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Coconut oil intake and its effects on the cardiometabolic profile – A structured literature review

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ABSTRACT

In recent years, health professionals and laypersons have disseminated misinformation regarding the consumption of coconut oil. Those encouraging the supplementation of coconut oil argue that it provides health benefits and protective cardiovascular effects. Our article examines the effects of coconut oil intake on the cardiometabolic profile by exploring various lipid indices, as well as potential non-lipid effects, such as weight loss. The majority of randomized controlled trials show that coconut oil intake or its supplementation increases low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL—C), and total cholesterol when compared with other vegetable oils. Lauric acid, a medium-chain fatty acid and the main constituent of coconut oil, increases LDL-C and HDL-C concentrations, since it plays a main role as a substrate for apolipoprotein (apo)A1 and apoB synthesis, which are the key molecules in HDL-C and LDL-C particles, respectively.Despite some findings demonstrating an increase in HDL-C, definitive long-term clinical trials are imperative to ascertain whether this effect is clinically relevant. In addition, coconut oil intake has failed as a weight loss strategy and should not be considered as a supplementation strategy to increase satiety and/or thermogenesis.If one desires to include coconut oil in the diet, then we suggest that it should be limited and encompassed within the current recommendations of SFA intake, which are up to 10% of total caloric intake.

Contents

Abbreviations and acronyms: Apo, apolipoprotein; ARIC, atherosclerosis Risk in Communities; ASCVD, atherosclerotic cardiovascular disease; CVD, cardiovascular disease; DXA, dual-energy X-ray absorptiometry; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, Homeostasis Model Assessment of Insulin Resistance Index; hs-CRP, high-sensitivity C-reactive protein; LCFA, long-chain fatty acids; Lp(a), lipoprotein(a); LDL-C, lipoprotein cholesterol; MCFA, medium-chain fatty acid; PURE, Prospective Urban Rural Epidemiology; SFA, saturated fatty acids; TC, total cholesterol; TG, triglycerides.

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The consumption of coconut oil and related products (e.g. coconut milk and fat) is growing among developing countries and developing countries, such as the Philippines, Indonesia, Brazil, and India.[1] Some reasons for the increased popularity of coconut oil are its advocacy for health benefits associated with cardiovascular disease (CVD), weight loss, Alzheimer's disease, bone loss, diabetes, dental caries and topical use, such as the prevention of atopic dermatitis and hair damage.[1] The growth and associated benefit claims are in contrast to medical guideline recommendations advocating that saturated fatty acids (SFA) ingestion should be limited to ~10% of total daily energy consumption, where the addition of coconut oil might lead to exceeding these recommendations.[2,3] Thus, it is important to acquire greater insight regarding the effects of coconut oil.[4]

Much of the advocacy for consuming coconut oil is based on its high concentration of medium-chain fatty acid (MCFA), which is a putative substance associated with the reduction of adipose tissue and the promotion of a more favorable lipid profile, compared to long-chain fatty acids (LCFA)[5] or other oils, i.e. other vegetable and olive oil.[5,6] However, studies on MCFA supplementation have inherent limitations due to the frequent *co*-ingestion with other substances like phytosterols and omega-3 polyunsaturated fatty acids.[5,6] These compounds introduce the potential for biased outcomes given their own lipid modulating effects.[7–10] Furthermore, dietary studies targeting weight loss are often lacking regarding dietary control when investigating MCFA.[11] In this review, we provide further insights regarding coconut oil intake on the cardiometabolic profile by exploring lipid indices as well as non-lipidic effects, with an emphasis on weight loss.

Methods

We performed a structured review by examining studies from August 2018 to August 2019 obtained from the electronic databases Pubmed, (MEDLINE) and Google scholar. We adopted MeSH terms through the function "MeSH Database" within Pubmed. Terms were combined with the Boolean operator "AND" coupled with "coconut oil," "*Cocos nucifera*," "dyslipidemia," "lipids," "lipid profile," "HDL," "LDL," "lipoprotein(a)," "total cholesterol," "triglycerides," "cardiovascular disease," "heart disease," "atherosclerotic coronary disease," "obesity," "fat mass," "thermogenesis," and "weight loss". Eligibility criteria included full-text English articles with a primary focus on interventional human studies, particularly randomized controlled trials, while in vitro and animal studies were excluded.

Results – lipids effects

Randomized controlled trials

A systematic review by Eyres et al. examined 21 interventional studies reporting on coconut oil intake and lipid profiles.[12] Their assessment showed that coconut oil intake led to increased levels of low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL—C), and total cholesterol (TC) levels, compared to other vegetable oils. No discernable effects were observed regarding serum triglycerides (TG). Among the studies analyzed, coconut oil intake increased LDL-C in six studies, TC in seven, and HDL-C in five. On the other hand, serum TG did not change in five studies, with only two studies reporting decreases in serum TG. Additionally, there is also evidence supporting no effect of coconut oil on lipid profiles.[13,14]

A crossover study by Mendis et al. examined the effects of ingesting soy vs. coconut oil in 25 healthy normolipidemic men consuming soybean or coconut oil for eight weeks, followed by a 3-week washout period.[13] Throughout the study, diet was isocalorically controlled (~2400 kcal/d) with a macronutrient composition corresponding to ~85 g/d of protein, ~80 g/d of total fat, ~350 g/d of carbohydrate and dietary cholesterol of ~250 mg/d. The diet was not hyperlipidemic albeit each oil type consisted of 70% fat, since the intervention limited total fat intake to ~30% of total calories. After eight weeks of soy oil consumption, the authors observed decreases in TC (37 mg/dL), TG (32 mg/dL), LDL-C (26 mg/dL), and HDL-C (7 mg/dL) levels, whereas coconut oil intake did not alter the lipid profile.

