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Red palm oil

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Red palm Laura Cassiday

For centuries, people on the African continent, including the ancient Egyptians, used red palm oil (RPO) for culinary purposes. Only recently has the minimally processed palm oil been introduced to Western palates, with variable results. Some people find the red-orange hue unappetizing, while others view the color as a welcome reminder of the oil's high carotene content. Like other "exotic" edible oils such as coconut and avocado, RPO has attracted a cult following for its supposed health benefits. Whether or not RPO can make the leap from a niche oil to widespread commercial success depends on substantiation of these health claims and on the versatility of the oil for a variety of food applications.

- Red palm oil is mildly processed, allowing it to retain beneficial components such as carotenes and antioxidants that are lost in traditional physical or chemical palm oil refining.
- Red palm oil has shown promise for combating vitamin A deficiency in some parts of the world. However, other potential health benefits have not yet been well established.
- The commercial success of red palm oil depends on consumer acceptance of the red color it typically imparts to foods. Blends with other oils may increase red palm oil's versatility.

PALM OIL PROCESSING

Palm oil is derived from the fruit of the oil palm tree, primarily the African oil palm *Elaeis guineensis*. In its natural, unprocessed state, palm oil is dark red in color due to a high content of carotenoids, including β -carotene (a vitamin A precursor that gives carrots their color) and lycopene. The oil is also rich in antioxidants, such as vitamin E isomers (tocopherols and tocotrienols), and phytosterols. However, without any processing, crude palm oil (CPO) has limited utility in the kitchen. "Red palm oil in its crude form is very strong tasting. It's very pungent and has a smell like overripe mushrooms. It's not very palatable," says Neil Blomquist, chief commercial officer for Natural Habitats (Rotterdam, The Netherlands), a supplier of organic palm oil from Ecuador and West Africa. "Companies have tried to introduce crude palm oil into the market, but it has not done well because it doesn't taste good, and it's hard to use in the kitchen." In addition, CPO contains free fatty acids (FFA), moisture, trace metals, and other impurities that limit its shelf life.

As a result, most CPO is refined to remove odors, flavors, and impurities, as well as the red color that many consumers find unappetizing. Refined, bleached, and deodorized (RBD) palm oil is bland, odorless, light yellow in color, and semisolid at room temperature, making it an ideal replacement for partially hydrogenated oils in many snack products and baked goods. Before or after refining, palm oil can be fractionated into palm olein (liquid fraction; 70–80% of palm oil) and palm stearin (solid fraction; 20–30%). Palm olein is typically used as a cooking or frying oil, whereas palm stearin can be found in shortenings and butter substitutes. RBD palm oil is now the most widely used vegetable oil in the world, a key component of foods ranging from baked goods to salad dressings to ice cream (Mancini, A., *et al.*, http://dx.doi.org/10.3390/molecules200917339, 2015).

CPO can undergo physical or chemical refining, although physical refining is more common because of CPO's high FFA content. During the deodorization step of physical refining, edible oils are subjected to high

EDIBLE OILS

temperatures (250–270°C) and low pressures (3–5 torr) to remove FFA and volatile compounds that affect the oil's odor and flavor. The deodorization step thermally degrades all carotenes, producing a light-colored oil, and strips away some of the tocopherols, tocotrienols, and phytosterols.

SEEING RED

"The key for producing red palm oil is that you have to deodorize the palm oil at a low temperature to avoid thermal destruction of the carotenes," says Wim De Greyt, R&D manager at Desmet Ballestra (Brussels, Belgium), a company that designs and builds edible oil refineries. "If you go for the classical physical refining, then you need a molecular distillation step so that you can strip off the free fatty acids at a deeper vacuum and lower temperature. Alternatively, if you can start from a very good crude palm oil with a low free fatty acid content, you can apply a chemical refining. You remove the free fatty acids with caustic, and then you also do the deodorization step at a lower temperature." Chemical refining, which removes most FFA by reaction with sodium hydroxide, uses a slightly lower-temperature deodorization (235°C or below) than physical refining. The deodorization temperature can be further decreased if the crude oil is low in FFA. "To retain the carotenes, you probably need to deodorize at temperatures below 220°C," says De Greyt.

