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# VIRGIN COCONUT OIL-BASED EMULSION AND ITS BENEFITS: A REVIEW

## (Emulsi Berasaskan Minyak Kelapa Dara dan Kebaikannya: Satu Tinjauan)

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**Abstract**

This review aims to provide a comprehensive overview of emulsions using virgin coconut oil (VCO) as the hydrophobic fat component. It focuses on the primary triglycerides in VCO, which convert into bioactive medium-chain triglycerides (MCTs) with diverse pharmacological properties. VCO's importance extends to aiding viral and microbial infections, leveraging its polyphenolic content as a potent antioxidant, and supporting weight reduction and metabolic improvements associated with obesity. Derived from *Cocos nucifera* L., VCO is a crucial plant-based oil predominantly produced in the Philippines, Malaysia, and Indonesia; regions where coconuts are in abundance. Despite VCO's extensive benefits, anti-saturated-fat bias has limited its exposure and acknowledgment in medical literature. This review addresses this gap, highlighting VCO-based emulsion applications and advantages for consumers and industries globally. By examining VCO's properties and its significant contributions to pharmaceuticals, the study aims to enhance understanding and appreciation of VCO-based emulsions. The findings underscore the need for broader recognition of VCO's potential, particularly in combating infections, acting as an antioxidant, and promoting health benefits linked to weight management and metabolic health. This review serves as a foundational reference for future research and development in utilizing VCO within pharmaceutical and health-related contexts.

**Keywords**: virgin coconut oil, viral, antioxidant, polyphenolic, metabolic

**Abstrak**

Kajian tinjauan ini berhasrat untuk memberikan gambaran keseluruhan tentang emulsi yang menggunakan minyak kelapa dara (VCO) bertindak sebagai komponen lemak hidrofobik. Kajian ini memfokus kepada komponen trigliserida utama dalam VCO yang ditukar menjadi bioaktif trigliserida rantaian sederhana (MCT) dengan pelbagai sifat farmakologi. Peripentingnya VCO menjangkaui dalam rawatan jangkitan virus dan mikrob, dan berpotensi digunakan sebagai enzim antioksidan kerana kandungan polifenolnya. Ia juga membantu dalam pengurangan berat badan dan penambahbaikan penunjuk metabolik yang berkaitan dengan obesiti. VCO ialah minyak yang dihasilkan daripada tumbuhan *Cocos nucifera* L., yang merupakan salah satu tumbuhan terpenting di dunia yang boleh didapati di Filipina, Malaysia, dan Indonesia, iaitu negara-negara yang kaya dengan kelapa. Walaupun banyak kelebihan VCO dilaporkan secara meluas, namun prasangka anti-lemak-tepu semasa telah membataskan penularan dan penerimaannya dalam bidang perubatan. Kajian ini bertujuan untuk merapatkan jurang tersebut dengan memberi pencerahan mengenai aplikasi emulsi berasaskan VCO, faedahnya kepada pengguna serta industri di seluruh dunia. Dengan menjalankan penyelidikan mengenai sifat-sifat semulajadi VCO dan sumbangan pentingnya kepada industri farmaseutikal, kajian ini dapat merangsang kefahaman dan penghargaan yang lebih baik tentang emulsi berasaskan VCO. Penemuan dalam kajian ini diharapkan dapat memberi pengiktirafan meluas mengenai potensi VCO terutamanya berperanan sebagai antioksidan dalam mencegah jangkitan penyakit, dan mempromosi pelbagai khasiat yang merujuk kepada pengurusan berat badan serta kesihatan metabolik. Ia juga boleh menjadi satu rujukan asas untuk penyelidikan serta pembangunan dalam penggunaan VCO pada masa hadapan bagi sektor industri farmaseutikal dan kesihatan.