Similar findings were observed in an open-label study of 20 overweight patients, where the daily supplementation of 30 mL coconut oil, fractionated into three servings, over four weeks, did not change any lipid profile marker.[14]

Effect on high LDL-C concentrations

Tight control of moderate and high LDL-C concentrations represents a common clinical goal in which lifestyle modifications are a primary recommendation before statin therapy.[15,16] In patients with moderate and high but not very high LDL-C concentrations (fasting LDL-C ≥ 115 mg/dL and < 190 mg/dL), Maki et al. (2018) randomized men ($n = 12$) and women ($n = 13$) in a crossover protocol to ingest four tablespoons (~54 g) per day of coconut or corn oil in muffins and rolls as part of their habitual diets for four weeks, with a three-week washout between conditions.[17] Overall, the corn oil intervention produced a more favorable plasma lipid profile than coconut oil. For instance, non-HDL cholesterol decreased 3% in the corn oil group yet increased by 5.8% in the coconut oil group. In addition, TC significantly increased 7.1% in coconut oil treatment, while it did not change during corn oil consumption. Both interventions increased HDL-C concentrations by +5.4% with corn oil and + 6.5% with coconut oil.[17]

Healthy patients

The primary prevention of atherosclerotic CVD (ASCVD) as well as stroke, and peripheral vascular disease are among the overall complications of CVD that are a concern deserving of attention even with healthy patients as a prevention strategy.[18] In this regard, Khaw et al. randomized 91 healthy men and women to four weeks of 50 g/d of extra virgin coconut oil, extra virgin olive oil, or unsalted butter incorporated into their usual diet or as a supplement. As a result, LDL-C concentrations were significantly increased with butter compared to coconut oil (+16 mg/dL) and olive oil (+15 mg/dL), but no differences were

found between the olive oil and coconut oil groups. Interestingly, coconut oil significantly increased HDL-C concentrations compared to butter (+6.9 mg/dL) or olive oil (+6.2 mg/dL).[19]

Obesity

Obesity, which is now considered a global pandemic disease, is usually accompanied by atherogenic dyslipidemia, subsequently improving with weight loss.[20,21] In an effort to examine the effects of dietary oil consumption accompanying a weight loss program, Oliveira-de-Lira et al. randomized 75 female obese individuals (body mass index, 30–39.9 kg/m^2) into coconut oil, safflower oil, or chia oil vs. a soybean oil placebo group for eight weeks in participants instructed to ingest two capsules (1 g/capsule) 30 min before their main meals (6 g/day), in the context of a hypocaloric diet (deficit of 500 kcal). While all groups improved their lipid profile, the chia oil responses were more favorable (TC: −45 mg/dL; LDL-C: −43 mg/dL; HDL—C: +3.7 mg/dL; TG-C: −49.7 mg/dL).[22]

Developed and developing countries

Coconut oil consumption is typically consumed more frequently in developing countries, such as several Africa countries and within tropical and sub-tropical regions of the world.[23] Since these regions have a paucity of monetary investment for research, studies on coconut oil are more susceptible to inaccuracy by virtue of unfavorable methods. An example is the use of coconut oil in the traditional cooking of Filipino people. A large-sample study of Philippine women ($n = 1839$) showed that individuals who had consumed higher amounts of coconut oil had statistically higher HDL-C levels compared to those with lower intakes.[24] However, HDL-C levels in women with a higher coconut oil intake were ~42 mg/dL, whereas the HDL-C levels of those with medium and low coconut oil intake were ~41 mg/dL and ~39 mg/dL, respectively. Therefore, it is uncertain whether coconut oil increases HDL-C based on these findings alone, as it is questionable whether a ~2–3 mg/dL difference in HDL-C concentrations is physiologically meaningful.

Furthermore, in the same study,[24] female patients with higher coconut oil intake had higher levels of TC, LDL-C, and TG than groups with low and middle coconut oil intake. Overall, these data show that coconut oil intake increases HDL-C levels but also impairs other lipid profile parameters, a fact that was not emphasized in this study. In addition, there was substantial bias since no caloric or macronutrient adjustment occurred between the groups. For instance, the caloric differences were inordinate, with some individuals consuming a daily caloric intake of <500 kcal and others consuming almost 2000 kcal per day. Caloric control between groups is fundamental in order to assess changes in lipid biomarkers since caloric restriction, per se, contributes to lipid profile changes.[25]

Cumulatively, several review articles were based on poor-quality studies from developing countries due to inaccurate methods and basic control of the randomized controlled trials.[23,26] Therefore, caution is recommended when using these articles to support global statements. Coconut oil may be a feasible foodstuff for some developing countries due to regional dietary habits, having an important contribution regarding calorie intake, while in other developing countries (e.g. Brazil), coconut oil may be, in fact, even more expensive than several vegetable oils, including olive oil. The incentive to add coconut oil into the regular dietary habits of developed countries may lead to an overconsumption of SFA, since the usual diet is already rich in SFA, regardless of any additional coconut oil intake.

On one hand, undernutrition remains a serious health issue in several developing countries;[27] while on the other hand, overnutrition in developed countries is a current concern. A global example is the United States, where CVD is the leading cause of death, even with medical modernization.[28] Since 1980, when the first Dietary Guidelines for Americans were initially promoted, the intake goal was to reduce SFA intake to <10% of daily calories; yet 42–65% of the adult population does not meet this recommendation.[29] Hence, a recommendation for consuming coconut oil would certainly increase the total daily intake of SFA among the American population. As such, it should be noted that 0.4 million metric tons of coconut oil consumption was reported in the U.S. during 2010, with an average intake of 1.28 kg per capita yearly.[12] To provide further insight into this issue, Harris et al. randomized 20 postmenopausal women to ingest 30 mL virgin coconut oil or safflower oil in addition to a typical U.S. diet for 28 days with a 28-day washout period.[30] The ingestion of virgin coconut oil significantly raised TC (+18 mg/dL), LDL-C (+14 mg/dL), and HDL-C (+6.6 mg/dL) when compared with baseline values, while safflower oil did not significantly change lipid values.

Coconut oil coupled with a low-calorie diet

In a randomized, double-blind clinical trial, 40 women were assigned to receive 30 mL of coconut oil or an equivalent amount of soybean oil in conjunction with a low-calorie diet (~1700 kcal/d) and exercise program (50 min of walking per day) over a 12-week period.[31] Overall, the coconut oil group displayed no change in TC nor LDL-C, while significantly increasing HDL-C levels by 3.2 mg/dL. In contrast, the group that consumed soybean oil increased TC and LDL-C levels (+19.8 and + 25.5 mg/dL), respectively, whereas HDL-C (−6.5 mg/dL) decreased. A strength of this study was the use of dietary control, with no statistically significant differences in macronutrients, calories and dietary fiber between the groups. A more strictly controlled human intervention, based on coconut oil intake, is likely to provide better information and accurate data by assessing general lipid types i.e., SFA, polyunsaturated, and monounsaturated fats.

