Title: Chemical Composition and Health Benefits of Coconut oil: An Overview

Running Title: *Health benefits of coconut oil*

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Abstract

Coconut oil is an integral part of Sri Lanka and many South Asian diets. Initially, coconut oil was classified along with saturated fatty acid food items and criticized for its negative impact on health. However, research studies showed that coconut oil is a rich source of medium-chain fatty acids. Thus, this has opened new prospects for its use in many fields. Beyond its usage in cooking, coconut oil grabs attention due to its hypocholesterolemic, anticancer, anti-hepatosteatotic,anti-diabetic,antioxidant,anti-inflammatory,anti-microbial and skin moisturizing properties. Despite all the health benefits, consumption of coconut oil is still underrated due to a lack of supportive scientific evidence. Even though studies done in Asian countries acclaim for the favorable impact on cardiac health and serum lipid profile, the limitations in the number of studies conducted among western countries impede the endorsement of the real value of coconut oil. Hence, long term extensive studies with proper methodologies are suggested to clear all the controversies and misconceptions of coconut oil consumption. This review discusses the composition and functional properties of coconut oils extracted by different processing methods.

Key Words: Coconut oil, Composition, Medium-chain fatty acids, Functional properties

1. Introduction

The coconut tree *(Cocos nucifera* L.) is considered as a precious gift from nature to mankind. It is also known as the "tree of life" since each part of the tree has its own value.[1,2] Coconut is the major source of fat in the diets of South Asians and South East Asians. Coconut development authority of Sri lanka reports that 60 % of total harvest was locally consumed in year 2015-2016. Despite the large consumption of coconut oil (CNO), Sri Lankans have a higher life expectancy than countries where coconut consumption is comparatively low.[3] Athauda *et al*.[4] examined the health effects of CNO consumption in Sri Lanka from 1992 to 2006 revealed that there was a consistency of CNO consumption during the period along with a negative correlation with the increased cardiovascular disease (CVD) death rates in the country. Thus, the study showed that a rise in cardiac mortality was unlikely due to CNO consumption in Sri Lanka. Recently,the demand for CNO has rapidly increased among western countries due to its incredible health benefits. Further, the Asian Pacific coconut community records show that CNO export from Asia has grown up to 3.3% annually over a five year period of time.[4]

The basic chemistry of CNO was figured out back in the 1920s and 1930s. Back then it was found to contain approximately 90% saturated fatty acids (SFAs) of the total fat contentand condemned for its adverse effects on health.[5–9] However, it was found that some of the nutritional and therapeutic benefits of CNO were due to saturated fatty acid in the oil leading to properties such as resistance to oxidation, long shelf life and remarkable taste and flavor in cooking.[10] Later on it was found that CNO was composed of medium-chain fatty acids(MCFAs) which correspond to 64% of total fat and made it unique and remarkable[1]. In addition to medium-chain fatty acids, CNO contains phospholipids, tocopherol, and other

minor constituents. CNO is also referred to as lauric oil since it contains approximately 40-50% of lauric acid of the overall fatty acid composition.[11-13] The significant presence of lauric acid plays an important role in making CNO chemically uniqueamong other oils.[14]

Numerous research studies have demonstrated the beneficial effects of CNO breaking out all the misconceptions that it held for ages due to being a source of SFA. Health advisors claim that this sensational food has remarkable functional properties such as hypocholesterolemic, anti-obesity, anti-hepatosteatotic, antioxidant, anti-inflammatory, anti-microbial including HIV preventive activity and cardio protective effect (Table1) [15-17]. Moreover,CNO exerts anti-diabetic property by balancing blood sugar levels. Marten *et al.* [18] showed that medium-chain triglycerides (MCTs) present in CNO improve insulin secretion and insulin sensitivity.Further, CNO is gaining attention as a potential cancer controlling and chemotherapy protective agent.[6] Apart from major health claims the abundance of vitamin E in CNO aids in soothing hair and skin.[19]

Despite the substantial amount of studies conducted to reinforce the beneficial health properties of CNO, the hypocholesterolemic and cardioprotective effects of oil remain under controversy.[11,12,20] A recent review, including 21 research studies stated that CNO is unhealthy in terms of cardioprotection.[12] However, studies by Nevin *et al.*[21] , Cox et al.[22] and Feranil *et al.*[23] showed CNO consumption has a positive effect on serum lipid profile and hypocholesterolemic effect. Thus, there are limitations in predicting the fact that CNO is completely healthy in terms of cardioprotection,and well-planned studies are needed to clear the disagreements.The main aim of this review is to focus on the composition along with the beneficial functional properties exerted by CNO.

2. Composition of coconut oil

CNO has become one of the most desired oils in the world due to its high degree of saturation and good stability. There are different types of CNO derived from different parts of the coconut. Copra oil (CO) is extracted from the dried kernel by mechanical milling and Virgin coconut oil (VCO) is extracted from the fresh kernel without high heat or chemical treatment. The oil extracted with isopropyl alcohol from coconut testa is known as coconut testa oil (CTO).[24] CNO is predominately composed of SFAs which account for 90% of its composition.[6] In addition to triacylglycerols (TAG) esterified with component fatty acids, CNO contains other minor components such as phospholipids, sterols, tocopherols, and volatile substances. Presence of these substances plays an important role in modulating the chemical and physical characteristics of CNO.[25] For instance, the melting pattern of CNO, which passes abruptly from solid to a liquid within a short-range, is mainly due to the nature of the composition. Also,VCO is found to be healthier than commercial CO due to its medium-chain saturated fatty acid content and higher amounts of polyphenols.[26] Hence, it is vital to understand the relationship of the composition tothe exact health benefits exerted by the oil.

2.1 Fatty acids

Fats and oils are concentrated forms of energy and the energy is obtained from the complete oxidation of fatty acids in food. Generally,fatty acids (FAs) are classified according to chain length and the degree of saturation. Concerning the degree of saturation, fatty acids can be classified as saturated (SFA), monounsaturated (MUFA), and poly-unsaturated (PUFA) fatty acids. Further, based upon chain length it can be sub-grouped into short (C2–C6), medium-

(C8–C12) and long- (C14–C24) chain fatty acids.[27] SFA are generally considered to be hypercholesterolemic, whereas, MUFA thought to be mildly hypercholesterolemic and (PUFA) are hypocholesterolemic.

