

# Palm Oil and Coconut Oil Saturated Fats: Properties, Food Applications, and Health

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**Abstract:** Fats and oils from plant sources are key components of a complete and healthful diet, as they supply essential fatty acids and liposoluble bioactive compounds. Many features and functions of dietary fats and oils have been studied extensively by the scientific community, with a focus on their impacts on human health. In this realm, an abundance of research has focused on the contribution of dietary fats and oils to the development of cardiovascular diseases, which is often attributed to their impact on the concentration of cholesterol in the blood. Such research has established that the degree of saturation plays a critical role in the impact of fats on cholesterol levels. Thus, consumption of polyunsaturated fatty acids and monounsaturated fatty acids decreases serum and low-density-lipoprotein cholesterol levels, while saturated fatty acids have cholesterol-increasing effects. Coconut and oil palm are the most prevalent sources of plant-derived saturated fatty acids in the diet, and in recent years there has been much debate centered around their health impacts throughout the scientific community. Consumers are hungry for scientific, fact-based guidance from reputable sources, as perception of these fat sources varies greatly from decade-to-decade, year-to-year, and month-to-month. This review on plant-derived saturated fats aims to put forth the most current research and issues related to cultivation, manufacturing of oils and derivatives, food applications, as well as health benefits and concerns, to allow the scientific community and consumers to make informed decisions when selecting foods to include as part of a healthful diet.

**Keywords:** Coconut Oil, Palm Oil, Saturated Fat, Food, Health, Sustainability

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## 1. Introduction

Palm oil and coconut oil are considered the most abundant plant-based sources of saturated fatty acids (SFA). As research has focused on the relationship between SFA intake and the development of health complications such as cardiovascular diseases (CVD) and more specifically, coronary artery diseases (CAD), concern has grown among consumers of these oils. The oil palm, *Elaeis guineensis* Jacquin, was first domesticated in West Africa and its cultivation has since been expanded globally to other areas, especially Southeast Asia, and has become the foremost oil crop worldwide [1]. Crude palm oil (CPO) and palm kernel oil (PKO) can be obtained from the oil palm fruit. CPO is produced from the fleshy palm fruit (mesocarp), while PKO is

extracted from the kernel inside the palm nut (endosperm) [1]. The production of these oils takes place in tropical regions, mainly in Southeast Asia. The coconut palm, known by its taxonomic name *Cocos nucifera* Linn, has been a particularly useful plant for humans. In fact, every part of the cocoa palm renders valuable material for economic use [2]. Coconut oil is a significant source of lauric oil and, in competition with palm kernel oil, is used by the food and oleochemical industries [3].

Heart disease, which is a type of CVD, is the leading cause of mortality for both men and women in the United States and was responsible for 23.4% of all deaths in 2015 [4]. This statistic, together with the influence of dietary guidelines and general perception led consumers to search for alternative vegetable oils and reduce their plant-based saturated fatty acids consumption. However, all the recommendations to reduce the consumption of saturated fatty acids are now being

challenged. Research on saturated fatty acids had not been conducted considering individual sources of SFA, like palm oil and coconut oil, but instead considered animal and plant sources as a whole. In recent years, studies have further investigated the health impacts of palm oil and coconut oil in an attempt to challenge historical assumptions, showing many health benefits of consuming them and calling into question general dietary recommendations. Despite these benefits, the view that palm oil and coconut oil consumption would lead to an increased consumption of SFA and a higher risk of CVD still stands. In this review, a broad perspective about the most recent research regarding palm oil, coconut oil, and other sources of plant-based fatty acids is provided, offering information that is useful in considering the health benefits, health detriments, and food applications of these products. Additionally, the role that public perception has on consumers' decisions to consume or not consume vegetable oils with a high content of saturated fatty acids is shown.

## 2. Production, Processing, and Food Applications

### 2.1. Cultivation

Oil palm is cultivated on large plantations and smaller holdings in humid areas of the tropics, generally between 20 degrees north and south latitude of the equator and has reached over 8.5 million hectares globally [5]. Production of palm oil is centered in Southeast Asia, with Indonesia and Malaysia responsible for 52.4 and 31.1 percent, respectively, of global exports in 2020 [6]. Other palm oil producing countries in decreasing order are Thailand, Colombia, Nigeria, Guatemala, Papua New Guinea, and Ecuador [7]. In 2012, palm oil made up 32% of worldwide fat and oil production, surpassing soybean oil as the most important vegetable oil [8, 9]. Coconut palms are grown and naturally occur in abundance in tropical and subtropical regions on more than 30,000 islands and coastal regions of Africa and Eurasia. As recently as 2018, the Food and Agricultural Organization of the United Nations (FAO) reported that coconut palms can be found in 94 of 284 countries or world areas [2].

### 2.2. Harvest and Production

Oil palms are the most efficient producers of plant oils, providing about 3.6–3.7 tons/ha/y palm oil and 0.42 tons/ha/y palm kernel oil [5, 8]. Palm oil production is carried out entirely free of the use of genetically modified organisms, and oil palms produce up to ten times more oil per unit area than other oil producing crops [9]. The oil palm yields fruit that can be harvested two to three years after field planting and can be harvested continually during the year for 25–30 years [3]. Coconut palm is an important crop in the tropics and is planted in 86 countries. Those with the highest volumes of coconut production in 2018 were the Philippines (19.5M tons), Indonesia (15.3M tons), and India (10.8M tons). Other countries with significant volume production include Sri

Lanka, Brazil, Vietnam, and Mexico [10]. Coconut palm is important because several products are obtained from it, such as coconut oil, raw kernel, copra, coconut water, coconut toddy, coconut cake, coconut shell, and other derivatives. In addition to these multiple uses, some products like coconut oil and derivatives have shown nutritional and medicinal benefits. The coconut is a very hard shell containing a white sweet liquid called coco milk that, as the fruit matures, is converted into albumen, which becomes what is known as copra after drying [11].