**Kata kunci**: minyak kelapa dara, virus, antioksidan, polifenolik, metabolik

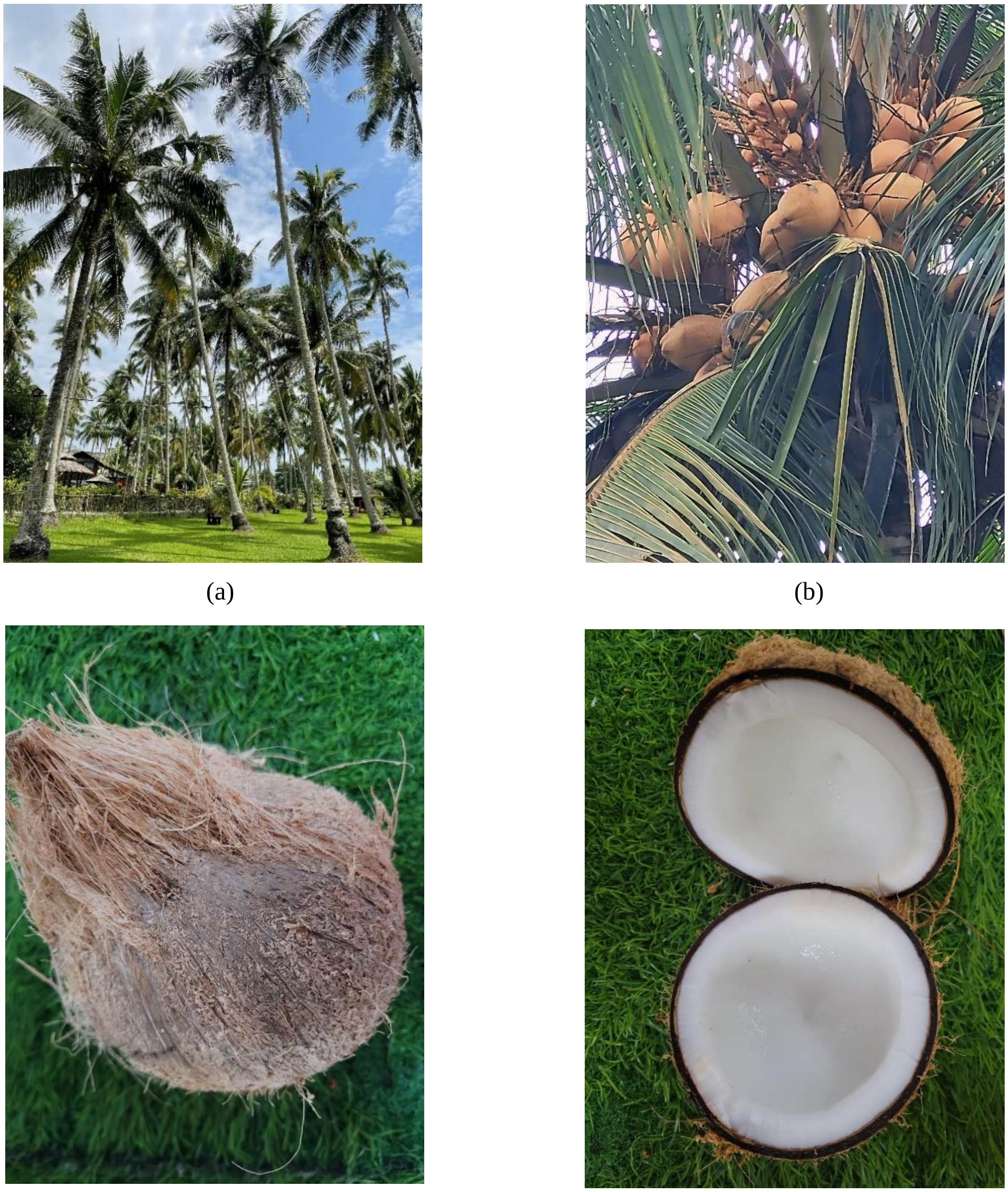
## Introduction

Virgin coconut oil (VCO) is oil extracted from *Cocos nucifera* L., commonly referred to as “the tree of life,” which belongs to the *Arecaceae* family (palm) [1,2]. It is one of the most essential plants, utilized for countless purposes globally. It is the only species of the genus Cocos known to have a tall trunk that may reach a height of 30 meters, pinnate leaves that are 4-6 meters long, and pinnae that are 60-90 cm long. Old leaves easily fall off, keeping the trunk smooth [3]. Figure 1 illustrates the *Cocos nucifera* L., commonly called the coconut tree. Fresh and matured coconut kernels are utilized by mechanical and natural techniques. No heating process is involved to maintain the natural quality of the oil [4].

VCO was identified as a colorless oil that retains its nutritional value and has a mild coconut scent by not undergoing refining, bleaching, or deodorizing. The phrase "cold extraction" refers to the process of extracting coconut oil from coconut milk without heating it [5]. The high stability of the coconut milk emulsion necessitates the destabilization of the coconut milk, which may be accomplished in three phases. The action of gravity separates the cream in the first step, resulting in two phases: the top phase with the creamy layer and the bottom phase with the watery layer. The second stage is flocculation and clustering, which involves the oil phase moving as a group without rupturing the interfacial coating that ordinarily covers it. The third step, coalescence [6], is the most crucial in the destabilization of coconut milk.

