism, weight loss, and prevention of heart disease and cancer. However, its high saturated fat content makes its consumption controversial [18]. Coconut oil, especially virgin coconut oil (VCO), is reported to have various positive health benefits. The antioxidant properties of VCO come from its fatty acid content and phenolic compounds. In animals, it has pharmacological activities such as anti-dyslipidemic, anti-inflammatory, and anti-hypertensive. In guinea pigs suffering from asthma, VCO can also help prevent inflammation and exacerbation of airway contractile responses [19].

VCO has many health benefits due to its rich nutritional content, including lauric, caprylic, and capric acids, which are known to have antimicrobial, antioxidant, and anti-inflammatory properties. In addition, VCO helps with metabolism, the immune system, and skin health. This study aims to analyze the composition, quality, and safety of VCO produced through enzymatic processes. The

research focuses on evaluating its physical, chemical, and microbiological properties to ensure that it meets high standards for food and health applications.

2. Research Methodology

2.1. Materials

VCO was sourced by CV Inovasi Anak Negeri and analyzed in collaboration with Saraswanti Indo Genetech Laboratory (SIG), an accredited facility located in Bogor, Indonesia. Saraswanti Indo Genetech SIG has undergone validation testing. The National Accreditation Committee (KAN) has accredited PT Saraswanti Indo Genetech, also known as SIG (registration no. LP-184-IDN), as the first testing laboratory in Indonesia authorized for the analysis of genetically modified organisms (GMOs). The laboratory in Bogor, Indonesia, conducted a content analysis of virgin coconut oil based on national standards in Indonesia.

2.2. Procedures

This study focuses on comparing several methods for producing VCO using the cold method, as shown in Table 1. Compared to heating methods, the production process of VCO using the cold method can offer benefits in terms of efficiency, quality, and environmental sustainability. The methods used in this study have been tested and standardized to ensure their reliability. Additionally, the various physical characteristics and evaluations associated with the cold method technology are also included in the table to provide comprehensive examples of the effectiveness of this technique.

Table 1. Virgin Coconut Oil Composition Analysis Method

Parameters	Method
Aflatoxin G2	18-12-27/MU/SMM-SIG (LCMSMS)
Aflatoxin G1	18-12-27/MU/SMM-SIG (LCMSMS
Peroxide Value	AOAC Official method 965.33
Moisture content (Karl Fischer)	18-11-44/MU/SMM-SIG
TPC	SNI ISO 4833-1 : 2015
Escherichia Coli	SNI ISO 7251 : 2012
Pseudomonas aeruginosa	18-7-121/MU/SMM-SIG
Salmonella sp.	ISO 6579-1:2017/Amd 1:2020
Shigella sp.	SNI ISO 21567 : 2017
Yeast Moid	SNI ISO 21527-2 : 2012
Shape	SNI 01-2891-1992 point 1.2
Texture	SNI 01-2891-1992 point 1.2
Taste	SNI 01-2891-1992 point 1.2
Appearance	SNI 01-2891-1992 point 1.2
Color	SNI 01-2891-1992 point 1.2
Odor	SNI 01-2891-1992 point 1.2
As	18-13-14/MU/SMM-SIG (ICP MS)
Hg	18-13-14/MU/SMM-SIG (ICP MS)
Cd	18-13-14/MU/SMM-SIG (ICP MS)
Pb	18-13-14/MU/SMM-SIG (ICP MS)
Linolenic acid	18-6-1/MU/SMM-SIG (GC)
Linoleic acid	18-6-1/MU/SMM-SIG (GC)
Oleic acid	18-6-1/MU/SMM-SIG (GC)
Omega 6 fatty acid	18-6-1/MU/SMM-SIG (GC)
Omega 3 fatty acid	18-6-1/MU/SMM-SIG (GC)
Omega 9 fatty acids	18-6-1/MU/SMM-SIG (GC)
Unsaturated fat	18-6-1/MU/SMM-SIG (GC)
Polyunsaturated fat	18-6-1/MU/SMM-SIG (GC)
Monounsaturated fat	18-6-1/MU/SMM-SIG (GC)
Free Fatty Acids	18-6-1/MU/SMM-SIG (GC)
Saturated fat	18-6-1/MU/SMM-SIG (GC)

3. Results and Discussion

VCO is a product derived from coconuts without significant processing to preserve their inherent qualities. VCO is very beneficial to the body's health. It is a natural antibacterial, antiviral, antifungal, and antiprotozoa. It also helps lower blood pressure, protect against osteoporosis, prevent liver disease, manage high blood pressure, maintain healthy heart and blood vessels, prevent cancer, aid in weight loss, maintain body stamina, and maintain healthy skin and hair. This section discusses the ingredients and benefits of virgin coconut oil.

3.1. Specification of Extracted Virgin Coconut Oil

To determine the extraction quality of an oil. Tests are carried out using parameters such as Aflatoxin G2, Aflatoxin G1, Peroxide Value, and Moisture content [20]. By comparing oils using these parameters, we can ascertain how the extraction conditions affect the quality of the oil. The analyzed data can be seen in Table 2 below.