Coconut fruit

Fresh coconut fruit is also an appreciable source of SFA.[32] To explore coconut oil ingestion via coconut fruit intake 58 healthy volunteers were randomized into a standardized diet along with 100 g (1) fresh coconut or (2) groundnuts and groundnut oil combination for three months. The coconut fruit diet significantly increased LDL-C and HDL-C levels (+12 and +3.8 mg/dL respectively), whereas groundnut diet reduced TC and HDL-C concentrations (−11 and −2.4 mg/dL respectively). Neither the coconut group nor the groundnut group altered the apolipoprotein (apo)-B/apo-A1 ratio. Interestingly, the authors also analyzed the fatty acid profile of erythrocytes and found no differences in many long-chain SFA or total SFA in either groups, despite coconut oil being a rich source of SFA.[32] Regarding SFA status, in a low-carbohydrate-high-fat diet, the SFA intake was not a determining contributor to circulating levels.[33] For instance, in a recent study the low-carbohydrate-high-fat diet decreased SFA concentrations in plasma TG, while the high carbohydrate diet resulted in greater incorporation of SFA.[33] The major determining factor for increasing the body concentrations of SFA is de novo lipogenesis, a biochemical process by which carbohydrate is converted to fat through hepatic metabolism.[33,34] Therefore, coconut oil as well as copra may be an interesting adjutant foodstuff on a low-carbohydrate diet but per se is not a candidate to improve cardiometabolic biomarkers.

Coconut milk porridge

Another food application is the use of coconut milk. In one study, 77 healthy individuals who received coconut milk porridge, five days a week, displayed a 10 mg/dL HDL-C concentration increase over an eight-week period.[35] After a washout period of two weeks, subjects exchanged coconut milk porridge for isocaloric soy milk over another eight weeks. Overall, there was a 9.6 mg/dL increase in HDL and a 15 mg/dL decrease in LDL concentrations after coconut milk porridge intake, while these parameters did not change with soy milk intervention.

Moreover, relevant amounts of fat ingestion were attained with coconut milk porridge, which provided 23 g of total fat mainly due to lauric acid contribution, while soy milk porridge provided 15 g of total fat, mainly from unsaturated fat. Regardless of these dietary details, there was a substantial information gap, since the diet was not analyzed.[35]

In other words, a recommendation to consume the popular oatmeal with cow's milk is more reasonable than coconut milk porridge, since these foodstuffs have several cardiovascular benefits supported by a significant body of literature.[36–38] These observations beg the question, "Is coconut oil an HDL-C booster?" In our view, this claim is highly questionable since an HDL-C increase of 10 mg/dL, as noted previously,[35] is likely inaccurate. Any foodstuff that increased HDL-C levels to this magnitude would certainly be mentioned in current dyslipidemia guidelines consensus. Even foods offering well established cardiovascular protection, i.e. decreased cardiovascular mortality, (e.g., olive oil and nuts) only increased HDL-C levels 2–5 mg/dL, after several bias adjustments.[39–41]

HDL-C pathway

In general, coconut oil ingestion may increase HDL-C concentrations[12] but it is highly questionable that these values might be of the previously reported magnitude (+10 mg/dL). Regarding a mechanism of action, we propose lauric acid, the main constituent of coconut oil, to be the cornerstone of the pathway. Lauric acid accounts for 50% of coconut oil content.[42] Although lauric acid is considered an MCFA, 70% is transported as LCFA, while the other 30% remains MCFA.[12] Thus, there are two ways of transporting lauric acid in the organism, as shown in Fig. 1. When lauric acid is delivered to the liver, it acts as a substrate to produce apoA1 and apoB, further contributing to the formation of both HDL-C and LDL-C particles.

Another proposed mechanism for the rise in HDL-C levels from lauric acid ingestion occurs by virtue of a decreased HDL-C and apoA-I catabolism coupled with increased reverse cholesterol transport. Decreased HDL-C catabolism may be due to the increased size of this molecule and apoA-I synthesis.[43,44] Our supposition is supported by a meta-analysis that confirmed that lauric acid intake increased HDL—C, apoA-I, LDL-C, and apo-B levels in humans,[45] hence supporting the link between these pathways and clinical biomarkers.

Lipoprotein(a)

The lipoprotein (Lp)-(a) is an incipiently different genetic molecule derived from LDL-C, presenting with a diameter and density similar to those of LDL-C and is linked to the development of ASCVD.[46] Despite the questionable effects of coconut oil on lipid indices, it may have more favorable effects on Lp(a) concentrations compared with unsaturated oils; so much so that, in a controlled crossover study of female students, Lp(a) concentrations were reduced 17 mg/L after a three-week period of a high-fat diet based on coconut oil, whilst increased 25 mg/L after a high consumption of unsaturated long-chain fatty acids.[47] Such an effect due to coconut oil may be desirable and possibly recommended for patients at intermediate to high risk for cardiovascular disease with a goal of achieving a Lp(a) target of <50 mg/dL.[46] However, it is important to note that there are no discernable effects of dietetic interventions on Lp(a) concentration and their subsequent associations to improve CVD related outcomes.[46]

Postprandial lipids

Postprandial lipids are a phenomenon strongly associated with increased levels of fat mass since disturbances in adipose tissue lead to insulin resistance and postprandial metabolic dyslipidemia.[48] In a study of adult women with excess body fat, Valente et al. showed that an isocaloric breakfast with 25 mL of virgin coconut oil, compared to extra-virgin olive oil, did not cause deleterious changes in TG, TC, HDL—C, LDL-C, and the TG/HDL-C ratio assessed during fasting and postprandial periods (up to 240 min). Likewise, other traditional cardiometabolic biomarkers were not altered, such as serum uric acid, glucose and the Homeostasis Model Assessment of Insulin Resistance Index (HOMA-IR).[49] Tan et al., in turn, through a controlled crossover trial, investigated the ingestion of 22.25 g of coconut oil in a test meal and detected an increase in the incremental area under the curve for postprandial TG (6 h), when compared with the controlled test meal.[50] Finally, a recent study investigated 16 healthy volunteers consuming test biscuits containing 40 g of either butter, coconut oil, or lard in a single-blinded, randomized crossover design. Blood samples were collected fasted and then at 2, 3, 4, and 6 h postprandially, displaying a ~59.8% lower postprandial TG response following coconut oil ingestion vs. butter ($p < .01$) and or lard ($p < .01$).[51]