During this stage, the interfacial regions are ruptured and reduced, which aids in the joining of oil globules. This approach is more appealing due to the elimination of the solvent and the refining, bleaching, and deodorizing processes, which may minimize the investment cost and energy needs, making it more ecologically friendly than solvent extraction [5].

Chilling, freezing, and thawing break the stability of the coconut milk emulsion in this process, and thawed cream is separated by centrifugation. To enable better packing of the coconut oil globules, the emulsion was centrifuged before chilling and thawing [7]. The chilling and freezing processes were carried out at temperatures of 10 °C and -4 °C, respectively, while the thawing procedure was carried out in a water bath at 40 °C until the coconut cream reached room temperature (25 °C). Furthermore, this action aids in the removal of undissolved materials during extraction. The elimination of particles present in high percentages in the dispersion of oil seed was critical for successful oil recovery by centrifugation [8].



(a) (b) (c) (d)

Figure 1. (a) *Cocos nucifera* L. at Penaga, Penang (b) edible fruit of coconut palm (*Cocos nucifera* L.) (c) dried coconut shell (d) white coconut meat (endosperm)

Some studies have stated that because of a general prejudice against saturated fats, information about VCO has been kept hidden in medical journals. VCO has been shown to have the potential to protect against not only heart disease but a wide variety of chronic health problems, including diabetes and cancer, as well as to prevent and even treat infectious diseases [9,10]. Therefore, this review paper aims to present a summary of virgin coconut oil, covering its phytochemical properties, components, nutritional advantages, and industrial applications, based on recent studies and research discoveries.

**Phytochemical properties in *Cocos nucifera* L.** Phytochemicals are chemical substances obtained from plants or fruits and are potentially medicinal. Dietary fibers, polyphenol antioxidants, and their anti-inflammatory properties lower the risk of cancer [11,12]. Numerous studies examining the nutritional content of coconuts have been conducted in recent years, and the bulk of them have come to similar or almost identical conclusions [13]. According to this research, *Cocos nucifera* L. is a fantastic source of nutrients and phytochemicals. These phytochemicals are created in relatively tiny amounts by secondary metabolism. Tables 1 and 2 indicate the comparative phytochemical analyses of coconut copra extract and milled endosperm obtained using aqueous extraction and n-hexane. Alkaloids, tannins, and resins were found in high concentrations in the endosperm of *Cocos nucifera* L., according to phytochemical tests. This was demonstrated by the strength of the colored solution and precipitates that were produced upon detection [2,14,15].

Alkaloids are vital for both human medicine and an organism's natural defense systems. They account for roughly 20% of all known secondary metabolites in plants [16]. Their fundamental characteristics include being lipid-soluble in basic and neutral environments and water-soluble in acidic ones. This is particularly crucial for protonated form disintegration and deprotonated form membrane penetration [17]. In the plant kingdom, alkaloids serve as protective agents against predators and help regulate growth. Medically, they are celebrated for their anesthetic, cardioprotective, and anti-inflammatory properties. Prominent alkaloids utilized in clinical practice include morphine, strychnine, quinine, ephedrine, and nicotine [18]. Tannins are recognized for their wide range of physiological effects. They can accelerate blood clotting and lower blood pressure, as well as reduce serum lipid levels. Additionally, tannins have been reported to cause liver necrosis and modulate immune responses [19].

Glycosides and saponins were detected in modest amounts. The least concentrated substances were terpenoids and steroids [12]. Various cultures throughout the world have employed plant materials with saponins for their detergent characteristics for a very long time [20]. These plants have a high concentration of glycosides called saponins, which are distinguished by their capacity to create a foaming aqueous solution (Latin: sapo, soap). They are also very toxic when injected into the bloodstream and have hemolytic characteristics [21]. However, saponins are generally safe to consume when taken orally. For instance, sarsaparilla, which is high in saponins, is frequently employed in the brewing of non-alcoholic drinks [22].