### 2.3. Composition

Palm oil is noted for its relatively balanced fatty acid profile. In composition, the content of saturated fatty acids is equivalent to that of unsaturated fatty acids. The major components are palmitic (44–45%) and oleic acids (39–40%), along with linoleic acid (10–11%). Palm oil's relative stability to oxidative deterioration can be attributed to the extreme low level of linolenic acid. At 28 °C, palm oil is semi-solid, with a melting point ranging from 32 to 40 °C and crystallizes in the desirable  $\beta'$  form, which is frequently added to margarines and shortenings. As palm oil is semi-solid, there is little need for hydrogenation [3]. There are three main types of triacylglycerols (TAGs) in palm oil: tri-saturated, desaturated, and monosaturated [12]. It also has considerable amounts of diacylglycerols and free fatty acids (FFAs) [13]. Palm oil is fractionated to isolate and concentrate lipids with similar physio-chemical properties. Two important fractions are olein and stearin, which are found in the mid-palm fraction. Stearin is high in saturated fatty acid (SFA) content, which boosts its rate of crystallization and raises its melting point [13]. Crude palm oil is comprised of saturated fatty acids, palmitic (44%) and stearic (4.5%), as well as unsaturated fatty acids, oleic (39.2%) and linoleic (10.1%) [14]. It is a significant source of provitamin A and vitamin E [15]. Palm kernel oil is praised for its high quality due to a content of up to 50% lauric acid and 15% myristic acid as well as other essential fatty acids [16].

Palm oil from Brazilian sources seems to be more unsaturated, with an average content of 43.2% oleic and 11.5% linoleic acids and an iodine value of 58 [3]. However, palm oil sourced from Nigerian wild populations of oil palm can contain 27–55% palmitic acid, 28–56% oleic acid, and 6.5–18% linoleic acid. In some palm species, oleic and linoleic acids are the most plentiful fatty acids, conceivably at greater levels than other vegetable oils [17]. Palm stearin is harder when it contains 79% of palmitic acid and tripalmitoyl glycerol and it is used as hard stock in soft margarines and baby formulas [3]. Crude palm oil is naturally rich in carotenoids (500–700 ppm), tocopherols, and tocotrienols (600–1200 ppm), which give it a typical red color, affect its stability, and enhance medicinal and nutritional characteristics [18]. Red palm oil (RPO) compares well to the health benefits of other vegetable oils due to its unique fatty acid content and triglyceride structure. RPO has a nearly balanced saturated fatty acid (SFA) to unsaturated fatty acid ratio of 1:1; made up of 51% SFA, 38% monounsaturated fatty acid (MUFA), and 11% PUFA [18], and is a rich source of  $\beta$ -carotene, having

500–800 mg per kg of RPO, which is 15 times the level in carrots and 300 times that in tomatoes [18]. Tocotrienols, a group of antioxidants up to 50 times more powerful than tocopherols, make up 66–79% of total vitamin E content of RPO, with 1015 ppm and 133 ppm, respectively. This tocotrienol content compares well to rice bran oil [18].

Coconut oil is an important tropical oil with a high SFA content (92%), the majority of which (38%) are LDL-C and total-cholesterol-raising lauric, myristic, and palmitic acids. With such elevated levels, it is classified as a saturated fat source to be used sparingly in the diet [19, 20, 21]. Coconut is largely comprised of lauric acid (49%), followed by myristic acid (18%), caprylic acid (8%), palmitic acid (8%), capric acid (7%), oleic acid (6%), linoleic acid (2%), and stearic acid (2%) [22]. Coconut oil is high in medium chain fatty acids (MCFAs), mostly lauric acid (46–50%), myristic acid (17–19%), and capric acid (6–8%) [23]. Given that MCFAs are readily absorbed in the intestine, are rapidly sent to the liver, and are quickly metabolized in the production of energy, they do not contribute to the biosynthesis and transport of cholesterol [23]. Because of the high lauric acid content, coconut oil is also called lauric oil [24]. Lauric oils, the major fatty oil, contain more than 80% SFAs and are usually identified as short- and medium-chain fatty acids. During digestion and metabolism, lauric acid is metabolized by a different pathway and is not deposited in adipose tissue, thus is reported to have minimum effect on plasma cholesterol levels [3, 25]. In contrast, most MCFAs (42%) are directly taken into the portal vein [19]. The lauric acid in coconut oil is high in medium chain triacylglycerols (MCT), which hydrolyze quickly in the digestive tract and readily provide energy [26, 27]. Another study contradicted the above findings about coconut oil being high in MCT and reported that the combination of fatty acid into triglycerides can be referred to as either medium or long chained. MCT, with a total carbon number of C24:0 to C30:0 comprise only about 4% of the triglycerides in coconut oil. Thus, since the mean molecular weight of MCT oil is 512, and the mean molecular weight of MCT from coconut oil is 638, it would be a mistake to think of coconut oil as principally made up of either MCFA or MCT [19].