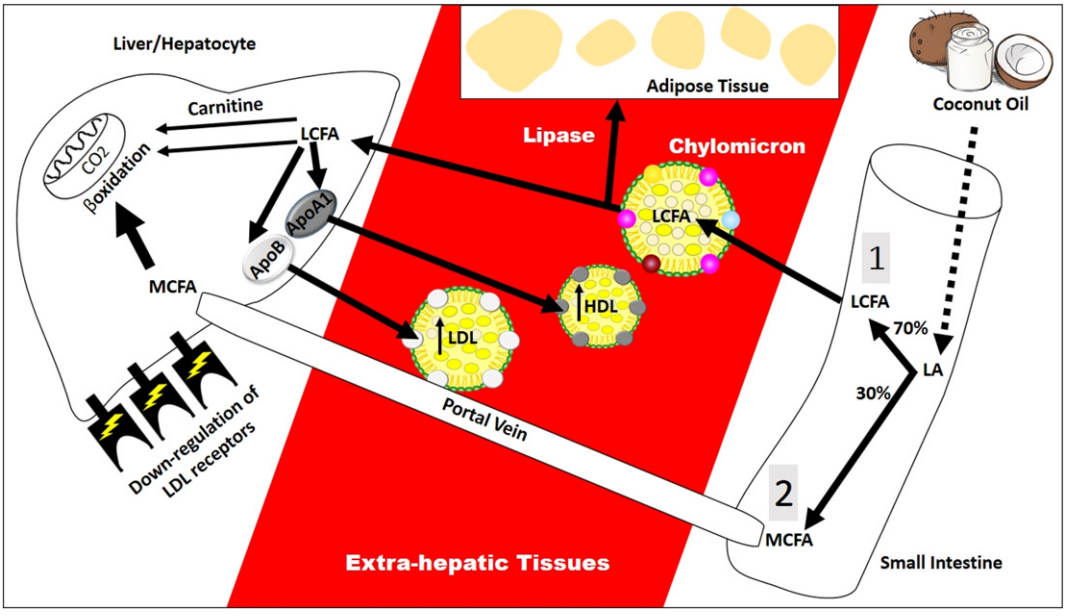

Fig. 1. Plausible pathways of coconut oil intake and lipoprotein modulation. 1: coconut oil transport as LCFA. 2: Coconut oil transport as MCFA. ApoA-1, apolipoprotein A-1; ApoB, apolipoprotein B; CO_2, Carbon dioxide; HDL, high density lipoprotein; LA, lauric acid; LCFA, long chain fatty acids; LDL, low density lipoprotein; MCFA, medium chain fatty acid.

Non-lipid effects

Thermogenesis

Although not scientifically supported, there is widespread misinformation that coconut oil is not stored in adipocytes and is a potent thermogenic foodstuff. The speculation comes from the concept of MCFA transport in the body where, after intestinal absorption, the molecules pass through the hepatic portal vein, thus being oxidized in the hepatocytes.[52] In the light of this purported mechanism arises the misconception that coconut oil intake acts as a "fat burning" agent. However, to prove a thermogenic action, there must be at least some increase in body temperature and/or indirect calorimetry analysis.[1–46,49–79]

To this end, Valente et al. demonstrated via an isocaloric breakfast composed of 25 mL of virgin coconut oil or extra-virgin olive oil, no increase in energy expenditure, diet induced thermogenesis, or lipid oxidation in adult women with excess body fat.[49] Likewise, in a randomized trial, LaBarrie and St-Onge (2017) showed that a coconut oil-rich meal did not enhance thermogenesis compared to corn oil.[55] A similar lack of results was demonstrated by Tan et al., who did not find any differences in energy expenditure measured by indirect whole-room calorimetry, after participants consumed a test meal composed of 22.25 g of coconut oil or a control meal. [56]

Body composition

In a study by Oliveira-de-Lira et al.,[22] investigators examined the consumption of coconut oil vs. safflower oil, chia oil, and soybean oil, demonstrating a decrease in body weight, body weight index, waist circumference, and body fat in all groups (~8.5%), as well as statistically significant increases in lean mass. The coconut oil intervention resulted in an increase of lean mass (2.6%) which, on an absolute basis, was significant when compared to the safflower oil group.

Altogether, these results probably occurred due to dietary intervention, per se, because there are no discernible actions by which coconut oil increased lean mass and its components. So much so that, St-Onge et al. demonstrated that even ingesting 18–24 g/d of MCFA for 4 months resulted in a greater loss of fat-free mass (−0.93 kg) than olive oil.[11] It is essential to note that this study was composed of overweight subjects on a weight-loss diet, where a considerable daily amount of MCFA did not promote an anti-catabolic effect.[11] Indeed, MCFA is an important point to be explained in order to avoid claims towards coconut oil intake based on the nature of MCFA. The point is true since there are current data promoting MCFA supplementation as a nutrient for sarcopenia.[57,58] However, dietary adjustment for the total daily protein is clinically more significant for muscle mass management, including the hypertrophic process, even in weight loss programs, especially when combined with resistance training.[59]

Moreover, the Oliveira-de-Lira et al. trial failed regarding an accurate conclusion, since they used bioelectrical impedance for body composition, whose method is less reliable than dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging.[60,61] Although neither groups changed body water content, the increases in lean mass in the coconut oil intervention did not justify a particular effect in muscle mass accretion. Among the oils examined, only chia oil would have biologically muscle-enhancing properties due to its omega-3 content, which is a candidate to improve myofibrillar protein synthesis when insufficient protein is consumed.[62] Intriguingly, coconut oil increased absolute lean mass to a greater magnitude than chia oil.[22] Finally, in sharp contrast with Oliveira-de-Lira et al., Harris et al. demonstrated that neither virgin coconut oil or safflower oil promoted DXA-measured body composition changes.[30]

Satiety

Valente et al. showed that an isocaloric breakfast with 25 mL of virgin coconut oil vs. extra-virgin olive oil in adult women with excess body fat (~37%) provided greater total satiety, total fullness, and hunger suppression at 240 min compared to a control breakfast.[49] In a controlled crossover trial, Tan et al. randomized normal-weight men ($n = 16$) into coconut oil in a test meal (25 g) and found no suppression of appetite vs. a control meal even though coconut oil provided a higher fat and energy content (total fat: 23.6 vs. 1.3 g/meal; energy: 1740 vs. 904 kJ/meal).[56] In a randomized single blinded study, 24 healthy participants consumed a test breakfast smoothie containing 205 kcal of either MCFA oil, coconut oil, or rapeseed oil (control) on three separate test days. The MCFA increased fullness over 3 h after breakfast and reduced food intake compared to the control and coconut oils. Nonetheless, coconut oil was reported as being less palatable than the MCFA oil.[63]

Inflammation

Endotoxemia is in its scientific ascendancy related to its pathogenesis of atherosclerosis and many other conditions.[64] A high-fat meal increases bacterial endotoxin levels, thereby contributing to the postprandial and chronic inflammatory state with atherosclerotic development through endothelial activation.[65,66] In a single-blinded, randomized, crossover study, healthy participants displayed an increase in serum postprandial (time up to 300 min) endotoxin concentrations after ingesting 16 g coconut oil, whilst a decrease was noted after an omega-3 isocaloric meal (docosahexaenoic acid = 500 mg; fish oil).[67]