Table 1. Comparative phytochemical analyses of coconut copra extract and milled endosperm obtained by aqueous extraction

| Parts of Coconut | Phytochemical Test | Reagent | Observation | Interference | Concentration | References |
|---|---|---|---|---|---|---|
| Coconut copra | Alkaloids | Dragendorff's reagent | Brick red precipitate | Alkaloids present | Low | [14,23] |
| | | Wagner's reagent | Reddish brown precipitate | | | |
| | Flavonoids | Ammonium test | No yellow colour change | Flavonoids absent | Not available | |
| | | Aluminium chloride test | No yellow colour change | | | |
| | Glycoside | Not available | Dense red precipitate | Glycosides present | Moderate | |
| | Saponins | Emulsion test | Emulsion formed | Saponins present | Moderate | |
| | | Frothing test | Stable froth formed | | | |
| | | Precipitate test | White precipitate | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Resin | Colour test | Light pink colour | Resins present | Moderate | |
| | Tannins | Ferric chloride test | No green precipitate | Tannins absent | Not available | |
| | Steroids | Conc. $H_2SO_4$ test | Reddish brown precipitate at interface | Steroids absent | Not available | |
| | Terpenoids | Conc. $H_2SO_4$ test | Red precipitate | Terpenoid absent | Not available | |
| | Acid compounds test | Moist litmus paper | No colour changes in moist blue litmus | Acid compounds absent | Not available | |
| Milled endosperm | Alkaloids | Picric acid | Light yellow precipitate | Alkaloids present | High | [12] |
| | | Mayer/s reagent | Milky precipitate | | | |
| | | Dragendorff's reagent | Brick red precipitate | | | |
| | | Wagner's reagent | Reddish brown precipitate | | | |
| | Flavonoids | Aluminium chloride test | No colour change | Flavonoids absent | Not available | |
| | Glycoside | Not available | Dense red precipitate | Glycosides present | Moderate | |
| | Saponins | Emulsion test | Emulsion formed | Saponins present | Moderate | |
| | | Frothing test | Stable froth formed | | | |
| | Resin | Precipitate test | Precipitate formed | Resins present | High | |
| | | Colour test | Light colour change | | | |
| | Tannins | Lead rub acetate test | White gelatinous precipitate | Tannins present | High | |
| | | Ferric chloride solution test | Green colours change to red | | | |
| | Steroids | Conc. $H_2SO_4$ test | Reddish brown precipitate at interface | Steroids present | Low | |
| | Terpenoids | Conc. $H_2SO_4$ test | Presence of grey colour | Terpenoids present | Low | |
| | Acid compounds test | Moist litmus paper | No colour changes in moist blue litmus | Acid compounds absent | Not available | |

Table 2. Comparative phytochemical analyses of coconut copra extract and milled endosperm obtained by *n*-hexane

| **Parts of Coconut** | **Phytochemical Test** | **Reagent** | **Observation** | **Interference** | **Concentration** | **References** |
|---|---|---|---|---|---|---|
| | Alkaloids | Dragendorff's reagent | Brick red precipitate | Alkaloids present | Low | |
| | | Wagner's reagent | Reddish brown precipitate | | | |
| | Flavonoids | Ammonium test | No yellow colour change | Flavonoids absent | Not available | |
| | | Aluminium chloride test | No yellow colour change | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Glycoside | Not available | Dense red precipitate | Glycosides present | Moderate | |
| | Saponins | Emulsion test | Emulsion formed | Saponins present | Low | |
| | | Frothing test | Stable froth formed | | | |
| Coconut copra | Resin | Precipitate test | White precipitate | Resins present | Low | [14,23] |
| | | Colour test | Light pink colour | | | |
| | Tannins | Ferric chloride test | No green precipitate | Tannins absent | Not available | |
| | Steroids | Conc. $H_2SO_4$ test | Reddish brown precipitate at interface | Steroids absent | Not available | |
| | Terpenoids | Conc. $H_2SO_4$ test | Red precipitate | Terpenoid absent | Not available | |
| | Acid compounds test | Moist litmus paper | No colour change in moist blue litmus | Acid compounds absent | Not available | |
| | Alkaloids | Picric acid | Light yellow precipitate | Alkaloids present | High | |
| | | Mayer/s reagent | Milky precipitate | | | |
| | | Dragendorff's reagent | Brick red precipitate | | | |
| | | Wagner's reagent | Reddish brown precipitate | | | |
| | Flavonoids | Aluminium chloride test | No colour change | Flavonoids absent | Not available | |
| | Glycoside | Not available | Dense red precipitate | Glycosides present | Moderate | |
| | Saponins | Emulsion test | Emulsion formed | Saponins present | High | |
| Milled endosperm | | Frothing test | Stable froth formed | | | [12] |
| | Resin | Precipitate test | Precipitate formed | Resins present | High | |
| | | Colour test | Light colour change | | | |
| | Tannins | Lead rub acetate test | White gelatinous precipitate | Tannins present | Moderate | |
| | | Ferric chloride solution test | Green colour change to red | | | |
| | Steroids | Conc. $H_2SO_4$ test | Reddish brown precipitate at interface | Steroids present | Low | |
| | Terpenoids | Conc. $H_2SO_4$ test | Presence of grey colour | Terpenoids present | Low | |
| | Acid compounds test | Moist litmus paper | No colour change in moist blue litmus | Acid compounds absent | Not available | |