CNO contains 92 % of SFA, which is significantly greater than other commonly consumed vegetable oils. A portion size of 100 g of CNO is found to contain 890 kcal and 82.5 g of saturated fat.[28] Thus, CNO is always classified along with butter, palm oil, and animal fats due to its high content of SFA. Multiple reports confirmed that the major fatty acids of CNO are lauric (12:0), myristic (14:0), and palmitic (16:0) acids, which represent about 32-51 %, 17-21 % and 6.9 -14 % respectively (Table 2). A comprehensive study by Zambiazi *et al.*[29] also revealed that lauric was the major fatty acid present in CNO comprising 45 % of total fatty acids.

Interest in medium-chain fatty acids (MCFAs) in plant oils has grown rapidly over the last few years due to the increasing awareness of their health benefits.[9] In contrast to long-chain fatty acids (LCFAs), MCFAs have smaller molecular sizes and lower melting points. Further, MCFAs are liquid at room temperature and less energy-dense (8.4 versus 9.2 kcal g^{-1}). These distinct physiochemical characteristics make MCFAs unique in terms of absorption and metabolism compared to LCFAs.[18] As such, they are directly absorbed by the intestine and sent to the liver to be used as energy.[6]Among various plant oils, coconut, palm kernel, and babassu oils are the only commercially important sources of MCFAs.[6]According to multiple reports, the health benefits exerted by CNO are attributed to its high content of MCFAs which correspond to 64% of the total fatty acids.[1,30] A comparative study done on five edible oils involving sunflower oil (5 samples), soybean oil (3 samples), palm oil (3 samples), mustard oil

(5 samples), and coconut oil (6 samples) showed that coconut oil had the highest MCFAs.[27] Further,a comprehensive study involving fourteen vegetable oils revealed that coconut oil had the highest percentage of MCFAs and the lowest percentage of LCFAs.[31]

2.2 Phenolic compounds

Phenolic compounds are important phytochemicals that exhibit several bioactive properties including antioxidant activity.[32] Several plant oils are known to be excellent sources of phenolics that can scavenge free radicals produced in our bodies.[33] Unlike other plant oils, studies focused on quantitative and qualitative analysis of phenolic compounds of coconut oil is less common. According to previous studies, phenolic acid present in CNO are attributed to health benefits such as anti-inflammatory, anti-hepatosteatotic, antioxidant and chemoprotective activities.[26] However,the method of processing such as wet processing and dry processing plays a significant role in modulating phenolic compounds present in CNO.[34] Likewise, phenolic content of the VCO is perceived to be higher than ordinary CNO. Hence, phenolic content in VCO has grabbed the attention of many. Several studies were reported on quantitative and qualitative analysis of phenolic compounds present in VCO.[26,34–36] A previous study by Seneviratne *et al.*[37] indicated that phenolic compounds such as ferulic,p-coumaric and catechin present in coconut oil aids in exerting antioxidant activity.[33] Information in (Table 3) summarizes the phenolic acid composition of different types of CNOs.

2.3Triacylglycerol

The major triacylglycerol (TAG) species of CNO are CCLa, CLaLa, LaLaLa, and LaLaM (where C for capric, La for lauric, M for myristic) and the rest of the remaining molecules

represent TAG molecular types, which occur in less than 10% level. Owing to their esterification with MCFA, the dominant TAG molecules of CNO are popularly known as medium-chain TAGs, which attributes to the nutritional significance and functional properties of CNO[38]. The major triacylglycerols of CNO are about 19 % of trilaurin (C36) followed by 16 % each of diaurylcapryl glycerol (C34) and diaurylmyristylglycerol (C38) and 10 % each of lauryldicaprylglycerol (C32) and lauryldimyristyglycerol (C40).[25] Confirming the above fact, a study by Bezard *et al.*[39] revealed that trilaurin represented10.6% of coconut oil TAGs. Despitethe high content of saturated fatty acids, CNO has still become an elite choice of treating certain alarming health conditions and promoting weight loss due to the presence of MCTs.[1]

2.4Phospholipids

Phospholipids are generally found in most natural oils and fats yet the amount and the composition differ depending on the source of origin.[40] As an important functional attribute, they are known to have a stabilizing effect on fatty foods. Moreover, crude CNO has a relatively low amount of phospholipids (0.2%) in comparison to other vegetable oils(1-3%).[25]The major components of the phospholipids present in CNO are phosphatidylcholine (34.6% total phospholipids), phosphatidylethanolamine (24.6%) and phosphatidylinositol (19.0%).[25]

2.5 Tocopherols (as Vitamin E)

Tocopherols (as Vitamin E) are the lipid-soluble natural antioxidants found in most vegetable oils. Among various vegetable oils, CNO is relatively low in tocopherols since it is less prone to auto-oxidation due to the low degree of unsaturation.[25] Researchers across the globe agreed that occurrence of the higher amount of tocopherols in oils is a self-defense mechanism to

protect oils. For instance, Schwartz *et al*.[41] reported that CNO contained the lowest amount of tocopherols(0.32mg/100g) when compared to olive oil (18mg/100g), extra virgin olive oil (26mg/100g), sunflower oil (63mg/100g) and corn oil (66mg/100g). Yet another study also confirmed that CNO had the lowest amount of tocopherol (1.7 mg/100g) among various vegetable oils.[42] Despite the low amount of tocopherols present in CNO, it prevents air oxidation, and aids in exerting anti-cancer properties and soothing effect on hair and skin.[8,43]

2.6 Sterols

In recent years, sterols received greater attention among researchers due to their hypocholesterolemic capacity and potential contribution to a decreased risk of cardiovascular diseases.[44] In edible oils, sterols are primarily in the free and esterified forms.[45] The sterol content of crude CNO was reported to be 100mg /100g[35]. According to Sabir*et al*.[46] coconut contained the lowest amount of sterols (0.8mg/g) when compared to other edible vegetable oils such as corn (23mg/g) and soybean (9 mg/g). A comparative study by Schwartz *et al*.[41] also confirmed the lowest content sterol (114mg/100g) compared to olive oil (283mg/100g), extra virgin olive oil (256mg/100g), sunflower oil (451mg/100g) and corn oil (871mg/100g). Several studies report the ability of β-sitosterol and stigmasterol on controlling cancer by inhibiting cancer cells in esophageal tissues, ovaries, breast, colon, and prostate. Despite lower content of sterol ,β-sitosterol was found to be the major sterol present in CNO, which corresponds to 70.4% of the total sterol fraction.[25] Supporting the fact, study by Schwartz *et al*.[41] showed that the sitosterol content of coconut oil (45mg/100mg) was greater than other sterols estimated in the study. Thus, the high content of β-sitosterol helps in understanding the anti- cancer ability of CNO.