#### **2.4. Extraction and Processing**

There are several industrial processes to produce crude vegetable oil. As discussed earlier, the sources of vegetable oils include palm, soybean, rapeseed (canola), sunflower seed, cottonseed, corn germ, coconut or copra oil, linseed (flaxseed), peanut, rice bran, and sesame seed. Palm, coconut, and olive oils have production processes that are different than the above seed oils because they are not extracted from seeds [5]. Additionally, palm and coconut oils are characterized for being rich in SFAs. The processes utilized depend on the type of sources and scale. A key factor to produce top-quality oils is a high-quality raw material. Consequently, proper handling during transportation, storage, and processing of raw materials is of paramount importance. Edible oil production starts with seed handling and storage, followed by preparation of oil

sources [28].

The processing of palm oil starts at the plantation and begins with proper handling procedures to avoid rapid enzyme degradation, which produces oil with poor quality. Therefore, it is highly recommended to have mechanization of the milling process. To stop the lipolytic enzyme activity, fruits are subjected to a sterilization process in steam autoclaves. Threshing follows sterilization where fruits are separated from the bunches and transported into a digester. The digested pulp and palm kernel nuts are pressed, clarified, and dried. The liquid phase is clarified normally by a continuous decantation or settling tank where the separated oil is then dried in vacuum dryers. The resulting crude palm oil is usually alkali refined by washing with a solution of sodium hydroxide or sodium carbonate. Other refining procedures can be used to remove other targeted impurities [5].

Coconut oil or copra oil is extracted from the flesh or kernel, also referred to as the meat, of mature coconuts. The extraction procedures vary from local or traditional methods, small-scale mechanical units, medium-scale mills, and large industrial mills [5, 29]. In general, the oil expression steps start with dehulling or cracking the shell for the separation of the coconut flesh from fibrous husk, cutting or shredding it to eliminate remaining milk, soaking in water, and finally squeezing and mixing by hand. The mixed product is subjected to boiling and held until oil and pulp are obtained as a result of water evaporation. The oil is then separated from the pulp by straining and hand squeezing and then dried to 6–8% [21]. Oil is refined by physical or chemical (caustic soda) treatments [21, 30].

Once the oil is extracted, additional processing can occur. Fractioning is the process used to separate the low and high melting triacylglycerols, olein and stearin, respectively. The type of fractioning can be dry, detergent, or solvent processes [31]. Hydrogenation is the direct addition of hydrogen to the double bonds in the fatty acid chain of the triacylglycerol. The reaction changes the functional characteristic of the oils that occur naturally for specific applications such as longer shelf life, fast and clean melting sensation, and improved taste and smell as compared with unsaturated oil [28]. Interesterification is an enzymatic reaction in which the fatty acids are exchanged within and among triacylglycerols. The rearrangement renders a new lipid that has different TAG with improved chemical and physical properties [32].

Virgin coconut oil (VCO) is extracted from the flesh or kernel. It is obtained by mechanical and cold pressing, or natural methods without the use of heat, chemical refining, bleaching, or deodorizing and does not come in contact with solvents [33].

#### **2.5. Food Applications**

##### **2.5.1. Frying**

Frying is a thermal procedure that happens in air and quickly causes oil quality deterioration. However, palm oil, olein, and stearin are superior in this regard, given their greater oxidative stability [34]. Out of total usage, 83% of coconut oils and 61% of palm kernel oils are used for food

purposes [8].

### 2.5.2. Margarine

Important applications of coconut and palm kernel oils are the production of margarines and low-calorie spreads. Margarine contains at least 80% fat, water, vitamins, and other ingredients. Table margarines can contain up to 50% palm oil in the fat blend, and as much as 60% palm olein may be used [35, 36]. Adding small amounts of palm products, especially hard palm stearin, to margarine and shortening formulations can delay unwanted textural changes. Blending palm oil with hydrogenated canola oil can postpone the development of  $\beta'$ -crystals in  $\beta'$ -prone hydrogenated canola oil [37, 38].

### 2.5.3. Shortening

Shortenings are generally food fats and oils that can influence the quality and physiochemistry of prepared food. A semi-solid fat that is highly suited for this purpose is palm oil, due to its beneficial tendency to form  $\beta'$  crystals, which provide better aeration in batters than  $\beta'$  forms. Unlike margarines, shortenings consist of 100% oils and fats, and some spreads may have the addition of emulsifiers [38, 39]. The incorporation of palm oil with other oils such as soft stearin result in products with the solid structure essential in a shortening.

### 2.5.4. Confectionary

Confectionary fats generally are used for toffees and chocolate substitutes. Since palm kernel and coconut oils are clean melting at body temperature and do not stick or leave an aftertaste or off-flavor in the mouth, they are especially appropriate for toffees, and their oxidative stability when hydrogenated makes them the first choice compared to other hydrogenated oils. Mixtures of hydrogenated palm kernel oil with hydrogenated palm or cottonseed oils that are then interesterified create a product appropriate for enrobing biscuits and assorted centers in enrobed bars. Blending other oils in combination with palm kernel and coconut oils yields confectionary products with a wide functional range [40].