Table 2. Specification of extracted virgin coconut oil

Parameter	Unit	Result	Limit Of Detection
Aflatoxin G2	mcg/kg	Not found	0.0183
Aflatoxin G1	mcg/kg	Not found	0.022
Moisture content (Karl Fischer)	%	0	-
Peroxide Value	mEq O_2 / kg	0.08	-

Aflatoxins G2 and G1 are harmful substances made by several types of fungi, mainly Aspergillus flavus and Aspergillus parasiticus. Aflatoxins have carcinogenic properties and are harmful to health. Their presence in foodstuffs, especially oils and fats, must be carefully monitored. Since aflatoxins G2 and G1 were not found, this VCO is safe for consumption [21]. The peroxide number serves as the main measure and can be used to determine the initial stage of oil oxidation. The initial product of the oxidation reaction in oil is hydroperoxide. The measurement results show that the peroxide level of virgin coconut oil is 0.08, indicating that this value is below the APCC threshold (<3). This indicates that the virgin coconut oil sample is very stable against oxidative rancidity [22].

A high peroxide number also indicates contamination that reduces the quality and purity of the oil, and it has low stability and is susceptible to oxidation processes, which can lead to rancidity. [23]. If the oil has a high moisture content, the activity of lipase enzymes from both microorganisms and the coconut itself may increase. This can accelerate hydrolysis, impacting the oil's quality and stability. [20]. Moisture content is also essential in the quality of oils and fats. The moisture content of virgin coconut oil of 0.08% should be limited as it can extend the shelf life by preventing oxidation and rancidity [24].

3.2. Sensory Properties Analysis of Virgin Coconut Oil

The sensory properties of VCO, including its appealing aroma, clarity, and texture, play a critical role in its suitability for food and health applications. To evaluate these characteristics, the physical attributes of VCO, such as appearance, texture, taste, color, and aroma, were systematically assessed through sensory and physical analyses. Table 3 presents the results of these evaluations, highlighting key parameters that define the quality and marketability of VCO for various uses.

Table 3. Sensory Properties of virgin coconut oil

Parameter	Unit	Result	Limit Of Detection
Shape	-	Liquid	-
Texture	-	Grassless	-
Taste	-	Normal, tasteless	-
Appearance	-	Normal	-
Color	-	Normal, no colour	-
Odor	-	Normal	-

The sensory evaluation of VCO samples produced by CV Inovasi Anak Negeri revealed diverse physical and sensory characteristics. The VCO samples exhibited the expected liquid consistency with a smooth and slippery texture, indicative of high-quality coconut oil. However, significant variations

were observed in the aroma of the samples, which ranged from sour or rancid to nutty or reminiscent of coconut jam, depending on the specific characteristics of each batch. These variations in aroma are likely influenced by differences in the production process, including factors such as processing temperature, duration, and extraction methods. Such factors play a critical role in shaping the sensory attributes of the final product. Consequently, these variations can significantly impact the sensory quality ratings and market acceptance of the VCO. Ensuring consistent production techniques is essential to achieving uniform sensory qualities and enhancing the product's appeal to consumers.

3.3. Heavy Metals Composition in Virgin Coconut Oil

A comprehensive analysis of heavy metal content in VCO was undertaken to confirm its safety for consumption. Heavy metals such as arsenic (As), mercury (Hg), cadmium (Cd), and lead (Pb) pose significant health risks when present in concentrations exceeding established safety thresholds. To ensure compliance with stringent food safety standards, this study assessed the concentrations of these heavy metals in VCO samples. The findings of the heavy metal analysis are summarized in Table 4, which details the detected levels of heavy metals in the samples alongside their permissible limits as defined by food safety guidelines.

Table 4. Heavy Metals Composition in Virgin Coconut Oil

Parameter	Unit	Result	Limit Of Direction
Arsenic (As)	mg/kg	Not found	0.0002
Mercury (Hg)	mg/kg	Not found	0.0005
Cadmium (Cd)	mg/kg	Not found	0.0005
Timbal (Pb)	mg/kg	Not found	0.001

Although many metals exist in our food and body, only a small amount is essential for survival and good health. Inadequate consumption of inorganic nutrients can result in biochemical degradation of cells and observable clinical symptoms [25]. Copper (Cu), iron (Fe), zinc (Zn), and trivalent chromium (Cr(III)) are some of the heavy metals involved in enzymatic functions and cytochrome structures and play essential roles in metabolic processes. Enzyme catalysis, electron transport, and regulation of metabolic activity are all critical roles in these metals, which support various important biochemical reactions in the body. In contrast, metals mercury (Hg), arsenic (As), lead (Pb), and cadmium (Cd) are regarded as pollutants and undesired materials in animal feed since they lack a known biological role. Additionally, even at lower exposure levels, the public health concerns, Cd, As, Cr, Pb, and Hg, have high toxicity because they can harm organs. Virgin coconut oil was determined to be free of arsenic, cadmium, mercury, and cobalt after its metal level was tested. Thus, consuming pure coconut oil is safe [26].