The Palm Oil Research Institute of Malaysia developed and patented a physical refining process that produces RPO of similar quality to RBD palm oil, but that retains most of the carotenes, vitamin E, and phytosterols of CPO (Table 1; Nagendran, B., et al., http://dx.doi.org/10.1177/156482650002100213, 2000). In the refining process, CPO is treated with phosphoric acid for degumming and with bleaching earth, followed by filtration. Then, the oil is deodorized and deacidified by molecular distillation at low temperature (less than 170°C) and low pressure (less than 100 mtorr). The resulting RPO retains up to 80% of the carotene and vitamin E content of CPO, with less than 0.1% each of FFA, moisture, and impurities. RPO produced by this process is blended with canola oil and marketed as Carotino (Carotino Group, Johor, Malaysia). In addition to liquid cooking and frying oils, Carotino is available as a margarine, shortening, and butter oil (ghee) substitute.

Natural Habitats has taken a different approach to RPO production. "We developed a cold filtration process to neutralize the flavor of red palm oil," says Blomquist. The procedure, which is done under vacuum, removes the phospholipids that carry flavor bodies, as well as moisture and some of the FFA. The cold filtration process, which Blomquist says is not refining

TABLE 1: Levels of minor beneficial components in palm oil

Sample	Carotenes (ppm)	Vitamin E (ppm)	Phytosterols (ppm)
Crude Palm Oil ^a	643	869	210-620
RBD Palm Olein ^a	Nil	561	109–170
Red Palm Olein ^b	513	707	325-365

^aSample from palm oil refinery

^bRed palm olein sample processed by molecular distillation at the Palm Oil Research Institute of Malaysia.

Credit: Adapted from data in Nagendran, B., *et al.*, http://dx.doi.org/10.1177/156482650002100213, 2000.

per se, retains most of the β -carotene and all of the tocopherols and tocotrienols of CPO. "Our process mostly affects the flavor profile of palm oil," says Blomquist. "In fact, we can kind of fine-tune the process. We have about 12 different flavor profiles to choose from."

RPO produced by cold filtration has a higher FFA content (about 3%) than RPO that has been physically refined by molecular distillation (Carotino, 0.1% max). However, Blomquist says that this relatively high level of FFAs has not caused any problems with stability, presumably because of the high natural content of antioxidants in RPO. "We've been guaranteeing a 12-month shelf life from the time the RPO is packed in bulk to the customer, but I think we could extend it," says Blomquist. One of Natural Habitats' major customers is the organic brand Nutiva (Richmond, California, USA), which offers RPO, as well as a shortening that is a blend of RPO and coconut oil (Fig. 1).

FATTY ACID COMPOSITION

RPO has the same fatty acid composition as RBD palm oil (Table 2). Like RBD palm oil, RPO contains approximately 50% saturated fat, 42% of which is palmitic acid (16:0) (Kritchevsky, D., 2000). The high saturated fat content makes RPO semisolid at room temperature and more stable to lipid oxidation than oils that are composed of mainly unsaturated fatty acids. The other major component of RPO, oleic acid, is a monounsaturated fat also present at about 42%. Minor components such as carotenoids, vitamin E, and phytosterols make up only about 1% of RPO.

"The fatty acid profile of palm oil, whether it is red or RBD, is high in saturated fat," says Gijs Calliauw, product development manager at Desmet Ballestra. "Red palm oil has been promoted for its higher content of minor nutritional components such as carotenes, but 99% of it is still just a palm oil with the negative effects that may come with saturated fatty acid consumption. I think you'd be better off eating carrots."

The health effects of saturated fats remain controversial, with some studies linking saturated fat intake to cardiovascular disease risk, whereas others have failed to find an association (Cassiday, L., *Inform*, 2015). In addition, some research indicates that the health effects of saturated fatty acids depend on their chain length. Medium-chain fatty acids, such as the lauric acid (12:0) plentiful in coconut oil, are metabolized more rapidly than long-chain saturated fatty acids, such as the palmitic acid (16:0) abundant in palm oil (Cassiday, L., *Inform*, 2016a). The slower metabolism of long-chain fatty acids may make them more likely to contribute to obesity and cardiovascular

disease than medium-chain fatty acids. Thus, some nutritionists consider coconut oil a more healthful dietary choice than palm oil.

Studies of palm oil consumption and cardiovascular risk have uncovered both favorable and unfavorable changes in disease biomarkers (Mancini, A., et al., http://dx.doi.org/10.3390/molecules200917339, 2015). However, in studies where palm oil is compared to other edible oils such as soybean, olive, sunflower, and canola, no substantial differences in human lipid serum profiles have been observed. Animal studies have even indicated an antithrombotic effect of palm oil. Although RPO may contribute beneficial carotenes and antioxidants that reduce cardiovascular risk, as will be discussed later, most of these studies were conducted using RBD palm oil, suggesting that the fatty acid composition of palm oil in general may not be particularly damaging to cardiovascular health.