## 3. Health Implications

Fats and oils from plant sources are key components of a complete and healthful diet, as they supply essential fatty acids and liposoluble bioactive compounds [17]. Many features and functions of dietary fats and oils have been studied extensively by the scientific community, with a focus on the impact on human health. Health implications that have been investigated include risk of cancer, obesity, and obesity-related diseases, such as hypertension, hyperlipidemia, type 2 diabetes mellitus, and myriad cardiovascular diseases [10, 41]. An abundance of research has focused on the contribution of dietary fats and oils to the development of cardiovascular diseases (CVD), which is often attributed to their impact on the concentration of cholesterol in the blood. Such research has established that the degree of saturation plays a critical role in the impact of fats on cholesterol levels, as consumption of PUFA and MUFA decrease serum and

low-density-lipoprotein (LDL) cholesterol levels, while SFAs have cholesterol-increasing effects [41]. A high serum level of LDL cholesterol leads to arterial cholesterol buildup, so it is widely considered to be “bad” cholesterol. Although dietary replacement of SFAs with MUFAs improves the makeup of lipids in the blood, there is limited evidence of this improvement impacting CVD risk [42]. Additionally, when replacing SFAs in the diet, PUFAs were found to reduce the risk of coronary artery diseases (CAD) and MUFAs were found to improve serum high-density lipoprotein (HDL) cholesterol levels [43]. HDL is often referred to as “good” cholesterol, as it functions to carry cholesterol to the liver for excretion from the body.

Cardiovascular diseases are the leading cause of death globally, and various cholesterol levels in the blood are the main biomarkers linked to CVD risk [10]. All SFAs, including those from plant (such as coconut oil and palm oil) and animal sources, were identified as the largest dietary contributors to CVD risk by studies in the 1950s and 1960s. In the wake of these early correlations, dietary guidelines urged individuals to minimize their intake of SFAs and increase their intake of PUFAs [44]. Not until recently have these all-encompassing recommendations been challenged, as studies have suggested that nutritional guidelines be reconsidered due to findings revealing that the potential to raise serum cholesterol varies based on the SFA source [41]. In fact, there is growing evidence that consumption of plant sources of SFA, such as coconut and palm oil, may reduce the risk of CVD, stroke, and diabetes due to an abundance of medium chain triglycerides (MTCs) in their composition [44]. Conflictingly, it is also well established that serum cholesterol is unaffected by stearic acid, whereas the most prominent fatty acid constituents of palm and coconut including palmitic, lauric, and myristic acids are hypercholesterolaemic [41]. Historically, fatty acid research and resultant dietary recommendations have been relegated to broad sources of fats, such as plant and animal sources, as the scientific community deemed it unfeasible to investigate SFAs from individual sources. That being said, it has been argued that dietary guidelines should focus on specific SFA-containing foods, instead of total SFA, as it has become clearer that the food source greatly impacts risk to health, with some sources associated with higher risk, no risk, or low risk [45]. Additionally, each unique source of SFA is also likely to contain other components that may impact health risk [46].

As the scientific community continues to investigate the links between nutrition and human health, consumption of fat has been and will continue to be a fundamental focus. Fat is an essential macronutrient and fats from vegetable sources, such as oil palm, are used ubiquitously in the formulation of food products. Palmitic acid is the major SFA found in palm oil, and controversial studies have recently identified its potential negative impacts on health. Many studies suggest that diets rich in palm oil increase CVD risk in humans, but conflicting findings have been reported [10].

Historically, palm oil has been viewed as an unhealthy fat due to its categorization as a saturated fat and the fact that saturated fats have been linked to cardiac diseases [3]. In

addition to containing only 50% SFAs, palm oil contains nearly no cholesterol or trans fats and has a high content of tocotrienols that have health promoting capabilities [41].

Copra oil and VCO are the two types of coconut oil, which is an edible vegetable oil rich in SFAs. Their fatty acid compositions are similar, but VCO contains higher concentrations of polyphenolics and other bioactive compounds, as well as vitamin E and other nutrients [47]. Although these health-promoting components are present in coconut oil, the British Heart Foundation and UK Department of Health recommend limiting coconut oil consumption due to its high SFA content and indicate that alternatives containing primarily unsaturated fatty acids are most ideal for routine use. Unlike MUFA-rich olive oil, which is bolstered in the scientific literature for its health benefits, or omega-3-rich rapeseed oil, some experts believe that there is little scientific evidence that supports health benefits of consuming coconut oil [20]. Notwithstanding, there is global interest in investigating the disease-fighting capacity of foods and numerous studies have suggested that dietary phenolic compounds, such as those found in coconut oil, are key contributors to positive health outcomes and disease prevention [26].

As previously stated, coconut oil and palm oil are considered the most abundant and mainstream plant-based sources of SFA in the diet, so they have been heavily scrutinized for their health consequences. Interestingly, utilization of these oils has increased in recent years, as consumers and food manufacturers identified them as suitable replacements for trans fatty acids that had been found to negatively contribute to all-cause mortality and incidence of CVD. Trans fatty acids are a subclass of unsaturated fatty acids, often created by the process of hydrogenation, that have been shown to negatively impact total cholesterol and HDL cholesterol in the body, ultimately leading to an increased risk of CAD [43]. Food authorities across the globe have banned the use of trans fats in manufactured foods, which has ignited the search for alternative macronutrients with similar functionality. Dietary guidelines also recommend limited consumption of SFAs, placing an additional burden on manufacturers and consumers to identify products or ingredients that meet their dietary or product requirements. Recommending alternatives to trans fats and SFAs is critical for food authorities as the health effects of increasing the consumption of the replacement macronutrient (PUFA, MUFA, simple or complex carbohydrates) must be cautiously considered [46]. For CAD specifically, research has consistently shown that replacing SFA with PUFA modestly lowers CAD risk, replacing SFA with carbohydrate has no benefit, and replacing SFA with MUFA has unclear effects [48]. It is abundantly clear that the role of SFAs in CVD risk and other ailments is complex due to the diversity of food sources and their unique compositions and biological impacts [45].

