Valuable Phytonutrients in Commercial Red Palm Olein

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INTRODUCTION

Red palm olein is a new product recently marketed in Malaysia. This edible oil is produced through a new process developed by Malaysian Palm Oil Board (MPOB) (Choo *et al.*, 1993a) and has been adopted on a commercial scale by a Malaysian company. Milder processing conditions are used so that important phytochemicals originally present in crude palm oil are retained in the refined oil. Vitamin E, carotenoids, ubiquinones and sterols, are among the phytochemicals of significant health importance present in the product. Many articles have been published about the phytonutrients in red palm olein produced in pilot trials (Choo *et al.*, 1993a, b; Choo, 1996; Ooi *et al.*, 1996). This article reviews the phytonutrients content of the commercial red palm olein (brand name Carotino).

CAROTENOIDS

The carotenoids in commercial red palm olein (CRPOo) consist of mixtures of oxygenated carotenes (xanthophylls) and carotenes. There are 11 types of carotenes in the mixture, similar to that in crude palm oil. Alpha- and β-carotene, including their *cis* isomers, comprise more than 80% of the total carotenoids. The carotene profile of CRPOo shows that α- and β-carotene are almost equal in proportion, unlike crude palm oil where β-carotene is higher.

Alpha- and β-carotene are well known for their high pro-vitamin A activity. Considering that they constitute the largest portion of the total carotene, CRPOo is a rich natural source of vitamin A. Alpha- and β-zeacarotene which exist in smaller quantities also possess pro-vitamin A activity, albeit at a lesser degree. The total carotene content of CRPOo measured spectrophotometrically is 665 ppm. This is equivalent to approximately 92 μg RE g^{-1} based on the assumption for pro-vitamin A activity of the various carotene (*Table 1*). Therefore, one tablespoon of oil (*i.e.* about 15 g) is able to meet the stipulated Recommended Daily Allowance (RDA) dosage for vitamin A for all individuals from young to old with differing needs (*Table 1*).

Apart from their pro-vitamin A activity, palm carotene especially α- and β-carotene are effective antioxidant. A study conducted by Serbinova *et al.* (1992) using palm-based carotene showed that the order of strength in *in vitro* prevention of lipid peroxidation was α-carotene > lycopene > β-carotene. The role of palm carotene as antioxidant may also explain their anti-cancer potential. This is because they are able to scavenge free radicals, which are implicated in the occurrence of cancer. Manorama *et al.* (1993) showed that red palm oil more effectively prevented chemical carcinogenesis in rats compared to Refined Bleached Deodorized Palm Oil (RBDPO) and attributed the effectiveness of red palm oil to its carotenoids. The *in vivo* and *in vitro* chemical carcinogenesis studies by Tan and Chu (1991) in the rat hepatic cytochrome-P450-mediated monoxygenase system showed that the order of reactivity as an anti-tumour agent was palm oil (with caro-tenoids) > beta carotene > canthaxanthin > palm oil (without carotenoids). This study also gave the impression that a mixture of carotenoids is more effective in inhibiting proliferation of cancer cells than individual carotene. Arising from this, consumption of CRPOo with its bouquet of

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TABLE 1. VITAMIN A EQUIVALENT OF CAROTENOIDS IN CRPOo

1 retinol equivalent (RE) = 1 μg of retinol = 6 μg of β-carotene = 12μg of other pro-vitamin A carotenes (Tee, 1992).

Recommended Daily Allowances per day for vitamin A (plus carotenoids)
Children 1 to 10 years, 400-700 μg RE
Males 11 - > 51 years, 1000 μg RE
Females 11 - > 51 years, 800 μg RE
Pregnant women, +200 μg RE
Lactating women, +400 μg RE

Source: RDA, Ninth edition (revised 1980).

carotenoids may help in reducing the risk of cancer more effectively than commercial β-carotene supplements.

Xanthophylls, the oxygenated carotene have also been identified in CRPOo. Preliminary results show that the ones found in CRPOo are dehydroretinal, ζ-caroten-dione and β-carotene-5,6-epoxide isomers. There are a few others, which are yet to be identified. Although this class of carotenoids are not widely known or studied for their physiological importance, their potential role as antioxidant should not be ignored. Terao (1989) found that carotenoids with *oxo* groups are more effective antioxidant than β-carotene against free radical attack on lipids. They suggested that the presence of oxygen atoms reduce the unpaired electron density on the carbon skeleton and enhance the reactivity of the carbon-centred radical in trapping molecular oxygen. If this is the case, then the presence of *oxo* groups in ζ-caroten-dione may increase its effectiveness as antioxidant compared to the carotenes.