2.7 Volatile compounds

The total volatile compounds of crude CNO was reported to be about 900 mg/dm^3. The two volatile compounds identified were methyl ketones of odd carbon number (CN) from CN-7 to CN-15 and gamma–lactones of even carbon number from CN-6 to CN-14.[25] Generally, ketones present in crude oil are a result of microbiological decomposition of fatty acids in the oil before it was pressed or extracted. This was further confirmed by the analysis of fresh CNO, which depicted the absence of the ketones.[12] Also the significant amount of lactones present in crude CNO is believed to be responsible for the flavor and aroma of coconut.[12] Confirming the above fact, a study done by Santos *et al.*[47] on volatile organic compounds in VCO and their sensory attributes revealed that lactones impart the coconut-like aroma and presence of octanoic acid was responsible for rancidity and acid-like aroma in the oil.

3. Functional properties of coconut oil

3.1. Hypocholesterolemic effect and cardioprotective effect

Owing to the perceived health benefits associated with CNO, the use of CNO and related products has increased over the past decade, particularly in the Western market.[20] The main concern limiting the widespread use of CNO is its reported link to the development of cardiovascular diseases. Despite the various health benefits reported for CNO, the reports on the relationship between CNO consumption and cardiovascular healthare are scarce and controversial.

Blood cholesterol is explained in terms of total cholesterol (TC), Low-Density Lipoprotein (LDL-C), High-Density Lipoprotein (HDL-C), and Very Low-Density Lipoprotein (VLDL-C) cholesterol.[48] Derangements in the blood lipid profile are considered as an important factor indicating increased risk for cardiovascular complications. Human feeding studies have proven the beneficial effect of coconut fats on HDL-C without a doubt. Several studies report coconut fat to increase HDL-C, the so-called good cholesterol in the blood with no significant effect on the total and LDL cholesterol levels.[6,49–52] Increase in total and LDL-C is associated with the pathogenesis of cardiovascular complications.In a randomized, controlled, cross-over trial, involving healthy volunteers aged between 18 and 25, VCO supplementation (30 mL/day for 8 weeks)improved HDL-C, with no change in TC and LDL-C compared to the control (2% carboxyl methylcellulose).[53] Similar type of outcome was reported by Damayanti*et al*.[50] where the CNO intervention (35 g/day) for 8 weeks significantly increased HDL-C and reduced the plasma inflammatory markers-associated with CVD, the soluble vascular cell adhesion molecule 1 (sVCAM1) and the matrix metalloproteinase levels compared to the peanut oil interventionVoon *et al.*[54] conducted a randomized crossover study in 45 healthy Malaysian adults to investigate the effect of virgin olive oil, palm olein and coconut oil consumption for 5 weeks on thrombogenicity indices and cell adhesion molecules. The three tests-fat diets did not affect thromboxane B2 (TXB2), TXB2/PGF1α ratios, and soluble intracellular and vascular cell adhesion molecule levels (sICAM, sVCAM) significantly. However, the olive oil diet effectively reduced the plasma proinflammatory LTB4 levels compared to the other two test diets.

A recent randomized trial conducted with 94 men and women (healthy) in the UK to study the effect of daily consumption of 50 g of extra-virgin coconut oil or extra-virgin olive oil or unsalted butter for 4 weeks showed no significant difference in the serum LDL-C levels between short-term consumption of extra-VCO and extra-virgin olive oil. LDL-C level was found to be significantly higher in the butter treated group compared to those treated with the extra-VCO and extra-virgin olive oil [51]. Also, CNO treatment significantly increased the HDL-C level compared to the other two test diets.[51] Extra VCO is reported to retain the phenolic compounds better than the standard CNO. Polyphenols present in VCO are identified as a great source, which can help in attenuating CVD risk factors.[55–57]A study to evaluate the beneficial effects of VCO over copra oil revealed that VCO was more effective in improving the serum lipid profile (total cholesterol, triglycerides, phospholipids, LDL, and VLDL cholesterol levels and increased HDL cholesterol in serum and tissues) than copra oil.[58] The positive outcome was attributed to the occurrence of high polyphenolic content in VCO.

Contrary to studies reporting a protective effect of coconut consumption on CVD, several studies also report the negative impact of CNO on the biomarkers of CVD. According to a review presented by Eyres *et al.*[12], covering 8 clinical trials and 13 observational studies, CNO was found to raise the TC and LDL-C in general, compared to other plant oils with unsaturated fatty acids, but not as much as butter. Two recent systematic reviews indicated CNO consumption to significantly increase the LDL-C and HDL-C levels.[59,60] For instance, Neelakantan*et al.*[59] indicated that CNO consumption would increase the LDL-C and HDL-C levels by 10.47 and 4.00 mg/dL, respectively, compared to non-tropical vegetable oils. According to Teng *et al.*[60], CNO significantly raised LDL-C by 0.26mg/dL and reduced HDL-

C by 0.37mg/dL in comparison to animal fats. Feranil *et al.*[23] examined the association between CNO consumption and lipid profiles in a cross-sectional, community-based study involving 1,839 of pre-menopausal Filipino women (age 35–69 years). According to this study, the levels of TC, LDL-C, HDL-C, and triglycerides were found to increase with increasing coconut oil consumption. In another study, Cox *et al*.[61] compared the effect of CNO, safflower, and butter consumption on the blood lipid levels of healthy and moderately hypercholesterolemic individuals.[62] The test was designed in a way to derive at least 50% of the total fat energy from the test fat. Both studies demonstrated that consumption of CNO to significantly increase the serum LDL-C levels than the safflower oil. However, the LDL-C levels of these groups were significantly lesser than that of the butter group. Another study comparing effects of palm olein, corn oil, and CNO on serum lipids of healthy subjects (75% of the fat calories from test fats) reported CNO to increase the TC levels by over 10% compared to the baseline levels, whereas palm olein and corn oil significantly reduced the TC, LDL-C, and HDL-C serum levels.