**Components in virgin coconut oil**

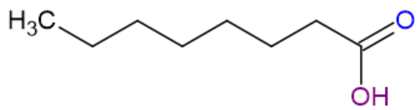
The primary triglyceride components of VCO were revealed to be dicapric monolaurin (14.32%), dilauric monocaprin (18.59%), trilaurin (21.88%), dilauric monomyristin (17.20%), and dimyristic monolaurin (9.62%) [14]. Since medium-chain triglycerides (MCT) are completely hydrolyzed by the pancreatic enzyme lipase into glycerol, monoglycerides, and fatty acids, medium-chain fatty acid (MCFA) molecules are very easily absorbed by the body [24]. Medium-chain monoglycerides (MCMs), such as monocaprylin, monolaurin, monocaprin, and monomyristin, are compounds with a single carbon chain length varying from 8 to 14 atoms in the acyl groups [25]. Caproic acid, caprylic acid, capric acid, lauric acid, and myristic acid are among the MCFAs in VCO [25, 26]. Table 3 and Figure 2 show the fatty acids, and their chemical structures found in coconut oil, respectively [9].

Table 3. Fatty acids found in coconut oil

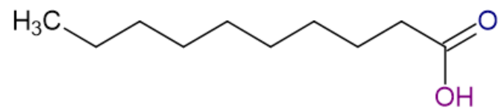
| Medium-Chain Fatty Acid (MCFA) | Molecular Formula | Fatty Acids Found (%) |
|---|---|---|
| Caprylic acid (C -8:0) | $C_8H_{16}O_2$ | 8 |
| Capric acid (C-10:0) | $C_{10}H_{20}O_2$ | 7 |
| Lauric acid (C-12:0) | $C_{12}H_{24}O_2$ | 49 |
| Myristic acid (C-14:0) | $C_{14}H_{28}O_2$ | 8 |
| Palmitic acid (C-16:0) | $C_{16}H_{32}O_2$ | 8 |
| Stearic acid (C-18:0) | $C_{18}H_{36}O_2$ | 2 |
| Oleic acid (C-18:1) | $C_{18}H_{34}O_2$ | 6 |
| Linoleic acid (C-18:2) | $C_{18}H_{32}O_2$ | 2 |

MCMs and MCFAs are bioactive forms of MCTs with a wide range of pharmacological properties that can aid in enhancing the immune system, treating conditions like inflammatory, gastrointestinal [27], and cardiovascular diseases, and combating a wide range of bacterial, fungal, and viral infections [28,29]. Since VCO is rich in MCFAs, which are first digested or metabolized in the body from carbohydrates, it can help reduce appetite. As a result, people consume fewer carbs, aiding in obesity reduction by increasing metabolism rates when ingested in the liver [30,31]. These MCFAs do not participate in the creation and transport of cholesterol because VCO is rich in medium-chain saturated fatty acids (lauric acid), which allow them to be immediately absorbed from the intestine and transported straight to the liver to be quickly utilized for energy generation [32]. Developing nations in West Africa that are coping with the nutrition shift and its accompanying rise in chronic diet-related diseases such as obesity and heart disease might benefit from coconut oil's cardioprotective properties [9,10].