VITAMIN E

The four major types of vitamin E (α-tocopherol, α-, γ-, and δ-tocotrienols) in crude palm olein are also present in CRPOo. Tocotrienol isomers constitute 80% of the total vitamin E in CRPOo. The concentration of vitamin E in CRPOo is about 810 ppm (range of 717-863 ppm) (*Table 2*). The National Research Council (USA) has stipulated, for dietary purposes, that vitamin E activity be expressed as RRR α-tocopherol, where one α-TE is equivalent to 1 mg of RRR-α-tocopherol. Referring to *Table 3,* one tablespoon of CRPo is able to meet the RDA for adults of both genders.

Besides having vitamin E activity, tocotrienols are strong antioxidant. Their role as antioxidant links them with some superb anti-cancer activity evidenced by various epidemiological studies (Komiyama *et al.*, 1989; Guthrie *et al.*, 1993; Goh *et al.*, 1994; Nesaretnam *et al.*, 1992). Tocotrienols are also superior to tocopherols as anti-cancer

TABLE 2. VITAMIN E COMPOSITIONS (%) AND CONTENTS OF CRUDE PALM OIL (CPO), CRPOo AND REFINED BLEACHED DEODORIZED PALM OLEIN (RBDPOo)

Samples	Vitamin E (%)				Vitamin E content (ppm)
	α-Tocopherol	α-Tocotrienol	γ-Tocotrienol	δ-Tocotrienol	
CPO	21	24	43	11	600-1000
CRPOo	19	29	41	10	717-863
RBDPOo	25	29	36	10	515-800

TABLE 3. VITAMIN E EQUIVALENT OF CRPo

One α-TE = 1 mg of RRR-α-tocopherol = 1.49 IU (American Institute of Nutritition, 1979).
Vitamin E equivalent of 810 ppm of CRPo = 11.34 mg α-TE or 16.90 IU per 15 g oil
(15 g is equivalent to one tablespoon oil)

Food and Nutrition Board, RDA (1989)
Adult males 10 mg α-TE or 15 IU
Adult females 8 mg α-TE or 12 IU

agents as shown by several studies (Kato *et al.*, 1985; Komiyama *et al.*, 1989; Sundram *et al.*, 1989). Being antioxidants, tocotrienols of palm olein were also shown to effectively inhibit oxidation of protein and lipid in rat liver microsomes (Kamar *et al.*, 1997). Therefore, tocotrienols are capable of protecting celullar membranes against oxidative damage.

UBIQUINONES

Crude palm oil contains 10-80 ppm of ubiquinone 10 (UQ_{10}) and about 5 ppm of ubiquinone-9 (Hamid *et al.*, 1995). Only the UQ_{10} was detected in CRPOo at a concentration in the range of 18-25 ppm. Ubiquinone-10, better known as coenzyme Q10 has been gaining prominence in the biomedical field due to the myriad's of significantly important physiological attributes, ranging from enhancement of immune system to prevention of heart diseases and hypertension (Yamamura, 1985).

STEROLS

The majors sterols in crude palm oil are also retained in CRPOo, with β-sitosterol at 59%, campesterol 22% and stigmasterol 17%. Cholesterol and other minor sterols are present in negligible quantities, *i.e.* at less than 2.6%. Sterols although not considered as a phytonutrient, may have some important physiological roles. A study by Farquhar (1996) showed that β-sitosterol has the ability to regulate the cholesterol level in the body system. The concentration of sterols in CRPOo is 325-365 ppm, which is higher than RBDPO (*Table 4*).

TABLE 4. STEROL COMPONENTS (ppm) OF CPO, RBDPO AND CRPOo

Sample	Cholesterol	Campesterol	Stigmasterol	β-sitosterol	Unknown	Total/ppm
Crude palm oil*	7-13	90-151	44-66	218-370	2-18	326-527
RBDPO**	2.1-2.4	25.6-30.4	12.4-23.3	67.7-114	Nil-1.2	109-170
CRPOo	6.6-11.5	76-83	59-64	187-218	6<	325-365

Sources : *Rossell *et al.* (1983).
: **Siew (1990).