In addition to the analysis of bacterial endotoxins, high-sensitivity C-reactive protein (hs-CRP) is another biomarker linking the human gut microbiota and the cardiovascular system.[68] Thus, an increase in hs-CRP concentration from coconut oil intake would be expected, given that it postprandially raises the concentration of bacterial endotoxins.[67] Despite this hypothesis, Maki et al. did not find an increase in hs-CRP concentrations with 4 tablespoons daily (~54 g) of coconut oil under four weeks.[17] Therefore, coconut oil ingestion may acutely induce inflammation similarly to other SFA sources typical in a Western-style diet.[67] On the other hand, it should be recognized that long-term consumption of coconut oil does not seem to increase inflammation, at least based on the surrogate biomarker hs-CRP.[17,69]

Discussion

Collectively, coconut oil intake does not improve CVD biomarkers to support any clinical recommendation when compared to other vegetable oils, i.e. olive oil. While ingesting coconut oil may increase HDL-C levels, to a greater extent than other vegetable oils, definitive long-term clinical trials are needed to confirm whether this effect is relevant in this context since the consumption of SFA, regardless of being coconut oil derived, may also increase HDL-C levels. Importantly, coconut oil intake may increase LDL-C and TC similarly to other rich food sources of SFA. Lastly, despite its mainstream media hype, the ingestion of coconut oil fails as a weight loss strategy and should not be considered a dietary strategy to increase satiety and/or thermogenesis.

Epidemiologic Studies and CVD Outcomes

Wang et al.,[70] through two large ongoing cohort studies involving 83,349 women from the Nurses' Health Study and 42,884 men from the Health Professionals Follow-up Study, reported that SFA intake led to an 8% increase in total mortality when compared to the extreme quintiles. Replacing 5% of energy from SFA with equivalent energy from polyunsaturated fatty acids and monounsaturated fatty acids was associated with an estimated reduction in total mortality of 27% and 13%, respectively, in patients free of CVD, cancer, and diabetes at baseline.[70] In 2017, the Prospective Urban Rural Epidemiology

(PURE)[71] demonstrated that total fat and individual types of fat were related to lower total mortality, whereas they were not associated with CVD, myocardial infarction, or CVD- mortality. Furthermore, SFA had an inverse association with stroke. Such an investigation was a large, epidemiological cohort study on individuals aged 35–70 years in 18 countries with a median follow-up of 7.4 years, in which through screening food frequency questionnaires of 135,335 individuals, higher carbohydrate intake (more than about 60% of energy) was associated with increased risk of total mortality and non-CVD mortality. Thus, the PURE study is in sharp contrast with current recommendations to limit total fat intake to <30% of energy and SFA intake to <10% of energy, recommending an increase in the consumption of fats while decreasing carbohydrate intake.[71] However, the PURE study has been under serious scrutiny since the macronutrient analysis did not quantify the type of dietary carbohydrate as either simple or complex.[72] It is well established that low income countries have a high consumption of carbohydrates from refined sources, i.e. white bread, white rice.[73,74] Additionally, the consumption of high glycemic index foods is associated with a linear increase in coronary heart disease risk, total mortality and CVD events.[75]

Subsequently, the prospective observational Atherosclerosis Risk in Communities (ARIC) study,[76] examined CVD risk factors in four US communities using dietary questionnaires from 15,428 adults aged 45–64 years, and reported a U-shaped association between the percentage of energy consumed from carbohydrate and mortality. During a median follow-up of 25 years, a percentage of 50–55% energy from carbohydrate was associated with the lowest risk of mortality. Summarizing, both high and low percentage carbohydrate diets counteracted long-term beneficial outcomes. Within low-carbohydrate diets, however, those richer in animal-derived protein and fat sources (e.g. lamb, beef, pork, and chicken) were considered less favorable regarding positive outcomes, whilst those rich in plant-derived protein and fat intake (e.g. vegetables, nuts, peanut butter, and whole-grain breads) were considered more favorable. Neither the PURE nor the ARIC research studies[71,76] investigated the independent effect of coconut oil intake, however they support the notion that individual types of fat differently influence mortality and cardiovascular outcomes. Given that the ARIC study[76] suggested that plant-based fats may be postulated as healthy foodstuffs, coconut oil could be a viable food pertaining to healthy dietary habits.

Recommendations

Currently, guidelines still limit the intake of SFA to 10% of total daily calories in the general population, as discussed in the American Heart Association[3] and in the Dietary Guidelines for Americans.[2] Hence, coconut oil intake, as well as any SFA oil source, needs to be accounted for when providing any dietary guidelines.

Smoke point

Coconut oil fails not only to improve lipid indices and weight loss but also may be less suitable for cooking.[23,77] Optimal frying temperatures are ~180 °C, whereas the smoke point of unrefined coconut oil is 177 °C.[23,77] Therefore, the use of unrefined coconut oil is less suited than other unrefined oils such as extra-virgin olive oil, which in turn has a smoke point of 191 °C,[77] and a wide body of evidence demonstrating its CV benefits.[40,41,78]

Nevertheless, the ingestion of repeated heating of coconut oil has carcinogenic potential. Such an ingestion in a rat model caused a genotoxic and preneoplastic change in the liver particularly due to increased formation of polycyclic aromatic hydrocarbons and oxidative stress status.[79] Therefore, the repeated heating at high temperatures during cooking of coconut oil, similar to any vegetable oil, is an unhealthy practice.

Conclusion

There is little data to support the use of coconut oil intake to improve lipid profiles and other metabolic aspects. Coconut oil intake may increase HDL-C concentrations, but it also increases LDL-C and TC similarly to other SFA-rich food sources. Long-term follow-up studies with well-characterized dietary intake are needed to evaluate the effects of coconut and coconut oil intake on important outcomes, e.g. cardiovascular diseases and mortality. No data are valuable to support claims regarding the value of coconut oil as a fat burner, and it has not been shown to influence thermogenesis or satiety. Coconut oil should be included only within 10% of total caloric intake, and considered similar to any SFA source in its adverse effects on lipids and cardiovascular disease.