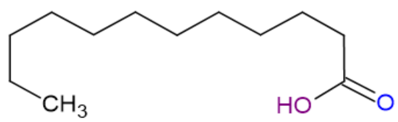
VCO, also known for its polyphenolic content, has a cardioprotective impact that can be helpful by decreasing lipid components, enhancing antioxidant enzymes, and lowering lipid peroxide levels [30]. VCO can also be utilized as an antioxidant and has an effect on healing after an ovariectomy [33]. Additionally, VCO can help to lower blood pressure [34,35]. Moreover, VCO can be used as an external medicament for cosmetics, such as wound medicine, and as a probiotic [31]. Because of its therapeutic significance, VCO has sparked a lot of attention in recent years [36]. On a daily basis, consumers are becoming more aware of the value of organic, non-chemically produced edible oils [37]. Many consumers, however, dislike the texture of VCO since it includes saturated fatty acids that are solid at ambient temperature. A revised VCO formulation was recently created to improve its appeal and stability, as well as to reduce the oily taste and texture of VCO. This new formulation is made into VCO in the form of an emulsion, which benefits both the VCO-producing industries and the VCO-consuming industries [38].



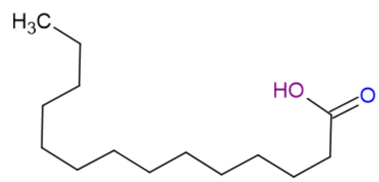

(a) Caprylic acid



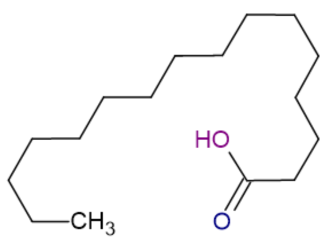

(b) Capric acid



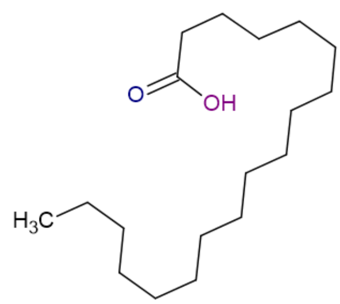

(c) Lauric acid



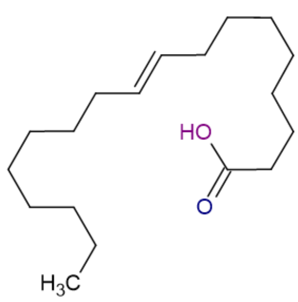

(d) Myristic acid



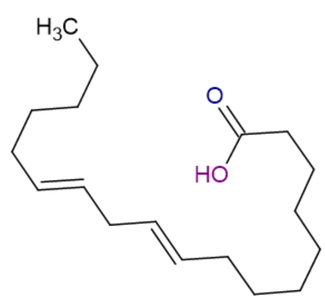

(e) Palmitic acid




(f) Stearic acid




(g) Oleic acid




(h) Linoleic acid

Figure 2. The chemical structures of medium-chain fatty acids (MCFA) in VCO (a-h)

**Virgin coconut oil as antiviral and antimicrobial properties**

VCO has been reported to have antibacterial, antiviral, antinociceptive, and anti-inflammatory properties [39,40]. Lauric acid, a primary fatty acid in VCO, is responsible for its potent antiviral and antibacterial properties [41]. The lipid membrane of bacteria can be destroyed by monolaurin, which is produced from the lauric acid in VCO [42]. This feature of VCO enables it to function as a natural food preservative by destroying microorganisms. According to reports, immersing chicken meat in VCO can increase the protein content and shelf life of the meat while lowering the moisture content and bacterial colony count. The shelf life of chicken meat kept at room temperature has been extended by soaking it for two hours in VCO [2].

The antibacterial activity of lauric acid, monolaurin, and various ester derivatives can be categorized into three primary pathways: 1) interference with biological functions including signal transmission and transcription, 2) destruction of gram-positive bacteria and lipid-coated viral cell membranes through physicochemical mechanisms, and 3) stabilization of human cell membranes. The existence of these multiple pathways may be one of the factors preventing bacteria from developing tolerance to these substances' effects [41].

Monolaurin has been demonstrated to reduce the transcription of Toxic Shock Syndrome Toxin-1 (TSST-1) and anti-hemolysin (thus reducing virulence) and also hinders the induction of beta-lactamase production (thus inhibiting antibiotic resistance) [43]. The bacterial cell membrane's surface receives signals that activate the transcription of virulence proteins and antibiotic-resistance genes [44]. Gram-negative cell membranes are thicker due to a substantial coating of lipopolysaccharide, which allows lipophilic free fatty acids (FFAs) to easily mix into them. Gram-positive cell membranes have a thinner fat layer, but monolaurin, a non-ionic surfactant with polar and hydrophobic sides, can damage and lyse them as well. Exoproteins are produced by bacterial cells through membrane-associated processes [43]. By disrupting the cell membrane, monolaurin disrupts this stage in which external metabolites activate signal transduction receptors on the cell membrane, which in turn activate exoprotein genes.