FABLE 2: Fatty	<i>i</i> acid	composition of	f red	l palm	oil
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Fatty Acid	Content (%)		
14:0 (myristic)	0.8		
16:0 (palmitic)	42.0		
18:0 (stearic)	5.1		
18:1 (oleic)	42.0		
18:2 (linoleic)	10.0		
Total	99.9		

Credit: Data from Kritchevsky, D., Food Nutr. Bull. 21, 182–188, 2000.

One possible explanation is the stereospecific positioning of palmitic acid within palm oil triacylglycerides (TAGs). In palm oil TAGs, oleic acid is primarily present in the *sn-2* position, while palmitic acid is found in the flanking *sn-1* and *sn-3* positions. Only 7–11% of the palmitic acid in palm oil is located at the *sn-2* position (May, C. Y., and Nesaretnam, K., http://dx. doi.org/10.1002/ejlt.201400076, 2014). In contrast, in animal fats palmitic acid or stearic acid is usually at the *sn-2* position. Seventy percent of the palmitic acid in lard is present at the *sn-2* position. This stereospecific positioning is thought to play a role in fatty acid absorption and metabolism, and perhaps cardiovascular disease risk (Mancini, A., *et al.*, http://dx.doi. org/10.3390/molecules200917339, 2015). Indeed, the atherogenicity of different TAGs has been linked to the degree of saturation of the fatty acid located at the *sn-2* position.

Although the healthfulness of the fatty acid profile of palm oil is controversial, minor components in RPO may reduce its cardiovascular risk compared with RBD palm oil. Some studies have found that the tocopherol-rich fraction (TRF) of red palm oil reduces serum cholesterol levels in humans, whereas



FIG. 1. Nutiva brand red palm oil is produced by a cold filtration process. Credit: Nutiva

others have not (Kritchevsky, D., 2000). In an animal study, rats fed diets high in RPO showed a reduced low-density lipoprotein (LDL) cholesterol level and a decreased ratio of total cholesterol to high-density lipoprotein (HDL) cholesterol compared with rats fed RBD palm oil or vitamin E-stripped palm oil (Kamisah, Y., et al., Pakistan J. Nutr., 2005). Rabbits fed RPO had a reduced severity of cholesterol-induced atherosclerosis than rabbits consuming RBD palm oil (Kritchevsky, D., 2000). Much more research is needed to determine whether minor components of RPO reduce cardiovascular risk compared with RBD palm and other edible oils.

CAROTENOIDS

Carotenoids are fat-soluble pigments found in fruits and vegetables. Carotenoids that contain oxygen in their structure are known as xanthophylls, whereas those that lack oxygen are called carotenes. Some carotenoids, such as α - and β -carotene, are converted by the body into retinol, or vitamin A₁. β -carotene has about twice the vitamin A activity of α -carotene (Nagendran, B., *et al.*, http://dx.doi. org/10.1177/156482650002100213, 2000). Some carotenoids can act as antioxidants by scavenging oxygen and peroxyl radicals.

CPO is the world's richest natural plant source of carotenoids, containing about 15 times more retinol equivalents than the same weight of carrots (Benadé, A. J., 2003). The carotenoids in RPO are primarily β -carotene (48.2%) and α -carotene (38.9%), with smaller amounts of 11 other carotenoids including lycopene, phytoene, and phytofluene.

Studies of the effects of β -carotene supplementation on cardiovascular disease have produced mixed results (Benadé, A. J., 2003). Some studies indicate that carotenes can inhibit the proliferation of certain types of cancer cells. But by far the best substantiated health benefits of carotenes are in preventing vitamin A deficiency and associated skin and eye diseases.

As a rich source of carotenes, RPO has been investigated as a fortification strategy to combat vitamin A deficiency in the developing world. The highest prevalence of vitamin A deficiency occurs in south Asia and sub-Saharan Africa, where 30–40% of preschool children are at an increased risk of poor health or death due to vitamin A deficiency (Benadé, A. J., 2003). In one study, researchers provided sweet snacks containing RPO to Indian schoolchildren, which increased their serum retinol levels. The researchers estimated that if RPO shortening was widely used in baked goods, it could supply 46–70% of the recommended daily allowance (RDA) of vitamin A in children aged 7–10 years.