Statement of conflict of interest

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References

1. Wallace TC. Health effects of coconut oil-a narrative review of current evidence. J Am Coll Nutr 2019;38(2):97-107. https://doi.org/10.1080/07315724.2018.1497562.
2. Report Index - 2015 Advisory Report. , health.govhttps://health.gov/dietaryguidelines/2015-scientific-report/ (Accessed June 24, 2017).
3. Sacks FM, Lichtenstein AH, Wu JHY, et al. Dietary fats and cardiovascular disease: a presidential advisory from the American Heart Association. Circulation January 2017. https://doi.org/10.1161/CIR.0000000000000510 CIR.0000000000000510.
4. Vijayakumar M, Vasudevan DM, Sundaram KR, et al. A randomized study of coconut oil versus sunflower oil on cardiovascular risk factors in patients with stable coronary heart disease. Indian Heart J 2016;68(4):498-506. https://doi.org/10.1016/j.ihj.2015.10.384.
5. St-Onge M-P, Lamarche B, Mauger J-F, Jones PJH. Consumption of a functional oil rich in phytosterols and medium-chain triglyceride oil improves plasma lipid profiles in men. J Nutr 2003;133(6):1815-1820. https://doi.org/10.1093/jn/133.6.1815.
6. Bourque C, St-Onge M-P, Papamandjaris AA, Cohn JS, Jones PJH. Consumption of an oil composed of medium chain triacyglycerols, phytosterols, and N-3 fatty acids improves cardiovascular risk profile in overweight women. Metab Clin Exp 2003;52(6):771-777.
7. Cabral CE, Klein MRST. Phytosterols in the treatment of hypercholesterolemia and prevention of cardiovascular diseases. Arq Bras Cardiol 2017;109(5):475-482. https://doi.org/10.5935/abc.20170158.
8. Santos HO. The need for sex hormone analysis in addition to long-term follow-up of phytosterol supplementation. Arq Bras Cardiol 2018;111(2):228-229. https://doi.org/10.5935/abc.20180132.
9. Simopoulos AP. Dietary omega-3 fatty acid deficiency and high fructose intake in the development of metabolic syndrome, brain metabolic abnormalities, and non-alcoholic fatty liver disease. Nutrients 2013;5(8):2901-2923. https://doi.org/10.3390/nu5082901.
10. O'Mahoney LL, Matu J, Price OJ, et al. Omega-3 polyunsaturated fatty acids favourably modulate cardiometabolic biomarkers in type 2 diabetes: a meta-analysis and meta-regression of randomized controlled trials. Cardiovasc Diabetol 2018;17(1):98. https://doi.org/10.1186/s12933-018-0740-x.
11. St-Onge M-P, Bosarge A. Weight-loss diet that includes consumption of medium-chain triacylglycerol oil leads to a greater rate of weight and fat mass loss than does olive oil. Am J Clin Nutr 2008;87(3):621-626. https://doi.org/10.1093/ajcn/87.3.621.
12. Eyres L, Eyres MF, Chisholm A, Brown RC. Coconut oil consumption and cardiovascular risk factors in humans. Nutr Rev 2016;74(4):267-280. https://doi.org/10.1093/nutrit/nuw002.
13. Mendis S, Kumarasunderam R. The effect of daily consumption of coconut fat and soya-bean fat on plasma lipids and lipoproteins of young normolipidaemic men. Br J Nutr 1990;63(3):547-552.
14. Liau KM, Lee YY, Chen CK, Rasool AHG. An open-label pilot study to assess the efficacy and safety of virgin coconut oil in reducing visceral adiposity. ISRN Pharmacol 2011;2011. https://doi.org/10.5402/2011/949686.
15. Ueda P, Gulayin P, Danaei G. Long-term moderately elevated LDL-cholesterol and blood pressure and risk of coronary heart disease. PLoS One 2018;13(7). https://doi.org/10.1371/journal.pone.0200017.
16. Mannu G, Zaman M, Gupta A, HU R, Myint P. Evidence of lifestyle modification in the management of hypercholesterolemia. Curr Cardiol Rev 2013;9(1):2-14. https://doi.org/10.2174/1573403138050763 13.