Mounting evidence suggests the type of fat to have a major effect on health outcomes.[63,64] Saturated fatty acids are generally considered to be hypercholesterolemic, whereas, mono and polyunsaturated fatty acids (PUFA) are considered hypocholesterolemic. According to studies published so far, the replacement of saturated fats with unsaturated fats (especially polyunsaturated fats) is reported to improve blood lipid profile (reduce total and LDL-C and increases HDL-C). The American Heart Association Presidential Advisory Report suggests the replacement of 5% of energy intake derived from saturated fats with polyunsaturated fats or monounsaturated fats to lower the incidence or risk of CHD by 25 and 15%, respectively.[63] The 2015–2020 Dietary Guidelines for Americans (DGA) suggests reducing saturated fat

consumption to less than 10% of total energy intake while replacing them with unsaturated fats, especially PUFAs.[63,64]In support of this statement, Mendis*et al*.[65,66] reported the replacement of saturated fat with unsaturated fats to favorably modulate the lipid profile. A feeding trial carried out on 25 healthy Sri Lankan male prison inmates, CNO intake for 8 weekswas associated with increased LDL-C levels (non-significant) compared to soybean oil.[66]Another study reported lowering of dietary saturated fat (derived from coconut) or partly replacing it with unsaturated fats to have a favorable effect on the serum lipoprotein levels.[65] However, some of the studies reported contrasting results to the above observation. For example, the study by Damayanti*et al*.[50] report CNO to improve the CVD markers better than peanut oil, which was comprised of 39% MUFA (oleic acid) and 31.8% PUFA (linoleic acid), whereas the unsaturation level in CNO was only around 6.8%. Similar outcomes have been reported with regards to soy-bean oil, a major source of PUFAs, linoleic (omega-6), and alpha-linolenic (omega-3) fatty acids.[13]Assunção *et al*.[13] reported that soy-bean oil supplementation (30 mL) for 12 weeks to increase total cholesterol and LDL-C and to reduce HDL-C significantly in women aged 20-40, whilst CNO increased HDL-C, with no change in TC or LDL-C. Inaddition, a study done by Voon*et al*.[67] aimed at determining the effect of palm olein, CNO and olive diet on the plasma homocysteine and inflammatory markers, no difference was reported in the total homocysteine level and the inflammatory markers, TNF-α, IL-1β, IL-6, and IL-8, high-sensitivity C-reactive protein, and interferon-γ.

The effect of dietary fats on the CVD risk factors does not seem to depend solely on the saturation level of the fatty acids, but it may also depend on the fatty acid composition, processing methods, and dietary patterns. Owing to the high content of saturated fatty acids

(92%), CNO has always been classified along with butter, palm oil, and animal fats, and is not advocated as a healthy dietary choice. A well-established misconception on CNO is that since coconut fats are saturated, they are believed to elevate plasma lipids in a similar manner as animal fats, such as butter. It should be noted that CNO is different from palm oil and animal fats in terms of its fatty acid composition and TAG profile. Several studies have reported the favorable effect of coconut fats on cardiovascular markers over animal fats.[51,60–62]The saturated fatty acid profiles of CNO vastly differ from animal fats where, CNO is predominantly made of lauric acid (~45-53%), , while the major fatty acids of butter are palmitic and stearic acids.[14,51] Studies done on lauric acid metabolism indicate that unlike other saturated fats, lauric acid is rapidly absorbed, directly transported to the liver, and oxidized to produce energy rather than being stored as fat.[14]This phenomenon probably explains the differential effects exhibited by coconut fats compared to other saturated fats. However, it should be noted that there are controversial results published in this regard.[14,68,69] Though lauric acid is classified as an MCT, some report it to behave as LCT in terms of solubility and intestinal absorption.[12,20]

Overall, the studies done so far on the association between CNO consumption and cardiometabolic health have reported conflicting outcomes. Majority of the studies are found to lack a proper study design and the evidence supporting the beneficial effect of CNO consumption on cardiometabolic health is vague and not informative enough to support the claim. For instance, a recent study to evalauate the effect of cooking oil such as coconut and sunflower oil on the blood lipid profile of patients with coronary artery disease over a period of 2 years, found no significant difference in the blood lipid profile of the two study groups. However, the point to consider here is that the study participants were continuously on statin

therapy, which makes it hard to interpret the study outcome.[70]Though CNO increases the HDL-C level, unfortunately, there is no proven evidence stating the positive effect of high HDL-C on CVD outcomes as does the decrease in LDL-C does. The causal relationship between LDL-C and CVD risk is well established, where 1 mmol/L increase in LDL-C concentrations are reported to increase the risk by 15% increase[51]. This was clearly mentioned in the presidential advisory report published by the American Heart Association.[63]However, from the evidence available so far, there is no strong reason to link CNO consumption directly with CVD incidence or otherwise. For decades, some nations have been consuming CNO and related products with low CVD incidence. For example, despite being a nation that derives its dietary fat mainly from CNO, Sri Lanka had the lowest death rate from ischemic heart diseases as quoted in the Demographic Yearbook of the United Nations in 1978 .[49] Although, the per capita consumption of coconut in Sri Lanka was around 130 nuts/person/year in the nineteen sixties, it has dropped to around 100–110 nuts/person/year in the recent times.[71] On the other hand, the CVD incidences in Sri Lanka was found to increase at an alarming rate compared to the developed nations.[71] This shows that coconut consumption alone is not the reason for the increasing trend CVD incidences. According to health authorities, changes in dietary habits and lifestyle factors over the years have played a major role in the increase of CVD incidence. In general, consumption of any dietary fatty acid in excess may not be desirable, and moderately balanced inclusion of dietary fatty acids in day to day diet is encouraged.

3.2. Anti-obesity effect

Obesity has become a serious health issue in the world due to changing lifestyles and dietary habits. It has reached the epidemic level in many countries representing a severe public health

problem.[13]The most interesting argument for weight control of CNO over other oils is that the energy expenditure of MCFA is greater than LCFA. CNO contains a larger proportion of water-soluble MCTswhichareeasilyhydrolyzed by lipaseandabsorbed through the intestine and directly sent to the liver to be rapidly metabolized into energy without storing in adipose tissue.[72]Hence, this is thought to decrease the basal metabolic rate.[13,72-73] Although CNO has recently gained attention as a source of weight loss, still, it is a controversial topic due to the effect of saturated fatty acids and their association with CVD.