Another mechanism of action is to prevent biofilm formation by acting as a surfactant on vulnerable substrates, such as catheters, stents, or prosthetics, and preventing bacteria from laying down the initial lipid-rich biofilm [45]. Table 4 summarizes the antimicrobial activities of VCO.

**Medium-chain fatty acids in VCO reduce obesity**

A research study has stated that obesity is linked to a persistent low-grade inflammation state and is a risk factor for inflammatory and metabolic illnesses [52]. Obesity is caused by a variety of variables, including genetics, lifestyle choices, environmental exposures, and the microbiome, but one of the most important causes is still nutrition, both in terms of the quantity and type of calories ingested [53]. Low-fat diets, physical exercise, and medication are the most regularly employed techniques for the treatment of obesity and subsequent illnesses [54]. Nonetheless, medication is frequently accompanied by negative side effects [55]. In this regard, researchers have been looking for some dietary substances, such as polyphenols and specific fatty acids, that have the ability to treat obesity-related metabolic diseases by laying down the first lipid-rich biofilm [52].

VCO, also known for its polyphenolic content, has a cardioprotective impact that can be helpful by decreasing lipid components, enhancing antioxidant enzymes, and lowering lipid peroxide levels [30]. VCO can also be utilized as an antioxidant and has an effect on healing after an ovariectomy [33]. Additionally, VCO can help to lower blood pressure [34,35]. Moreover, VCO can be used as an external medicament for cosmetics, such as wound medicine, and as a probiotic [31]. Because of its therapeutic significance, VCO has sparked a lot of attention in recent years [36]. On a daily basis, consumers are becoming more aware of the value of organic, non-chemically produced edible oils [37]. Many consumers, however, dislike the texture of VCO since it includes saturated fatty acids that are solid at ambient temperature. A revised VCO formulation was recently created to improve its appeal and stability, as well as to reduce the oily taste and texture of VCO. This new formulation is made into VCO in the form of an emulsion, which benefits both the VCO-producing industries and the VCO-consuming industries [38].

Table 4. Antimicrobial activities of VCO

| No. | Microorganism Tested | Activity | References |
|---|---|---|---|
| 1. | *Staphylococcus aureus* | Lactic acid has a synergistic impact in the presence of lauric acid and monolaurin, which is assumed to be owing to enhanced fatty acid absorption into the membrane, leading in membrane disruption. | [46] |
| 2. | *Staphylococcus aureus, Salmonella typhi* and *Escherichia coli* | Saponification or an enzymatic process converts fat into fatty acids and monoglycerides. Hydrolysis by the enzyme lipase (lipozyme) or partial hydrolysis of VCO boost bacterial inhibition. | [47] |
| 3. | *Enterococcus faecalis* | Restricted biofilm growth as indicated by fewer viable biofilm-associated microorganisms and lower biofilm biomass | [48] |
| 4. | *Clostridium diffificile* | It is metabolised by digestive lipases, releasing specific fatty acids and eventually limiting the development of microbes in vivo. | [49] |
| 5. | *Clostridium perfringens* | Not available | [50] |
| 6. | *Staphylococcus aureus, Streptococcus pneumoniae, Escherichia coli, Salmonella* species and *Mycobacterium tuberculosis.* | Not available | [51] |

Coconut oil appears to aid in weight loss and the improvement of metabolic markers related to obesity [56]. Because of its short chain length, MCFA is easily hydrolyzed and absorbed, participating in cholesterol transport and providing a fast source of energy [57]. MCFA enters the portal circulation after absorption in the proximal intestine and is delivered to the liver bound to albumin [58]. A tiny fraction remains in the circulation and is accessible to peripheral tissues, rather than being stored in adipocytes. After being transported across the mitochondrial membrane by acyl CoA synthases, MCFA is mostly employed in hepatic oxidation [59].