### **3.1. Health Benefits**

An extensive review conducted in 2008 concluded that there was no credible mechanism for associating the consumption of saturated fats with negative health

consequences, and that historical conclusions were entirely based on epidemiological interpretation [3]. Furthermore, a 20-year study of over 78,000 women revealed that intake of SFAs was not a statistically significant predictor of CAD when adjusted for non-dietary and dietary risk factors [49]. Nutritional research has established that coronary risk is influenced significantly by the ratio of total cholesterol to HDL cholesterol and the ratio of LDL to HDL cholesterol. Diets abundant in SFAs increase both HDL and LDL cholesterol levels, suggesting that palm oil, a natural fat containing only 50% saturation, should not be of any harm to human health [3]. Some findings have also indicated that the overall saturation of the fat may not be the lone factor enhancing cardiac diseases risk, identifying the specific SFAs and their position on the triacylglycerol as other factors [50]. In addition to their impact on serum cholesterol levels, research has also suggested that certain varieties of palm oil may reduce hypertension, which also impacts heart disease risk [18]. Research has also revealed the antioxidant activity of palm oil constituents, such as  $\beta$ -carotene and tocopherols and tocotrienols (members of the vitamin E family), and their activity in aging and role in CVD and cancer prevention [10].

In 1992, a study was conducted where palm oil replaced a large portion of the customary fat content in a Dutch-type diet, and serum cholesterol and triglyceride levels were either unaffected or improved. These results suggest that consumption of palm oil as part of a Dutch-type diet does not increase CVD risk, and it was proposed that minor components of palm oil with potent biological activity may have played a critical role in the results [41]. Additionally, it has been observed that arterial lipid buildup increased with increasing levels of palmitic acid in the sn-2 position. Unsaturated oleic and linoleic fatty acids are most prevalent at the sn-2 position of palm oil and palm olein triglycerides, which could explain why these oils do not typically increase cholesterol [3]. Research has also revealed that palmitic and oleic acids appear to be neutral in influencing serum cholesterol levels in normal individuals, and that palm oil may lessen cardiovascular issues associated with lipoprotein and apolipoprotein [51]. RPO specifically, has been proven to protect against hypertension, oxidative stress, and resultant cardiovascular disorders [18].

Palm oil is the richest source of  $\alpha$ -tocotrienol, one of the natural vitamin E analogs, which has unique biological activity due to its antioxidant capacity, and recent research has revealed its neuroprotective properties in brain tissue rich in PUFAs. Crude palm oil contains up to 800 mg/kg of tocotrienols and is considered one of the most abundant natural sources. Palm oil also contains the more commonly cited tocopherols, but the distribution of vitamin E is 30% tocopherols and 70% tocotrienols. Members of the tocotrienol family possess biological functions that are not shared by tocopherols, such as the ability to slow cholesterol synthesis through suppression of the enzyme responsible for it, 3-hydroxy-3-methylglutaryl coenzyme A reductase. Palm oil-derived tocotrienols have also been shown to protect against the growth of breast cancer cells in humans, protect

against acute ischemic stroke injury *in vivo*, protect against neurodegeneration, and have shown promise in the treatment of cancer and hypercholesterolemia [52]. Additionally, the tocotrienol rich fraction of RPO has shown anti-aging effects in humans in a recent study [18]. Although palm oil is a good source of tocotrienols, it is unknown whether humans receive the identified benefits via a dietary source alone, especially in western diets where palm oil is historically uncommon. It has been deduced that tocotrienol from crude palm oil could be marketed and used as an economical and abundant dietary supplement [52].

In addition to palm oil's abundance of vitamin E, RPO specifically, it is also a rich natural source of  $\beta$ -carotene, a readily bio-available form of vitamin A. Recent data suggests that dietary RPO is beneficial for the cardiovascular system and as an economic and effective supplement to combat vitamin A deficiency among children and prenatal/postpartum infants in developing areas. Additionally, a recent 12-month consumer study centered on the fortification of biscuits with  $\beta$ -carotene revealed that there was no significant difference in the increase in serum retinol concentrations of school children who consumed biscuits fortified with RPO as a source of  $\beta$ -carotene versus biscuits fortified with synthetic  $\beta$ -carotene. Research has also shown RPO to effectively boost immune and cognitive functions and reduce incidences of anemia, low birth weight, and preterm delivery, all of which are associated with low serum retinol levels in the third trimester. Scientific evidence of the health benefits of RPO have been affirmed by human trials encompassing subjects of all sexes, ages, and ethnicities, revealing the diversity of its health promoting capabilities [18].

Clinical trials conducted on VCO and copra oil have revealed that VCO has higher antioxidant potential, resulting in more health benefits, which are widely attributed to copra oil having a diminished composition of biologically active compounds due to the refinement, bleaching, and deodorizing processes. In a recent study, VCO was found to have superior antioxidant effects in rats fed coconut oil extracted via numerous processes. In another rat model, lipid levels and thrombotic risk factors were higher in rats fed copra oil compared to VCO, and VCO performed equivalently to sunflower oil. Additionally, the levels of antioxidant vitamins were higher in VCO-fed rats compared to the other groups, and LDL from VCO-fed rats was significantly more resistant to oxidation than animals fed copra or groundnut oils [26]. Another study suggested that coconut oil may be protective against liver cancer, but that the protective effect may be eliminated by the consumption of soybean oil [44]. Moreover, a recent review presents the evidence of neuroprotective properties of coconut oil on cognition, amyloid- $\beta$  pathogenicity, inflammation and oxidative stress, and discusses how the metabolism of CO and MCFA may aid in compensating the glucose hypometabolism observed in brains of people with Alzheimer's disease [53].