Studies have indicated some promising outcomes on the use of CNO as an MCT oil to promote weight loss, despite its high content of saturated fat.[1] However, the fatty acid profile of CNO is different from the MCT oils used in studies. The majority of MCTs in CNO comes from lauric acid. Classification of lauric acid as MCFA is still controversial due to clinical studies pointing out the lower percentage of lauric acid directly transported to liver.[73] However,Kinsella *et al*.[74] revealed that CNO cannot be promoted as an MCT oil since it depicts the different effect on food intake and satiety. In Support,Maher*et al*.[75]also reported that MCT oils are better in fullnessperception compared to CNO. Nevertheless, few clinical studies done on the impact of CNO consumption on body weight control showed positive outcomes. In a study of 40 women with abdominal obesity, supplementing with 30 ml (2 tablespoons) of CNO per day led to a significant reduction in both body mass index and waist circumference within 12 weeks.[13]

Apilot study byLiau *et al.*[76] reported a dosage of 30 mL of VCO for a period of four weeks has reduced the weight circumference significantly among male subjects. But according to the results, there was no change in lipid profile among the men. Hence the study failed to conclude

the impact of VCO consumption on weight control. Further, Xavier *et al.*[77]evaluated the effect of consumption of VCO and extra virgin olive oil on energy metabolism, fat oxidation rates, and cardiometabolic risk markers in 17 women aged between 19 to 42. The authors reported that there was no difference in the above parameters studied between two groups yet lower hunger suppression, satiety, and total fullness were observed for the VCO ingested group.Still, the experimental duration in the study brought a limitation in concluding the beneficial effect of the CNO. According to a review by Clegg *et al.*[9]on CNO consumption and weight loss concluded that there is no enough evidence to support the beneficial effect of CNO consumption and weight loss. Therefore, consumption of CNO as a weight controlling method remains unsupported by enough scientific evidence.[73]

3.3 Anti-diabetic property

There was a general belief that saturated fats might induce insulin resistance in humans, which leads to the development of metabolic disorders such as diabetes. On the contrary, VCO is found to exert anti-diabetic property by balancing blood sugar levels.[91]A Comparative study by Siddalingaswamy*et al.*[92] on the protective potential in a streptozotocin-induced diabetic model using hot extracted VCO, cold-pressed VCO, and commercial CO showed that H-VCO to be better hypoglycemic and insulin-sensitizing agent comparing to other coconut oils used. Iranloye*et al.*[93] and Maidin*et al.*[94] showed that F-VCO effectively reduces hyperglycemia in alloxan-induced diabetic rats. Similarly,Narayanankutty*et al.*[95] also found that F-VCO to prevent the development of insulin resistance and dyslipidemia in high fructose-fed rats. However, detailed scientific investigations on the mechanism of the antidiabetic effect of different types of VCOs are scares. However, Lekshmi *et al.*[96] have stated that the presence of

phenolic acids in VCOs aid in the inhibition of dipeptidyl peptidase-4 (DPP-4) or insulin sensitization. In addition, the presence of phenolic compounds in VCOs is believed to offer protection against secondary diabetic complications such as diabetic nephropathy by inhibiting polyol pathway. A study by Akinnuga*et al.*[97] showed that F-VCO could exert a protective effect on diabetic nephropathy in animals

3.4Anti-cancer property and chemotherapy protective effect

Some studies reported the anticancer activity of CNO against mammary,colon,liver, lung, and oral cancer cells.[24] supporting the above fact, a study done bySalerno*et al.*[80]showed that coconut oil rich in lauric and palmitic acids had a greater inhibition power on HT-29 malignant human colon cellsthan linoleic acid.Further, in a separate study, Enos*et al.*[81] observed that a diet rich in coconut oil efficiently reduced the ulcerative colitis and associated colon cancer incidence in Azoxymethane/Dextran sodium sulphate induced colon cancer model. It has been found that treatment with CNO increases the levels of intestinal protein Mucin 2, which is involved in the proper maintenance of intestinal barrier integrity. In the *in vitro* system, lauric acid, which is the major form of fatty acid inVCO, has recently shown to induce apoptotic changes in various colorectal cancer cells and breast and endometrial cancer cells mediated by reactive oxygen species.[82,83]Lauric acid, the predominant fatty acid in CNO showed cytotoxicity towards HCT-15 (human colon cancer), HepG2 (human hepatocellular carcinoma), and Raw 264.7 (murine macrophages) cells in Silico and *in vitro* study.[84] Moreover, coconut oils have shown the inhibitory effect of mammary tumorigenesis in experimental animal models.In a separate study, VCO, Processed Coconut Oil(PCO) and

Fractionated Coconut Oil (FCO) have shown anticancer activity towards the liver and oral cancer cells. Further, Kamalaldin *et al.*[85] reported that VCO induced the apoptosis in NCI-H1299 and A549 lung cancer cell lines, and safe to be consumed. Distinctive morphological changes, such as the appearance of massive cytoplasmic vacuolization and blebbing of the cell membrane, were observed in both cell lines after treatment with VCO.

Apart from the anticancer properties, VCO is emerging as functional oil to abrogate the undesirable side effects associated with chemotherapy. In an animal study, FVCO has effectively ameliorated the myelosuppression and disturbed antioxidant status induced by chemotherapeutic drug cyclophosphamide.[86] Further, the methotrexate-induced hepatotoxicity, and oxidative damage have been reduced by F-VCO via improving antioxidant status in rats.[87]In another study, oxidative nephrotoxicity induced by methotrexate was reduced by antioxidative and anti-inflammatory effects of VCO.[88]Further the chemotherapy-induced side effects of breast cancer patients are shown to improve with the consumption of VCO.[89]Similarly VCO incorporated mouth wash has shown to reduce the mucositis caused by radiation in nasopharyngeal carcinoma patients.[90]Bioactive polyphenols in VCO may be responsible for these observations and more comprehensive studies are needed to investigate the anticancer properties and chemoprotective effect of coconut oil[87].

3.5Antioxidant and anti-inflammatory activity

Free radicals adversely affect biomolecules such as proteins, lipids, and DNA and trigger oxidative stress. Antioxidants are compounds capable of either delay or inhibit the oxidation process by scavenging free radicals.[98] Several studies have been performed to analyze the antioxidant property of highly consumed vegetable oils including CNO. When compared to

other oils,the number ofstudies done on the antioxidant activity of CNO is limited. Nevertheless, VCO is gaining attention as oil with higher antioxidant activity. A comparative study done by Janu*et al.*[33] to investigate the total phenolic content and antioxidant potential of commonly consumed vegetableoils namely coconut oil (CNO), sunflower oil (SFO), rice bran oil (RBO), groundnut oil (GNO),sesame oil (SESO) and mustard oil (MO) showed the order GNO>CNO>RBO>MO >SFO >SESO and the study revealed that GNO, CNO, and RBOhada higher potency towards free radicals.[33]

Recent studies displayed that unrefined VCO is given priority due to its incredible health benefits.Among the various VCO preparations, fermented virgin coconut oil (F-VCO) and hot extracted virgin coconut oil (H-VCO) showed higher radical scavenging and inhibition activity.[24] Unlike ordinary coconut oil, VCO also has been shownto have the capability of increasing antioxidant enzymes and declining the lipid peroxidationcontent.Nevinet al.[99] has investigated the effect of VCO in comparison to CNO and ground oil on both *in vitro* and *in vivo* lipid peroxidation.Results showed that consumption of VCO extracted from fresh coconut meat, with its high content of biologically active components was superior in antioxidant property than ordinary CNO extracted by dry process.