17. Maki KC, Hasse W, Dicklin MR, et al. Corn oil lowers plasma cholesterol compared with coconut oil in adults with above-desirable levels of cholesterol in a randomized crossover trial. J Nutr 2018;148(10):1556-1563. https://doi.org/10.1093/jn/nxy156.
18. Arnett DK, Blumenthal RS, Albert MA, et al. ACC/AHA guideline on the primary prevention of cardiovascular disease. Circulation 2019(March 2019). https://doi.org/10.1161/CIR.0000000000000678 CIR0000000000000678.
19. Khaw K-T, Sharp SJ, Finikarides L, et al. Randomised trial of coconut oil, olive oil or butter on blood lipids and other cardiovascular risk factors in healthy men and women. BMJ Open 2018;8(3), e020167. https://doi.org/10.1136/bmjopen-2017-020167.
20. Fruh SM. Obesity: risk factors, complications, and strategies for sustainable long-term weight management. J Am Assoc Nurse Pract 2017;29(suppl 1):S3-S14. https://doi.org/10.1002/2327-6924.12510.
21. Klop B, Elte JWF, Castro CM. Dyslipidemia in obesity: mechanisms and potential targets. Nutrients 2013;5(4):1218-1240. https://doi.org/10.3390/nu5041218.
22. Oliveira-de-Lira L, Santos EMC, de Souza RF, et al. Supplementation-dependent effects of vegetable oils with varying fatty acid compositions on anthropometric and biochemical parameters in obese women. Nutrients 2018;10(7). https://doi.org/10.3390/nu10070932.
23. Boateng L, Ansong R, Owusu WB, Steiner-Asiedu M. Coconut oil and palm oil's role in nutrition, health and national development: a review. Ghana Med J 2016;50(3):189-196. , https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5044790/. Accessed March 9, 2019.
24. Feranil AB, Duazo PL, Kuzawa CW, Adair LS. Coconut oil predicts a beneficial lipid profile in pre-menopausal women in the Philippines. Asia Pac J Clin Nutr 2011;20(2):190-195. , http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3146349/.
25. Christensen P, Meinert Larsen T, Westerterp-Plantenga M, et al. Men and women respond differently to rapid weight loss: metabolic outcomes of a multi-centre intervention study after a low-energy diet in 2500 overweight, individuals with prediabetes (PREVIEW). Diabetes Obes Metab 2018;20(12):2840-2851. https://doi.org/10.1111/dom.13466.
26. MASTER EDITORA. Periódicos científicos, livros eletrônicos, E-books, editoração e distribuição de obras, caráter científico. , http://www.mastereditora.com.br/busca. Accessed June 24, 2017.
27. Delisle H, Batal M. The double burden of malnutrition associated with poverty. Lancet 2016;387(10037):2504-2505. https://doi.org/10.1016/S0140-6736(16)30795-4.
28. Murphy SL, Xu J, Kochanek KD, Arias E. Mortality in the United States, 2017. NCHS Data Brief 2018;328:1-8.
29. Liu AG, Ford NA, Hu FB, Zelman KM, Mozaffarian D, Kris-Etherton PM. A healthy approach to dietary fats: understanding the science and taking action to reduce consumer confusion. Nutr J 2017;16. https://doi.org/10.1186/s12937-017-0271-4.
30. Harris M, Hutchins A, Fryda L. The impact of virgin coconut oil and high-oleic safflower oil on body composition, lipids, and inflammatory markers in postmenopausal women. J Med Food 2017;20(4):345-351. https://doi.org/10.1089/jmf.2016.0114.
31. Assunção ML, Ferreira HS, dos Santos AF, Cabral CR, Florêncio TMMT. Effects of dietary coconut oil on the biochemical and anthropometric profiles of women presenting abdominal obesity. Lipids 2009;44(7):593-601. https://doi.org/10.1007/s11745-009-3306-6.
32. Nagashree RS, Manjunath NK, Indu M, et al. Effect of a diet enriched with fresh coconut saturated fats on plasma lipids and erythrocyte fatty acid composition in normal adults. J Am Coll Nutr 2017;36(5):330-334. https://doi.org/10.1080/07315724.2017.1280713.
33. Hyde PN, Sapper TN, Crabtree CD, et al. Dietary carbohydrate restriction improves metabolic syndrome independent of weight loss. JCI Insight 2019;4(12). https://doi.org/10.1172/jci.insight.128308.
34. Wu JH, Lemaitre RN, Imamura F, et al. Fatty acids in the de novo lipogenesis pathway and risk of coronary heart disease: the Cardiovascular Health Study123. Am J Clin Nutr 2011;94(2):431-438. https://doi.org/10.3945/ajcn.111.012054.
35. Ekanayaka RAI, Ekanayaka NK, Perera B, PGSM DS. Impact of a traditional dietary supplement with coconut milk and soya milk on the lipid profile in normal free living subjects. J Nutrition Metab 2013;2013, e481068. https://doi.org/10.1155/2013/481068.
36. Whitehead A, Beck EJ, Tosh S, Wolever TMS. Cholesterol-lowering effects of oat β-glucan: a meta-analysis of randomized controlled trials. Am J Clin Nutr 2014;100(6):1413-1421. https://doi.org/10.3945/ajcn.114.086108.
37. Kristek A, Schär MY, Soycan G, et al. The gut microbiota and cardiovascular health benefits: a focus on wholegrain oats. Nutrition Bull 2018;43(4):358-373. https://doi.org/10.1111/nbu.12354.
38. Anderson JJB, Kruszka B, Delaney JAC, et al. Calcium Intake From Diet and Supplements and the Risk of Coronary Artery Calcification and its Progression Among Older Adults: 10-Year Follow-up of the Multi-Ethnic Study of Atherosclerosis (MESA). J Am Heart Assoc 2016;5(10). https://doi.org/10.1161/JAHA.116.003815.
39. Estruch R, Ros E, Salas-Salvadó J, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. N Engl J Med 2013;368(14):1279-1290. https://doi.org/10.1056/NEJMoa1200303.
40. Guasch-Ferré M, Hu FB, Martínez-González MA, et al. Olive oil intake and risk of cardiovascular disease and mortality in the PREDIMED Study. BMC Med 2014;12:78. https://doi.org/10.1186/1741-7015-12-78.
41. Medina-Remón A, Casas R, Tressserra-Rimbau A, et al. Polyphenol intake from a Mediterranean diet decreases inflammatory biomarkers related to atherosclerosis: a substudy of the PREDIMED trial. Br J Clin Pharmacol 2017;83(1):114-128. https://doi.org/10.1111/bcp.12986.
42. McCarty MF, DiNicolantonio JJ. Lauric acid-rich medium-chain triglycerides can substitute for other oils in cooking applications and may have limited pathogenicity. Open Heart 2016;3(2), e000467. https://doi.org/10.1136/openhrt-2016-000467.
43. Hayek T, Ito Y, Azrolan N, et al. Dietary fat increases high density lipoprotein (HDL) levels both by increasing the transport rates and decreasing the fractional catabolic rates of HDL cholesterol ester and apolipoprotein (Apo) A-I. Presentation of a new animal model and mechanistic studies in human Apo A-I transgenic and control mice. J Clin Invest 1993;91(4):1665-1671. , https://www.ncbi.nlm.nih.gov/pmc/articles/PMC288145/.
44. Srivastava RA. Saturated fatty acid, but not cholesterol, regulates apolipoprotein AI gene expression by posttranscriptional mechanism. Biochem Mol Biol Int 1994;34(2):393-402.
45. Mensink RP, Zock PL, Kester ADM, Katan MB. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials. Am J Clin Nutr 2003;77(5):1146-1155.
46. Santos HO, Kones R, Rumana U, Earnest CP, Izidoro LFM, Macedo RCO. Lipoprotein (a): current evidence for a physiologic role and the effects of nutraceutical strategies. Clin Ther July 2019. https://doi.org/10.1016/j.clinthera.2019.06.002.
47. Müller H, Lindman AS, Blomfeldt A, Seljeflot I, Pedersen JI. A diet rich in coconut oil reduces diurnal postprandial variations in circulating tissue plasminogen activator antigen and fasting lipoprotein (a) compared with a diet rich in unsaturated fat in women. J Nutr 2003;133(11):3422-3427. https://doi.org/10.1093/jn/133.11.3422.
48. Hsieh J, Hayashi AA, Webb J, Adeli K. Postprandial dyslipidemia in insulin resistance: mechanisms and role of intestinal insulin sensitivity. Atheroscler Suppl 2008;9(2):7-13. https://doi.org/10.1016/j.atherosclerosissup.2008.05.011.
49. Valente FX, Cândido FG, Lopes LL, et al. Effects of coconut oil consumption on energy metabolism, cardiometabolic risk markers, and appetitive responses in women with excess body fat. Eur J Nutr April 2017. https://doi.org/10.1007/s00394-017-1448-5.
50. Tan S-Y, Wan-Yi Peh E, Marangoni AG, Henry CJ. Effects of liquid oil vs. oleogel coingested with a carbohydrate-rich meal on human blood triglycerides, glucose, insulin and appetite. Food Funct 2017;8(1):241-249. https://doi.org/10.1039/c6fo01274d.
51. Panth N, Dias CB, Wynne K, Singh H, Garg ML. Medium-chain fatty acids lower postprandial lipemia: a randomized crossover trial. Clin Nutr February 2019. https://doi.org/10.1016/j.clnu.2019.02.008.
52. Babu AS, Veluswamy SK, Arena R, Guazzi M, Lavie CJ. Virgin coconut oil and its potential cardioprotective effects. Postgrad Med 2014;126(7):76-83. https://doi.org/10.3810/pgm.2014.11.2835.
53. da Rocha EEM, Alves VGF, da Fonseca RBV. Indirect calorimetry: methodology, instruments and clinical application. Curr Opin Clin Nutr Metab Care 2006;9(3):247-256. https://doi.org/10.1097/01.mco.0000222107.15548.f5.
54. Mazerolle SM, Ganio MS, Casa DJ, Vingren J, Klau J. Is oral temperature an accurate measurement of deep body temperature? A systematic review. J Athl Train 2011;46(5):566-573.
55. LaBarrie J, St-Onge M-P. A coconut oil-rich meal does not enhance thermogenesis compared to corn oil in a randomized trial in obese adolescents. Insights Nutr Metab 2017;1(1):30-36. , https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5531289/. Accessed March 9, 2019.
56. Tan S-Y, Peh E, Lau E, Marangoni AG, Henry CJ. Physical form of dietary fat alters postprandial substrate utilization and glycemic response in healthy Chinese men. J Nutr 2017;147(6):1138-1144. https://doi.org/10.3945/jn.116.246728.
57. Abe S, Ezaki O, Suzuki M. Medium-chain triglycerides (8:0 and 10:0) are promising nutrients for sarcopenia: a randomized controlled trial. Am J Clin Nutr July 2019. https://doi.org/10.1093/ajcn/nqz138.
58. Abe S, Ezaki O, Suzuki M. Medium-chain triglycerides in combination with leucine and vitamin D increase muscle strength and function in frail elderly adults in a randomized controlled trial. J Nutr 2016;146(5):1017-1026. https://doi.org/10.3945/jn.115.228965.
59. Longland TM, Oikawa SY, Mitchell CJ, Devries MC, Phillips SM. Higher compared with lower dietary protein during an energy deficit combined with intense exercise promotes greater lean mass gain and fat mass loss: a randomized trial. Am J Clin Nutr 2016;103(3):738-746. https://doi.org/10.3945/ajcn.115.119339.
60. Boneva-Asiova Z, Boyanov MA. Body composition analysis by leg-to-leg bioelectrical impedance and dual-energy X-ray absorptiometry in non-obese and obese individuals. Diabetes Obes Metab 2008;10(11):1012-1018. https://doi.org/10.1111/j.1463-1326.2008.00851.x.
61. Pateyjohns IR, Brinkworth GD, Buckley JD, Noakes M, Clifton PM. Comparison of three bioelectrical impedance methods with DXA in overweight and obese men. Obesity (Silver Spring) 2006;14(11):2064-2070. https://doi.org/10.1038/oby.2006.241.
62. Smith GI, Atherton P, Reeds DN, et al. Dietary omega-3 fatty acid supplementation increases the rate of muscle protein synthesis in older adults: a randomized controlled trial123. Am J Clin Nutr 2011;93(2):402-412. https://doi.org/10.3945/ajcn.110.005611.
63. Kinsella R, Maher T, Clegg ME. Coconut oil has less satiating properties than medium chain triglyceride oil. Physiol Behav 2017;179:422-426. https://doi.org/10.1016/j.physbeh.2017.07.007.
64. Munford RS. Endotoxemia—menace, marker, or mistake? J Leukoc Biol 2016;100(4):687-698. https://doi.org/10.1189/jlb.3RU0316-151R.
65. Erridge C, Attina T, Spickett CM, Webb DJ. A high-fat meal induces low-grade endotoxemia: evidence of a novel mechanism of postprandial inflammation. Am J Clin Nutr 2007;86(5):1286-1292. https://doi.org/10.1093/ajcn/86.5.1286.
66. Herieka M, Erridge C. High-fat meal induced postprandial inflammation. Mol Nutr Food Res 2014;58(1):136-146. https://doi.org/10.1002/mnfr.201300104.
67. Lyte JM, Gabler NK, Hollis JH. Postprandial serum endotoxin in healthy humans is modulated by dietary fat in a randomized, controlled, cross-over study. Lipids Health Dis 2016;15(1):186. https://doi.org/10.1186/s12944-016-0357-6.
68. Schicho R, Marsche G, Storr M. Cardiovascular complications in inflammatory bowel disease. Curr Drug Targets 2015;16(3):181-188.