Medium chain triglycerides (MCT) from coconut oil are commonly utilized by clinicians for enteral and parenteral nutrition to treat patients with difficulty with fat absorption as

they are more easily absorbed and digested than long chain fatty acids due to their higher solubility [26, 54]. The use of MCT has increased in recent years because research has shown numerous health benefits, including improved insulin sensitivity, antimicrobial activity, and reduced body fat [54]. Some experts believe that coconut oil should be more properly exploited for its concentration of MCT and used as a source of energy in the treatment of severely malnourished children. Studies have revealed the benefits of inclusion of coconut oil in the recovery diet of malnourished children, as the condition is improved rapidly. Coconut oil also enhances the absorption of calcium and magnesium, which may augment the treatment of rickets in infants who are prescribed formulas fortified with these minerals [55].

Even with epidemiologic evidence that high SFA consumption leads to high serum cholesterol and the fact that coconut oil is MCT rich, which is associated with increase in triacylglycerols in the blood, some experts attest that functional substances present in the oil may improve an individual's lipid profile. A recent study revealed that coconut consumption in Polynesian populations was not associated with CVD. In animal models, it has also been observed that VCO consumption resulted in significantly lower serum triglycerides and LDL cholesterol and significantly higher HDL cholesterol when compared to copra oil consumption, further strengthening the theory that functional substances, such as phenolic compounds, are instrumental in the health-promoting effects of VCO [26]. Another study revealed serum cholesterol improvements when diets high in palmitic acid were substituted with myristic acid, suggesting that coconut oil could help reduce CAD risk. The researchers attest that conflicting results on the impact of coconut oil on CAD risk may result from the quantity of oil consumed from study to study. Studies concluding that coconut oil consumption increases serum cholesterol supply subjects with oil at a level greater than 30% of total energy, whereas other studies conclude that moderate or infrequent coconut oil consumption does not appear to raise serum cholesterol [55].

Lauric acid—the most prevalent fatty acid found in coconut oil—has strong antimicrobial and antiviral properties and inhibits a variety of food pathogens. This ability is exhibited by the fatty acid derivative, monolaurin, which research has also shown to protect infants from infections from viral, bacterial, and protozoal sources [26, 54]. Along with monolaurin, monocaprin, a fatty acid derivative from capric acid, has been reported to inactivate or kill *Chlamydia pneumoniae*, a pathogen suspected to play a role in increasing the risk atherosclerosis. Monolaurin and monocaprin effectively disintegrate the lipid membrane surrounding lipid-coated viruses and bacteria, which have been implicated in the cause of stomach ulcers, sinusitis, dental cavities, food poisoning, and urinary tract infections. One study revealed that emulsions of 1.25 mM monocaprin could reduce viable *Salmonella* spp. *E. coli* by 6–7 logs in only 10 minutes. Studies have also found coconut oil to be effective in destroying viruses including Visna virus, CMV, Epstein-Barr virus, influenza virus, leukemia virus, pneumo virus, and

hepatitis C virus. These antiviral effects are cumulative, as the total concentration of the antiviral compounds are instrumental in the inactivation of viruses [23].

A recent study where mice were fed diets consisting of some combination of coconut oil, soybean oil, and fructose showed that soybean oil was more obesogenic and diabetogenic than coconut oil. Soybean oil induced these negative effects even in the diets also containing coconut oil, which contains MCTs that have been shown to have anti-obesogenic, anti-inflammatory, and insulin-sensitizing effects. Researchers concluded that additional research examining how lauric acid is absorbed and metabolized will give greater insight into whether coconut oil can be effectively utilized for the treatment of common chronic disease states, as many experts contend that lauric acid does not provide the same health benefits as lower chain length MCTs [44]. Additionally, experts believe that larger and longer human clinical and observational studies on the consumption of coconut oil are greatly needed, as research on MCTs cannot be directly applied to coconut oil. They also state that many food products containing coconut oil carry claims that are based only on animal and/or in vitro studies as well as MCT research [47].

### **3.2. Health Detriment**

Many experts hypothesize that increasing palm oil consumption will increase SFA consumption, like that observed in many developing countries, ultimately raising the risk of CAD. CAD and stroke are conditions of particular concern for developing countries, as rising incomes, urbanization, and decreased child mortality have enhanced the burden of such diseases. More so than any other economic, demographic, or nutritional trend, including smoking, palm oil consumption is increasing in these countries, and it has been associated with increased CAD associated deaths [56]. More specifically, research has suggested that consumption of palmitic acid, approximately 45% of palm oil's fatty acid composition, might be associated with an increase in CVD risk, leading to nutritional and image-related reasons for seeking suitable palm oil alternatives in diets and in formulated food products [57]. Many experts state that experimental evidence confirms that consumption of palm oil increases total cholesterol and LDLs in the blood when compared to more heavily unsaturated vegetable oils, increasing the risk of CVD. Epidemiological evidence from Poland suggested that a transition away from saturated fats and toward nonhydrogenated rapeseed and soybean oil played a critical role in the rapid decline of CAD mortality from 1990 to 2002 [56, 58].