3.4. Virgin Coconut Oil Content by Microbiological Test

Microbiological testing ensures that VCO is free from pathogenic microorganisms and other contaminants that could compromise product quality or consumer health. These tests are designed to verify compliance with food safety standards, making VCO suitable for direct consumption and as an ingredient in the production of other products. Table 5 presents the results of the microbiological analysis, encompassing critical parameters such as total microbial counts, molds, yeasts, and the presence of specific pathogenic microorganisms that may indicate contamination.

Table 5. Virgin Coconut Oil Content by Microbiological Tes

Parameter	Unit	Result	Limit Of Detection
TPC	Colony / g	<10	-
Escherichia Coli	MPN / g	0	-
Pseudomonas aeruginosa	Colony / g	<10	-
Salmonella sp.	/ 25 g	Negative	-
Shigella sp.	/ 25 g	Negative	-
Yeast Mold	Colony / g	<10	-

The results revealed that the total plate count (TPC) was below the detection limit (<10 colonies/g), and *Escherichia coli* was not detected, confirming the absence of bacterial contamination. Additionally, the samples showed no significant presence of *Salmonella sp.* or *Pseudomonas*

aeruginosa (<10 colonies/g), and yeast and mold were similarly undetected at substantial levels. These findings demonstrate that the VCO samples are free from pathogenic microorganisms that could compromise product quality or safety. Consequently, the analyzed VCO is considered safe for consumption and suitable as an ingredient in other food products or formulations.

3.5. Fatty Acid and Fat Content in Virgin Coconut Oil

The fat composition analysis of virgin coconut oil aimed to identify the different types of fatty acids and the total fat contribution to energy value, as shown in Table 6. This analysis provides a comprehensive picture of the fat profile of virgin coconut oil.

Table 6. Fatty Acid and Fat Content in Virgin Coconut Oil

Parameter	Unit	Result	Limit Of Direction
Linolenic acid	%	Not detected	0.00151
Linoleic acid	%	1.3474	-
Oleic acid	%	6.006	-
Polyunsaturated fat	%	1.3621	-
Omega 6 fatty acid	%	1.3474	-
Unsaturated fat	%	7.415	-
Omega 9 fatty acids	%	6.006	-
Monounsaturated fat	%	6.0529	-
Omega 3 fatty acid	%	0.0147	-
Saturated fat	%	92.505	-
Free Fatty Acids	%	0.11	-

Most of the fatty acids in VCO are medium-chain. Lauric acid is the primary fatty acid in VCO; however, the amount of lauric acid in VCO may differ depending on the growing environment and extraction technique [27]. Based on the findings, it is evident that the virgin coconut oil sample has a high level of saturated fat (92.505%). Despite popular belief that it is a bad fat, it is thought to be a significant risk factor for heart disease [28]. Consuming long-chain saturated fats was long thought to be detrimental to heart health. However, a recent meta-analysis of prospective observational studies did not discover any connection between the risk of myocardial infarction mortality, coronary heart disease, or stroke and the consumption of saturated fat. A randomized controlled research, however, discovered that replacing saturated fats with polyunsaturated fatty acids (PUFAs) can lower fat intake and is linked to a 17% lower risk of cardiovascular disease [29]. Together with saturated fatty acids, corn oil also contains polyunsaturated fatty acids. The benefits of essential polyunsaturated fatty acids (PUFAs) include elevated blood levels of high-density lipoproteins, lowered risk of heart attack and stroke, and prevention of cancer and cardiovascular disease [30].

Although VCO offers numerous uses and health benefits, its commercialization has been significantly hindered by persistent media narratives portraying coconut oil as a harmful saturated fat that should be avoided. The production of value-added coconut products often remains a small-scale enterprise catering to local markets in developing countries. Governments must establish robust and supportive regulatory frameworks to promote the broader distribution of coconut-based products in rural and urban areas (Yashi Srivastava).

4. Conclusion

Indonesian VCO also possesses high quality, is pure, and has considerable health benefits. Various tests, from microbiological analysis to heavy metal content evaluation, confirm the safety of the oil for consumption. VCO was free of harmful microorganisms, including *Escherichia coli*, *Salmonella sp.*, and *Pseudomonas aeruginosa*, with a total microbial count below the detection limits. Besides, the absence of aflatoxins and heavy metals like arsenic, mercury, and cadmium indicates its safety. The low peroxide value of the oil points toward stability against oxidative rancidity, and the moisture content suggests a good shelf life. While there has been concern over the high levels of saturated fat in VCO, recent studies indicate that the unique composition of VCO, including medium-chain fatty acids such as lauric acid, confers several health benefits, which include antimicrobial properties and potential cardiovascular protection. Given its proven safety and promotion of health, further research and development are encouraged to extend its applications in both the food and health sectors.

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