69. Pendyala S, Walker JM, Holt PR. A high-fat diet is associated with endotoxemia that originates from the gut. Gastroenterology 2012;142(5). https://doi.org/10.1053/j.gastro.2012.01.034 (1100-1101.e2).
70. Wang DD, Li Y, Chiuve SE, et al. Association of specific dietary fats with total and cause-specific mortality. JAMA Intern Med 2016;176(8):1134-1145. https://doi.org/10.1001/jamainternmed.2016.2417.
71. Dehghan M, Mente A, Zhang X, et al. Associations of fats and carbohydrate intake with cardiovascular disease and mortality in 18 countries from five continents (PURE): a prospective cohort study. Lancet 2017;390(10107):2050-2062. https://doi.org/10.1016/S0140-6736(17)32252-3.
72. Gianos E, Williams KA, Freeman AM, Kris-Etherton P, Aggarwal M. How Pure is PURE? Dietary lessons learned and not learned from the PURE trials. Am J Med 2018;131(5):457-458. https://doi.org/10.1016/j.amjmed.2017.11.024.
73. Brand-Miller JC, Holt SHA, Pawlak DB, McMillan J. Glycemic index and obesity. Am J Clin Nutr 2002;76(1). https://doi.org/10.1093/ajcn/76/1.281S (281S-5S).
74. Ludwig DS, Hu FB, Tappy L, Brand-Miller J. Dietary carbohydrates: role of quality and quantity in chronic disease. BMJ 2018;361:k2340. https://doi.org/10.1136/bmj.k2340.
75. Fan J, Song Y, Wang Y, Hui R, Zhang W. Dietary glycemic index, glycemic load, and risk of coronary heart disease, stroke, and stroke mortality: a systematic review with meta-analysis. PLoS One 2012;7(12), e52182. https://doi.org/10.1371/journal.pone.0052182.
76. Seidelmann SB, Claggett B, Cheng S, et al. Dietary carbohydrate intake and mortality: a prospective cohort study and meta-analysis. Lancet Public Health 2018;3(9):e419-e428. https://doi.org/10.1016/S2468-2667(18)30135-X.
77. Vieira SA, McClements DJ, Decker EA. Challenges of utilizing healthy fats in Foods123. Adv Nutr 2015;6(3):309S-317S. https://doi.org/10.3945/an.114.006965.
78. Ros E, Martínez-González MA, Estruch R, et al. Mediterranean diet and cardiovascular health: teachings of the PREDIMED study. Adv Nutr 2014;5(3). https://doi.org/10.3945/an.113.005389 (330S-6S).
79. Srivastava S, Singh M, George J, Bhui K, Murari Saxena A, Shukla Y. Genotoxic and carcinogenic risks associated with the dietary consumption of repeatedly heated coconut oil. Br J Nutr 2010;104(9):1343-1352. https://doi.org/10.1017/S0007114510002229.