**Antioxidant properties in VCO**

Natural phenolic substances, which are widely distributed as secondary metabolites in berries, fruits, vegetables, coffee, herbs, and edible oils, include main categories such as phenolic acids, phenolic alcohols, and flavonoids. These plant phenolic compounds have garnered significant attention from researchers due to their potent antioxidant properties, with the mechanisms of their antioxidant activity being well-established [60]. Coconut oil stands out from other seed oils because it includes the skin of the coconut kernel, known as the 'coconut testa,' which significantly boosts its phenol content [2]. The solubility of polar phenolic compounds in non-polar coconut oil increases at high temperatures, giving virgin coconut oil (VCO) higher phenolic-dependent antioxidant capabilities compared to copra oil [61]. Among the phenolic compounds found in VCO are caffeic acid, p-coumaric acid, and ferulic acid [62]. Interestingly, syringic acid, which is present in VCO, is not found in refined bleached deodorized coconut oil, highlighting the superior phenolic profile and potential health benefits of VCO [63].

The antioxidant capability of plants is directly related to their phenolic content. VCO has been researched for its antioxidative properties, which include impacts on many antioxidant pathways in the body. The antioxidant activity of specific compounds and extracts of natural products (such as coconut oil) is typically measured using both chemical and automated assays and technologies [64]. These compounds help protect the human body in several ways. They neutralize harmful free radicals by donating electrons, which stop these radicals from damaging our cells. They also bind to metal ions, which prevent these metals from creating more free radicals. Additionally, they inhibit certain enzymes that contribute to oxidative stress. Altogether, these actions help VCO protect our cells from getting damaged and eventually support our overall health and well-being [45,61,65].

There has been a growing number of studies focusing on the phenolic fraction of coconut oil. Emulsions of virgin coconut oil (VCO) containing ferulic acid and p-coumaric acid have been prepared with various sweeteners to enhance the palatability of VCO [66]. The inclusion of VCO in dark chocolate formulations has demonstrated that the phenolic compounds in VCO enhance the nutritional properties of dark chocolate [67]. Recent studies indicate that coconut oil improves the absorption of phenolic compounds in both rats and humans, suggesting that the naturally occurring phenolic compounds in coconut oil are more bioavailable than those in aqueous foods [68].

## Future recommendations

Virgin Coconut Oil (VCO) is currently receiving significant attention due to increased awareness of its potential health benefits. Production of coconut value-added products primarily serves local markets in underdeveloped nations and represents a cottage industry. Governments should implement robust supportive policies to promote widespread distribution of coconut products in both rural and urban areas. Future research on VCO is likely to focus on its anti-inflammatory effects, notwithstanding its marketing as the latest "superfood" with attributed features ranging from weight loss promotion to cancer prevention. This shift is a result of growing scientific interest in inflammation as a potential mechanism underlying various diseases.

Recent research indicates that VCO exhibits antiviral and immunomodulatory properties, which can complement antiviral medications in preventing host cell infection, halting viral replication, or mitigating the severe inflammatory effects of COVID-19. VCO's antiviral and immunomodulatory attributes can hinder virus spread and enhance the immune system's ability to combat infections, respectively. Other phytochemical compounds present in VCO, including tocopherol, tocotrienol, flavonoids, and polyphenols, act as antioxidants, preventing oxidative stress, inflammation, and neuronal death. Furthermore, phytosterols in VCO reduce LDL cholesterol levels by inhibiting its absorption, which benefits individuals with type 2 diabetes. Despite its high saturated fat content, VCO has been studied as a dietary supplement with positive outcomes and no adverse effects reported. Long-term ingestion of VCO has been deemed safe, with an eight-week daily regimen showing no increased risk of cardiovascular disease.

In summary, future research is likely to focus on VCO's anti-inflammatory and ketogenic/lipid oxidizing effects, particularly in the context of preventing COVID-19 caused by the SARS-CoV-2 virus and aiding weight reduction. Although findings in these areas are preliminary, they have been central to recent studies on VCO's health impact, indicating ongoing research into VCO's effects on inflammation, lipid levels, weight reduction, and SARS-CoV-2.

## Conclusion

Due to growing public awareness of its health benefits, VCO is gaining popularity as a functional food oil. VCO is obtained without the use of chemical refining, bleaching, or deodorizing processes, preserving essential amino acids, tocopherols (vitamin E), and other valuable compounds found in coconut oil. The demand for VCO has increased due to recent publications highlighting its health benefits. The medium-chain fatty acids (MCFAs) in VCO, particularly lauric acid, are metabolized to create ketone bodies, serving as a rapid energy source without accumulating as fat. VCO contains increased levels of saponification, phenolic compounds, and tocopherols, along with low iodine and peroxide values, making it a potentially beneficial addition to a typical diet.

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