In addition to antioxidant activity, the anti-inflammatory activity of VCO is proven several years back. Inflammation involves many other processes of the immune system; for example, during both acute and chronic inflammatory responses, the immunological component cells are activated in response to foreign organisms or antigenic substances.[2]Certain research studies depict that VCO tends to increase antioxidant enzymes and decrease the expression of inflammatory genes such as COX-2, iNOS, and IL-6. Intahphuak *et al.*[2] reported thata dosage

of 4 mg/20 µl of VCO showed moderate anti-inflammatory effects on ethyl phenylpropionate-induced ear edema in rats. However, the efficacy of VCO was not higher than the standard drug Indomethacin. Further, Zakaria *at al.*[100] Using *in –Vivo* modelsobserved that F-VCO efficiently reduces acute inflammation, whereas,in chronic models, it is found to be less effective.There should be more studies focused on anti-inflammatory activity of different types of CNO for better understanding of the property with scientific support.

3.6 Inhibition and reversal of hepatosteatosis

The liver is an important organ dealing with detoxification and elimination of wastes and toxic products of metabolism. During this process, hepatocytes are known to get damaged. Ingestion of drugs and chemicals through diets are known to harm hepatocyte adversely leading to hepatotoxicity. Hepatosteatosis, a form of non-alcoholic fatty liver disease is recognized as a major issue in the world. Hence, the trend towards discovery of dietary nutraceuticals to prevent this condition is increasing. VCO was found to reduce the effect of paracetamol-induced toxicity by restoring liver function markers and hepatic morphology. Zakaria *et al.*[101] found that elevated levels of hepatic damage serum markers (AST, ALT ALP) due to paracetamol-induced toxicity have reduced at the highest concentration (10 mL/kg) of VCOs used. Similarly, Otuechere*et al.*[102] found that common antibiotic trimethoprim-sulfamethoxazole induced toxicity is also reduced by cold-pressed VCO intake. Supplementation of VCO has ameliorated trimethoprim-sulfamethoxazole (TMP-SMX) induced toxicity by restoring the levels of total bilirubin, alkaline phosphatase, and lactate dehydrogenase. According to a study by Narayanankutty*et al.*[79] reversal of hepatosteatosis in male Wistar rats fed high fructose diet was observed in 4 weeks time. In this study, administration of VCO caused the natural

reversion of established hepatosteatosis condition by improving HDL-c level and reducing hepatic and serum triglycerides. Based on studies done so far, it can be concluded that VCOs, regardless of the differences in their methods of preparation, possess a promising hepatoprotective effect. This hepatoprotective effect of VCO may be partly attributed to its antioxidant activity. Furthermore, studies are needed before the exact conclusion could be drawn on the actual hepatoprotective activity of coconut oil.

3.7 Antimicrobial Activity

A series of studies reported in the 70s on MCFA with carbon 6-12 are responsible for the potent activity towards gram-positive bacteria, lipid-coated viruses, as well as fungi and protozoa.[16,103-104] Presence of 12-carbon lauric acid, makes the oil potent towards microbes.[13] According to multiple reports, particularly lauric acid (C12:0) in its monoglyceride form (monolaurin or ML) was found to be responsible for antimicrobial property.[14,105-106]According to studies reported so far, CNO was identified as an effective source against lipid-coated microorganisms such as visna virus, CMV, influenza virus, leukemia virus, pneumono virus hepatitis c virus.[103] Moreover, the presence of monolaurin has broadened the antimicrobial spectrum to some fungal species such as *Aspergillus*Sp, *Penicillium*Sp, *Cladosporium*Sp, *Fusarium*Sp, and *C. albicans.* A study by Ríháková Z *et al.*[107]using CNO as a monoglycerol source in antifungal activity showed that CNO could be used as a preservative with antifungal activity. FurtherKannan *et al.*[108] revealed that there is a strong potential therapeutic value of VCO against *Candida Sp.* which is one of the common causes for oral candidias in the world.

Shino*et al*.[109] performed a study using two types of CNO such as activated VCO and crude extract of VCO on *Candida albicans* showed that exposure of *C. albicans* to activated VCO was the inhibitoriest to its growth.

CNO was found to exhibit antibacterial activity against *P.aeruginosa*, *E.coli*, *Proteusvulgaris.* and *Bacillus subtilis*[72]. Manohar *et al.*[16] conducted a comparative rodent study using two types of coconut oil,namely;RBD refined, bleached, deodorized CNO and VCO found that these two types of CNO were less effective than the pure monolaurin towards the *Staphylococcal* organism. However, Oyi AR *et al.*[17] formulated a cream using CNO which was found to exhibit both antibacterial and antifungal properties. Hence, the study demonstrated the importance of formulating CNO into a cream. Emulsifying agents present in the cream aids in the penetration of active compound monolaurin present in CNO. Bacterial resistance to antibiotics is considered as an important public health issue because of the potential effect on the ecosystem and human health. A novel study done infusing nanotechnology with CNO has addressed the above issue. Low cost eco-friendly silver nano-particles made using coconut oil to display antibacterial activity. The silver nano-particles (AgNPs) reduced the growth rate of multi-ARB (antibiotic resistant bacteria) such as *Citrobacter sp.*, *Aeromonas sp*. and *Acinetobacter sp.*[110]