STABILITY OF THE ANTIOXIDANTS

Antioxidants such as vitamin E, carotenoids and ubiquinones are highly reactive, due to their ability to scavenge for free radicals in the environment. This means that there is a possibility that one or more of these components may be depleted with time during storage when exposed to different storage conditions. A study was therefore, carried out to monitor how these important components in the oil fared under three simulated storage conditions prevalent in Malaysia, *i.e.* supermarket (20°C), kitchen (30°C) and warehouse (40°C) conditions for a period of one year (assumed as its shelf life). The quantities of phytonutrients present before and after storage are shown in *Tables 5* and *6* respectively. For vitamin E, there was a 30% drop in concentrations for supermarket and kitchen conditions, and almost 40% for warehouse condition at the end of the storage period. Oxidation may have occurred more drastically due to the higher temperature. Heat is a catalyst for the formation of free radicals. With the production of more free radicals, more vitamin E are consumed.

TABLE 5. THE PHYTONUTRIENTS OF CRPOo (before storage)

Components	Concentration/(ppm)
Vitamin E	710 - 774 (742)
Carotene content	600 - 750 (677)
Coenzyme Q10	18 - 25 (22)

TABLE 6. PHYTONUTRIENTS CONTENT OF CRPOo (after 12th months of storage)

Storage conditions	Vitamin E (ppm)	Carotene (ppm)	Ubiquinone (ppm)
Supermarket (20°C)	519-531 (525)	720-733 (727)	4.2
Kitchen (30°C)	490-590 (540)	663-710 (687)	4.0
Warehouse (40°C)	436-441 (439)	603-607 (605)	n.d

In the case of the carotene, for all conditions, virtually no drop in their contents was noted. The profiles also showed that all the 11 types of carotene were still intact (*Table 7*).

As for the ubiquinone content, only trace amount (less than 10 ppm) were detected in the samples for all three conditions. The almost total depletion of ubiquinone is probably due to its high reactivity as antioxidant. The quinol group in the structure is the most active form of antioxidant. In fact, a study by Suarna *et al.* (1992) showed that in homogeneous systems, the relative reactivities of various antioxidants decreased in the following order: ubiquinol-10 > α-tocopherol and α-tocotrienol > beta carotene and lycopene > γ-tocopherol and tocotrienol. This finding seems to parallel the results of the present study, where vitamin E and coenzyme Q10, being stronger antioxidants were oxidized first, therefore the carotenes were not jeopardized.

TABLE 7. CAROTENE COMPOSITIONS (%) OF CRPOo BEFORE AND AFTER 12 MONTHS STORAGE

Carotene	Storage conditions			
	Before storage*	Supermarket (20°C)	Kitchen (30°C)	Warehouse (40°C)
Phytoene	0.2	0.7	0.1	0.8
Phytofluene	0.6	0.1	1.2	0.2
β-Carotene	41.0	38.3	37.0	38.7
α-Carotene	41.3	47.0	46.0	47.0
cis-α-Carotene	10.2	7.8	11.2	7.6
ζ-Carotene	0.6	1.0	0.7	0.8
γ-Carotene	0.8	1.3	0.6	1.0
δ-Carotene	0.8	0.9	0.4	0.9
Neurosporene	0.2	0.3	0.06	0.1
β-Zeacarotene	1.3	1.0	1.0	1.2
α-Zeacarotene	0.5	0.5	0.35	0.4
Lycopene	1.0	1.1	1.4	0.8

TABLE 8. CONCENTRATIONS IN MILLIGRAMS OF PHYTONUTRIENTS IN ONE TABLESPOON OF CRPOo

Phytonutrients	One tablespoon (15 g)
Total carotene	10
Beta-carotene	4
Alpha carotene	4
Other carotene	2
Total vitamin E	12.2
α-Tocopherol	2.3
α-Tocotrienol	3.5
γ-Tocotrienol	5.0
δ-Tocotrienol	1.2
Coenzyme Q10	0.33
Sterols	4.8
Campesterol	0.74
Stigmasterol	0.92
Beta-sitosterol	3.04
Cholesterol and unknown	< 0.14

CONCLUSION

CRPO is one of the richest and safest source of important phytonutrients, vitamin E and carotenoids. The major components for carotenoids (*e.g.* α- and β-carotene) and Vitamin E (*e.g.* tocotrienol isomers) in CRPOo are the most active forms of the nutrients, as supported by various epidemiological studies. These components exist in comfortable concentrations, suitable for consumption for all individuals. Furthermore, these components are well retained for up to 12 months of storage under three simulated storage conditions prevalent in Malaysia, namely supermarket (20°C), kitchen (30°C) and warehouse (40°C) conditions.

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