The recent reduction in the use and consumption of trans fats in developed countries, due to changes in regulatory policy aimed at reducing CVD risk, has inadvertently led to an increase in the consumption of palm oil in some countries. This increase undermines the health goals of the regulatory policy changes [56]. Scientific literature has revealed the link between the consumption of elevated levels of SFAs and negative impacts on total cholesterol, LDL cholesterol, CAD, and stroke. In developing countries specifically, the impact of

increased palm oil consumption on CAD mortality agrees with the link between SFA consumption and CAD mortality. Hence, researchers and experts in the field do concede that the use of country-level data may disguise individual variability and the impact on true health consequences. Additionally, many studies do not consider all factors that impact cardiovascular health [56].

In recent years, scientific investigation of the impact of palm oil on cardiovascular health has been much more targeted, aiming to eliminate the interference of epidemiological studies and studies focusing only on SFAs. One such study revealed that consumption of palm oil resulted in significantly higher LDL and HDL cholesterol levels when compared to vegetable oils that were low in SFAs and significantly higher HDL cholesterol when compared to trans fats. These results were expected due to the SFA content of palm oil, and researchers suggest that this supports its replacement with vegetable oils that are low in SFAs and trans fatty acids [59]. Currently, one of the most difficult hurdles to the dietary reduction of palm oil is the fact that it is the most inexpensive vegetable oil to produce, which has resulted in it continuing to be a major source of SFAs in developing countries, where incidences of CVD are rapidly increasing [60].

Most of the research investigating the effect of coconut oil on CVD risk in humans is in relation to its impact on serum lipids, but it is generally considered harmful to heart health due to its high concentration of SFAs. Many experts contend that there are limited high-quality studies supporting the health benefits of coconut oil consumption, so they do not recommend frequent use [20]. Recent increases in the consumption of coconut oil products have resulted from the perceived health benefits of consuming MCTs, which many proponents claim to be abundant in coconut oil. However, lauric acid, which comprises nearly 50% of coconut oil's fatty acid profile, has been suggested to be metabolized as both a medium- and long-chain fatty acid, so research on pure MCTs cannot be applied to coconut oil. Furthermore, MCT research cannot be directly applied to any oil or oil product, as each material has a diverse fatty acid profile [47].

The scientific literature reports the consumption of SFAs in coconut oil to be strongly atherogenic and one of the primary causes of CAD in certain regions of the world. In addition to CAD and other CVDs, recent research suggests that elevated SFA intake may also be a risk factor for insulin resistance, a key component in the pathogenesis of type II diabetes [55]. Coconut oil consumption has also been linked to increased risk of obesity, hypertension, hyperlipidemia, and artery hardening, due to its high SFA content and propensity to increase serum triacylglycerol and LDL cholesterol [61]. Research has shown lauric and myristic acids, the major fatty acid components of coconut oil, to be hypercholesterolemic, the latter of which is more atherogenic. Additionally, a recent study conducted on rats fed coconut oil or soybean oil enriched diets concluded that rats on the coconut oil diet had significantly higher liver and plasma triglycerides than rats consuming diets containing fresh or

oxidized soybean oil [55]. Many experts attest that results of epidemiological studies are frequently cited as evidence that coconut oil does not negatively affect cardiovascular health; however, most indigenous populations consume coconut flesh or coconut cream, both of which differ greatly in composition when compared to coconut oil. Furthermore, the extraction and consumption of coconut oil is a relatively recent phenomenon, which weakens the strength of epidemiological findings. Additionally, some researchers believe that there is currently no concrete proof that consumption of coconut oil as a substitute for more unsaturated vegetable oils results in improved serum lipid profiles and decreased CVD risk. Conversely, historical scientific evidence suggests that replacing coconut oil with less saturated vegetable fats reduces CVD risk [19].

## 4. Public Perception

### 4.1. Saturated Fats Awareness

A consumer survey showed that omega-3 fatty acids are the best-known type of fat with 80% of respondents having heard of them, followed by saturated fats with 71% recognition. However, the awareness of fats is different between developed and emerging countries. In developed countries, 65–89% of those surveyed indicated familiarity with the various types of fats, while in emerging countries, 74% had an awareness of omega-3 fatty acids, and then the recognition for saturated fats dropped to 54%, and for trans fats to 26% [62]. It is also important to mention that this study predates the use of front-of-pack labeling, which is a policy strategy used to influence healthy choices among consumers [63].

### 4.2. Health Awareness

The first step in choosing a healthier fat is understanding the types of fats, followed by knowing which fats are better choices. Half of the people in a global survey indicated that they did not know which fats were a better choice. Additionally, 67% of respondents in developed countries reported that saturated fats were bad, versus 30% of respondents in emerging countries. Over 90% of people associate something negative with fat [62]. These associations may be further influenced by the use of front-of-package labeling systems that lead to greater accuracy in consumers' ability to identify the healthier of two products [63].