In addition to antifungal and antibacterial activities, CNO is gaining attention due to its potency towards the HIV virus. According to reports, 42 million people in the world have been affected by HIV/AIDS for 22 years .[11]The first-ever clinical trial of monolaurin (ML) on 15 HIV-infected patients was demonstrated at the San Lazaro Hospital, Manila; these patients never

received any anti-HIV medication. The study was conducted by assigning 3 random groups based on the amount ofoilgiven (7.2g ML, 2.4 gML, and 50 ml of coconut oil daily for 6 months). Viral, CD4, CDS counts, complete blood counts, blood lipids and tests for liver and kidneyfunctionhavebeeninvestigatedbefore and after 3 and 6 months of treatment. The results showed that a reduction in the viral load of 50% of the patient by 3 months. When the study was continued to 6 months 8 patients (2 receiving 7.2g ML,4 receiving 2.4g ML, and 3 receiving CNO), it was observed to have favorable effects without any serious side effects.[105]Further, a study with 40 HIV subjects with $CD4^+$ T lymphocyte counts less than 200 cells/µL were divided into two as VCO group (45 mL daily) and a control group (no VCO). The VCO group showed significantly higher average $CD4^+$ T lymphocyte counts compared to control group after 6 weeks.[111] The demonstrated antiviral ability of coconut oil due to the presence of lauric acid has urged scientists to start clinical experiments on its potential use of CNO as a cure for pandemic nCoV-2019.[112]

4. Other Properties

4.1 Moisturizing skin and hair

It is found that CNO to have a beneficial impact on the external part of the body such as hair and skin**.** People in tropics used CNO as a natural moisturizer for centuries. In Ayurvedic medicine,CNO has been used to treat numerous skin disorders which include wound healing and microbial infections.[19] Nevin*et al*.[19] has shown the beneficial effect of VCO for the healing of the dermal wound in rats.Further,CNO is applied as a remedy to heal the pain of the burn wound.[2] A comparative study done to determine the efficacy of VCO and mineral oil as a therapeutic moisturizer for mild to moderate xerosisshowed that both oils had considerable

hydration ability on the skin and increasedthe skin surface lipid levels. Grading of xerosis by the investigators and visual analogue scales used by the patients showed greater improvement for CNO than mineral oil.[113]

CNO is found to have a strong affinity for hair proteins and it easily penetrates the hair shaft due to its lower molecular weight and straight linear chain.[43] Supporting to the above fact,a study done using mineral oil, CNO and sunflower oil on prevention of hair damage showed that CNO was the only oil to show a remarkable decline in protein loss for both damaged and undamaged hair when it was used as a pre-washed or post washed product. This observation was explained in the means of fatty acid composition of CNO. Lauric acid, the principal fatty acid has made CNO as a hair enriching oil comparing to other oils tested.[43]Ruetsch SB1 *et al*.[114] worked on the penetration of CNO and mineral oil into the human hair fiber. The study showed a higher penetration of CNO compared to mineral oil. The observation was supported by the polar nature of CNO compared to mineral oil due to the presence of MCFA and a certain amount of MCTs. Moreover, CNO is principally a lauric acid triglyceride oil. Thus, the lower molecular weight (lower 1000 Da) of the oil makes it easy to penetrate the hair shaft. Also, this study indicates that CNO provides better hair protection from damage by hygral fatigue.

5. Conclusion

Coconut oil is a tropical oil that is consumed in many Asian region countries. Though it was criticized for its adverse health effects in the early days due to the presence of saturated fatty acids, recent studies acclaim the positive health effects of coconut oil consumption owing to the presence of MCTs. Recent *in vivo* and *in vitro* studies reveal the ability of CNO to suppress

certain adverse health issues such as cancer,hepatosteatosis, HIV, and diabetes. Furthermore,CNO is found to possess antioxidant, anti-obesity, anti-microbial, and anti-inflammatory properties.However, the findings on hypocholesterolemic and the cardioprotective effect of CNO are inconclusive.Several studies based on Asian communities support the cardioprotective effect of CNO, but the real value of CNO is obscure due to the limited number of research studies done in Western countries.Hence, properly planned long term studies may help in understanding the impact of CNO consumption in cardiac health.

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7. Conflict of Interest

The authors have declared that there is no conflict of interest.

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Abbreviations : CNO, Coconut oil, **VCO**, Virgin coconut oil, **SCFA**, Short chain fatty acid,**CTO**,Coconuttesta oil,**FA**, Fatty acid, **LCFA**, Long chain fatty acid , **MCFA**, Medium chain fatty acid , **MCT**, Medium chain triglyceride **, LCT,** Long chain triglyceride**, ML**, Monolaurin, **RBD**, Refined bleached deodorized, **CVD,** Cardio vascular disease, **LDL**, Low density lipoprotein, **HDL**, High density lipoprotein,**TC**, Total cholesterol,**FCO**,Fractionated Coconut Oil,**PCO**,Processed Coconut Oil, **FAs,**Fatty acids, **MUFA**, Monounsaturated fatty acids , **PUFA,** poly-unsaturated fatty acids, **TMP-SMX**, Trimethoprim- sulfamethoxazole ,**H-VCO,** Hot extracted virgin coconut oil **, F-VCO ,** Fermented virgin coconut oil **, C-VCO,**cold extracted virgin coconut oil**, CCO,**Commercial coconut oil.

Table 01: Significant Human and animal Intervention Studies on Beneficial Health Effects of CNO

Property	Reference	Study (Country)	Intervention	Outcome
Cardioprotective effect / Hypocholesterolemic	(Chinwong, Chinwong and Mangklabruks, 2017) [53]	A randomized cross over trial. Plasma lipoproteins levels were measured after 8 weeks (Thailand)	Group 01:15 mL VCO Control group : 15 mL 2% carboxymethylcellulose (CMC) solution	VCO consumed group showed an increase in HDL-C levels compared to Control Group
Cardioprotective effect / Hypocholesterolemic	(Khaw et al., 2018)[51]	A randomized trial. Plasma lipoproteins levels were measured after 4 weeks (United kingdom)	Group 01:Extra VCO Group 02:Extra virgin olive oil Group 03 :Unsalted butter were consumed 50 g per day for 4 weeks	Short term consumption of extra-VCO and extra-virgin olive oil did not show any significant change in the serum LDL-C levels
Anti- obesity	(Liau, Lee, Chen, & Rasool, 2011)[76]	An open-label pilot study Weight, associated anthropometric parameters and lipid profile were measured one week before and one week after VCO intake. (Malaysia)	30mL of VCO per day was given half an hour before each meal.	Waist circumference of men significantly reduced with a mean reduction of 2.86 cm .
Anti-obesity	(Xavier et al., 2017)[77]	A randomized, cross-over, controlled study	Group 01: breakfasts containing 25 mL of VCO	VCO consumption did not acutely change energy