In another study, researchers examined the effects of RPO supplementation during pregnancy on maternal and neonatal vitamin A status (Radhika, M. S., *et al.*, 2003). The double-blind, randomized controlled trial assigned 170 pregnant Indian women (16–24 weeks gestation) to: 1. a group receiving RPO containing 1 RDA (2,400 micrograms) of β -carotene per day, or 2. a control group receiving an equivalent amount of groundnut oil. At 34–36 weeks gestation, women in the RPO group had significantly higher levels of serum retinol and significantly lower incidences of vitamin A deficiency and anemia. After delivery, the infants of mothers in the RPO group likewise had higher levels of serum retinol in their cord blood than babies born to the control group.

TOCOPHEROLS AND TOCOTRIENOLS

As vitamin E isomers, tocopherols and tocotrienols are potent antioxidants that confer oxidative stability to RPO. Researchers have detected five vitamin E isomers in RPO: α - and γ -tocopherol; and α -, γ -, and δ -tocotrienols. Approximately 70% of the vitamin E in RPO is in the form of tocotrienols, which are more potent antioxidants and are thought to confer

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greater health benefits than tocopherols (Cassiday, L., 2013). A number of beneficial health effects for both tocopherols and tocotrienols have been reported in the literature, including antitumor and antithrombotic properties and enhancement of the immune response (Kamisah, Y., *et al.*, *Pakistan J. Nutr.*, 2005). Tocotrienols have cholesterol-lowering activity, possibly due to their inhibition of HMG CoA reductase, the rate-limiting enzyme in cholesterol biosynthesis.

OTHER COMPONENTS

Phytosterols are plant steroid compounds that have been shown to lower plasma LDL cholesterol. RPO has a higher phytosterol content, including β -sitosterol, campesterol, and stigmasterol, than RBD palm oil (Nagendran, B., *et al.*, http://dx.doi.org/10.1177/156482650002100213, 2000). RPO also contains ubiquinones, primarily coenzyme Q₁₀, a potent antioxidant. Squalene, an antioxidant with antitumor activity in animal models, is present at trace amounts. RPO also contains polyphenols, including phenolic acids and flavonoids, with antioxidant activity.

RED-DY OR NOT?

In 2013, US television personality Dr. Oz declared that RPO "may very well be the most miraculous find of 2013." Perhaps as a result of this publicity, RPO has been showing up in an increasing number of health food stores, and even in some large supermarket chains. But according to Calliauw, RPO remains very much a niche oil. "The vast majority of the big palm oil producers don't put red palm oil out," he says. "Desmet Ballestra does not receive many requests to design refining plants specifically for the production of RPO. Most palm oil refining plants are not even able to do it."

Calliauw sees the red color of RPO as the primary impediment for widespread consumer acceptance. "The big fast-food companies typically fry in palm oil, but I doubt they would ever use red palm oil," he says. "The red color is actually something you want to get rid of because the average consumer doesn't like the appearance, nor appreciate the perceived health benefits. For a whole lot of applications, red palm oil would not be suitable just because of the color."

Blomquist agrees that color has been an issue for consumers. In an attempt to mitigate this problem, Natural Habitats tested some blends of regular palm olein and RPO olein as frying oil. "The blend actually turned the potato chips and corn chips a really beautiful darker yellow color," he says. "Personally, I think RPO has potential in a blend like that, or in a blend with high-oleic sunflower oil." A blend with another oil would also reduce the cloudiness that can be a problem for single-fractionated palm olein. In addition, using a blend of RPO and a high-oleic oil would reduce the amount of saturated fat compared to pure RPO, which could help with marketing. "I think that would make a really great frying oil for snacks," says Blomquist.

Although RPO contains beneficial components not present in RBD palm oil, it could lack two detrimental ones: 3-monochloropropane-1,2-diol (3-MCPD) esters and glycidyl esters. These process contaminants are formed during the high-temperature deodorization of palm oil (Cassiday, L., 2016b). "The hot topic in palm oil refining today is the MCPD and glycidyl esters issue," says De Greyt. "Red palm oil is, almost by definition, low in glycidyl esters and may also contain less 3-MCPD esters because it is more mildly refined. So maybe that could cause a renewed interest in red palm oil."

Laura Cassiday is an associate editor of Inform *at AOCS. She can be contacted at laura.cassiday@aocs.org.*

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