### 4.3. Dietary Fat Education and Guidelines Impact

Education about healthful eating is lacking, as indicated by the fact that consumers cannot recognize that foods such as cheese, chocolate, bacon, pastries, and many other foods are contributors of dietary fat. The Food and Health Survey of the International Food Information Council found that when consumers find nutrition and health information confusing, they do not try to sort out the information, and do not make changes to their nutritional habits. Consumers fail to consume appropriate amounts of healthful fats on a regular basis because information presented on fat does not convey a usable

or complete message [62]. Many people overlook that palm oil is an important element of the diet, like other oils and fats [64]. Consumer surveys show that nutrition communications, such as low fat or reduction in fats, has led to confusion on the understanding of dietary fat. In fact, 59% of respondents think fat should be avoided, 65% think a low-fat diet is healthy, while 38% claim to avoid foods containing fat. [62] The American Heart Association recommends not only limiting saturated fats, but also considering the overall dietary picture, as fats are only a part of what should be taken into consideration regarding nutrition. In a recent article, they mention that, for any information about food and diets, the source should be checked to confirm if it considers the latest scientific evidence [65].

Consumer perceptions of fat have been greatly influenced by decades of recommendations to consume low-fat diets, as well as the abundance of low-fat products. The average fat intake in the United States has decreased from 36.6% to 33.6% since 1971 [45], and 76% of men and 71% of women consume more than the recommendation of 10% of calories from saturated fat [66]. The intake of SFAs has steadily decreased since the first Dietary Guidelines for Americans in 1980. Since then, the decrease in total and saturated fat as a percent of calories has resulted in increased energy from dietary carbohydrates. With a decrease in fat consumption and an increase in carbohydrates intake, there has been a significant increase in the total energy intake and the obesity rate in the United States [45].

### 4.4. Plant-Derived Saturated Fats Awareness: Perceived Health Implications

There is an increased consumer interest in alternative sources of vegetable oils based on demand for healthy foods [17]. Compared to other plant-based oils, palm oil is higher in saturated fat and, as a result, was the target of past nutrition campaigns [13].

Because coconut oil is solid at room temperature, it has the stigma of being higher in saturated fat compared to palm oil, which is sold in a liquid form known as palm olein [2]. The high saturated fat content has led to a bad reputation for coconut oil because there is a greater incidence of high blood cholesterol with the consumption of high amounts of saturated fat. The SFA content (up to around 92 g/100 g) exceeds other edible fats, including butter [20].

Consumers' perceptions of tropical oils have received little attention as the discussion is often technical due to the complexity of agronomic, environmental, and health concerns. However, consumers' positions are important for policymakers who define regulatory interventions, as well as international food companies and non-governmental organizations [67]. As research indicates, consumers do not understand the importance of dietary fat, including the quality and quantity of fats needed for health [62].

In 1965, a literature review singled out fat and cholesterol as the dietary causes of coronary heart disease and downplayed evidence that sugar consumption was also a risk factor. However, this review was sponsored by the

Sugar Research Foundation, which set the review's objective, and whose funding and contributing role was not disclosed [68].

A nutrition campaign in the 1980s was launched to inform consumers that tropical oils increased the risk of coronary heart disease. However, this finding was a theoretical association between saturated fat and coronary heart disease during a time when tropical oils were competing with the U.S. soybean oil market as an alternative vegetable oil. In response to these national campaigns, food manufacturers removed tropical oils from their products and replaced them with hydrogenated vegetable oils. As a result, consumption of trans fatty acids increased, which later became the focus of the same advocacy groups. Now, palm oil is promoted as being a suitable replacement for hydrogenated vegetable oils [69].

Recently, coconut oil has been denoted as a cure-all product by recipe books, advertisements, and some journal articles, including claims for weight reduction, lowering cholesterol, wound healing, and immune-, energy-, and memory-boosting effects, as well as treatment for Crohn's disease, irritable bowel syndrome, thyroid conditions, diabetes, and Alzheimer's and Parkinson's diseases [20]. However, such health claims of coconut oil are often based solely on animal or in vitro studies or on human studies fed only a component of coconut oil rather than the whole food [70]. In 2015, a claim based on unpublished data suggested that coconut oil produces fewer aldehydes than unsaturated oils when heated, making it a healthier oil choice [20].

#### 4.5. Influences on Perception

A lab experiment conducted in France in 2011 was designed to evaluate consumers' willingness to pay for food products made with and without palm oil. Successive messages emphasizing the characteristics of palm oil and palm oil-free milk rolls were delivered to participants. The experiment shows that information influences consumers' decision making. Revealing environmental and health messages negatively impacts the consumers' willingness to pay for the palm oil product, while land use information negatively influences the willingness to pay for the palm oil-free product. This finding suggests that consumers are concerned about the palm oil issue, and a significant proportion of consumers are strongly negative toward palm oil [67].

## 5. Conclusions

The initial research studies focused on the negative health effects of consuming SFA, which led to recommendations of minimizing their consumption. However, in several studies presented in this review, they reported health benefits by consuming palm oil and coconut oil, which are the most abundant plant-based sources of SFA. Additionally, there are other factors such as location of cultivation, handling, and processing procedures that influence the composition and properties of the finished oil product that should be taken into consideration because they may have a different impact on health. This suggests reconsidering the general

recommendations of the dietary guidelines to consume less SFA and making the recommendations more specific to different sources of SFA. Furthermore, nutritional education about fat consumption, the benefits, and detrimental effects of consuming SFA should be enhanced and improved, especially in developing countries, where awareness of fat consumption and health is deficient. Therefore, further research about SFA production sources, composition and consumption is necessary. The studies should include variations of palm and coconut oils composition related to their cultivation locations, processing and refining technologies, comparative studies on the health benefits and detriments due to the consumption of specific SFA components and proportions from different sources. These studies would generate actual and specific information that would enhance consumer's perception, thus impacting the future dietary guidelines that would lead to a better understanding about the consumption of SFA from palm and coconut oils.

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