		Energy metabolism factors and Cardiometabolic risk markers were measured (Brazil)	Control: 25 mL of extra-virgin olive oil	metabolism and cardiometabolic risk markers observed
Anti- cancer	Kamalaldin*et al*., (2015) [85]	Two human lung cancer cell lines (NCI-H1299 and A549)were used. Morphological changes of the cancer cells were observed after treatment (Malaysia)	Two lung cancer cell lines were exposed to series of concentration of VCO for 72 hrs.	VCO inhibited the growth of cancer cells and induced cell death via the apoptosis pathway at concentrations as low as 8.64% (v/v) and 12.04% (v/v)
Anti-diabetic	(Narayanankutty et al., 2016) [95]	Rat study 3 groups (n=6) Blood glucose level , Serum lipid levels,liver enzymes were observed (India)	Group 1 :control Group 2 :semi synthetic diet composed of 60 % fructose and CO Group 3 :semi synthetic diet composed of 60 % fructose and VCO	Animals fed VCO diet had only 17 % increase in blood glucose level compared to CO fed animals which was 46 %
Anti-diabetic	(Siddalingaswamy, Rayaorth, & Khanum, 2011) [92]	Rat Study, 4 groups (n=8) Blood glucose and lipid levels were observed (India)	Group 1 :control Group 2: Commercial coconut oil (CCO), Group 3:C-VCO Group4: H-VCO	The overall effect of H-VCO was better than C-VCO in enhancing the antioxidant status, reducing the blood glucose and lipid levels
Anti-inflammatory	(Zakaria et al., 2011)[100]	Rat study,5 groups (n = 7) carra- geenan-induced rat	1% Tween 80, 100 mg/kg ASA ,VCO_A and VCO_Bin 10, 50 or	Both VCOs exhibited significant ($p < 0.05$) anti-

		paw edema test was performed to analyze acute inflammation (Malaysia)	100% concentrations	inflammatory activity .
Hepatoprotective activity	(Otuechere *et al.*, 2014)[102]	Rat Study,4 groups (n=5). Biochemical parameters, Organ weights and coefficients were evaluated (Nigeria)	Group A –control, Group B -TMP-SMX at the dose of 8/40 mg/kg body weight twice daily Group C- VCO at a dose of 600 mg/kg body weight per day Group D- TMP-SMX (8/40 mg/kg) and coconut oil (600 mg/kg)	VCO was found to ameliorate TMP-SMX-induced effects by restoring the levels of total bilirubin, alkaline phospahatase, and lactate dehydrogenase
Anti-viral	(Dayrit, C. S. (2013)[105]	A clinical study on 15 HIV-infected patient, randomly assigned to 3 treatment groups Viral, CD4 and CD8 countsand important other health parameters were observed after 3 and 6 months of treatment (Philippine)	1 st -group-7.2 g ML, 2nd -group 2.4 g ML 3rd group -50 ML of coconut oil daily for 6 months	3rd month, (50%) showed reduced viral load and by the 6th month 8 patients (2 receiving 7.2h ML, 4 receiving 2.4 g ML and 3 receiving, CNO) had a lowered viral count.
Anti-viral	(Dr. Kadek Dharma Widhiarta, 2016) [111]	A clinical study on 40 HIV-infected patient, randomly assigned to 2 groups (n=20) CD4+ T Lymphocyte counts were taken after 6th	Group 01- VCO 3 x 15 ml/day for six weeks Group 02- non-VCO group	VCO supplementation 3 x 15 ml/day for 6 weeks significantly increased CD4+ T Lymphocyte concentration in HIV patient compared to non –VCO.

week of the experiment
(Jakarta)

Table 02: Fatty acid composition of different coconut oil

Fatty Acid	CO (Lekshmi *et al*.2016)[96]	RBD (Kumar & Krishna, 2015)[115]	CTO (Appaiah*et al*.2014)[116]	HEVCO (Srivastava *et al.*, 2016))[36]	CEVCO (Srivastava *et al.*, 2016)[36]
Caproic acid (C6:0)	–	0.02	–	0.35	0.45
Caprylic acid (C8:0)	9.6	7.24	1.6-3.9	7.87	7.10
Capric acid (C10:0)	6.4	5.25	2.2-3.8	6.07	5.55
Lauric acid (C12:0)	51.5	50.9	32.4-42.9	49.55	50.0
Myristic acid	19.1	21.3	20.2-20.9	17.03	18.01
Palmitic acid (C16:0)	6.9	9.22	11.3-14.1	8.02	7.05
Stearic acid (C18:0)	1.1	0.38	1.2-1.6	2.71	2.42
Linoleic acid (18:1)	4.3	4.81	12.2-17.8	7.01	7.26
Linolenic acid (C18:2)	1.1	0.81	5.3-10.6	1.39	1.66

CO – Copra oil, RBD -refined, bleached, deodorized, virgin coconut oil (VCO) and coconut testa oil (CTO), Hot extracted virgin coconut oil (HEVCO), cold extracted virgin coconut oil (CEVCO)

Table 03: Amount of phenolic acids present in different coconut oils (mg/Kg)

	CO (Appaiah et al., 2014)[116]	RBD (Seneviratne et al., 2008)[37]	VCO (Seneviratne et al., 2008)[37]	CTO (Appaiah *et al.*, 2014)[116]	HEVCO (Srivastava et al., 2016)[36]	CEVCO (Srivastava et al., 2016)[36]
Total Polyphenols	131.2	618	322	313.9	–	–
Protocatechuic acid	–	0.16	–	–	–	–
Phenolic acid						
Gallic acid	24.7	–	–	32.1	25.29	18.01
Hydroxy benzoic	7.6	–	–	126.4	–	–

acid						
Vanillic acid	63.8	–	2.08	–	1.80	1.03
Syringic acid	17.9	–	0.45	–	–	–
p-Coumaric acid	10.0	0.34	2.0	42.1	0.53	–
Caffeic acid	3.1	0.13	3.0	12.8	1.59	–
Ferulic acid	1.7	0.31	3.3	47.5	12.83	2.36
Cinnamic acid	2.4	–	–	4.1	–	–
Catechin	–	–	–	–	18.15	12.35
Sinapic	–	–	–	–	3.35	1.89

CO – Copra oil, RBD -refined, bleached, deodorized, virgin coconut oil (VCO) and coconut testa oil (CTO),Hot extracted virgin coconut oil (HEVCO), cold extracted virgin coconut oil (CEVCO)