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Review

Health Promoting Effects of Phytonutrients Found in Palm Oil

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ABSTRACT

The oil palm tree, *Elaeis guineesis,* is the source of palm oil, otherwise known as the 'tropical golden oil'. To date, Malaysia and Indonesia are the leading producers of palm oil. Palm oil is widely used for domestic cooking in Malaysia. Palm oil is a rich source of phytonutrients such as tocotrienols, tocopherol, carotene, phytosterols, squalene, coenzyme Q10, polyphenols, and phospholipids. Although the phytonutrients constitute only about 1% of its weight in crude palm oil, these are the main constituents through which palm oil exhibits its nutritional properties. Among the major health promoting properties shown to be associated with the various types of phytonutrients present in palm oil are anti-cancer, cardio-protection and anti-angiogenesis, cholesterol inhibition, brain development and neuro protective properties, antioxidative defence mechanisms, provitamin A activity and anti-diabetes.

Keywords: *Elaeis guineesis,* health promoting effects, phytonutrients

INTRODUCTION

The composition of palm oil determines its physical, chemical and physiological characteristics. As shown in Table 1, triglycerides are the major components of crude palm oil. The other components of palm oil include diglycerides (2-7%), monoglycerides (<1%) and free fatty acids (3-5%) (Choo *et al*., 2005). Red palm oil is also a rich source of health promoting phytonutrients (see Tables 2 and 3). These phytonutrients are the main constituents through which palm oil exhibits its nutritional properties. Table 4 shows the health benefits that have been shown to be associated with the various types of phytonutrients present in palm oil.

About 80% of the carotenes and vitamins present in crude palm oil could be recovered through a novel process that involves pre-treatment, deacidification and deodorisation of the crude palm oil using molecular distillation. Palm oil methyl esters from the crude palm oil can be utilised as a renewable energy source substituting fossil fuels. In

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Table 1*. Major components of palm oil

Component	*Percentage (%)*
Triglycerides	>90
Diglycerides	2-7
Monoglycerides	<1
Free fatty acids	3-5
Phytonutrients	1

*Adapted from Choo *et al.*, 2005

Table 2#. Composition of palm phytonutrients

Palm Phytonutrients	*Content(ppm*)*
Vitamin E	600-1000
Carotenoids	500-700
Phytosterols	300-620
Squalene	250-540
Phospholipids	20-100
Co-enzyme Q10	10-80
Polyphenolics	40-70

**ppm: parts per million*
#Adapted from Tan *et al.*, 2007

Table 3*. Composition of vitamin E in palm oil

Vitamin E	*Isomer*	*Percentage (%)*
Tocotrienol	α	22
	δ	12
	γ	46
Tocopherol	α	20

*Adapted from Tan *et al.*, 2007

the process of obtaining this biodiesel, palm phytonutrients concentrate is obtained as a by-product. Palm phytonutrients could also be recovered as a palm oil mill by-product from palm pressed fibres, palm oil mill effluent and the refining process (Tan *et al.*, 2007).

Palm oil offers a wide range of culinary delights unrivalled by any other oil whilst simultaneously promoting nutritional and health benefits. Palm oil has faced some serious adverse comments regarding its saturated fat content, which in turn has raised concerns related to its nutritional value. This paper highlights some of the health promoting properties of the phytonutrients contained in palm oil.

Table 4. Health benefits of phytonutrients found in palm oil

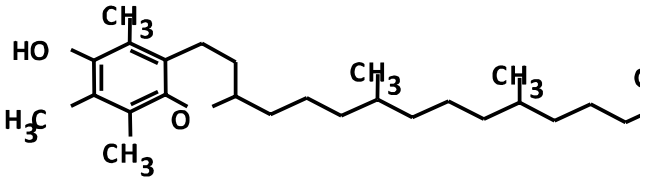
Palm Phytonutrients	*Health Effects*
Vitamin E	• Anti-cancer effects (Srivastava & Gupta, 2006; Nesaretnam *et al*. 2004) • Anti-angiogenesis (Wong *et al*., 2009; Shibata *et al*., 2008;) • Antioxidant (Suzana *et al*., 2005; Suarna *et al*.,1993) • Inhibition of cholesterol synthesis (Song & Boyd, 2006; Packer *et al*., 1993; Qureshi *et al*., 1991) • Cardio-protection effects (Das *et al*., 2008; Narang & Khalid, 2004) • Anti-diabetes (Budin *et al*., 2006; Nazaimoon & Khalid,2002) • Neuroprotective properties (Sen *et al*., 2000)
Carotenoids	• Provitamin A activity (Rao, 2000; Scrimshaw, 2000) · Cardioprotection effects (Rooyen *et al*., 2008) · Anti-cancer (Tamimi *et al*., 2005; Nesaretnam *et al*., 2002; Toniola *et al*., 2001)
Phytosterols	• Cholesterol lowering properties (Zadak *et al*., 2006; Miettinen *et al*., 2000) • Anticancer properties (Awad & Fink, 2000)
Squalene	• Cardioprotection (Verma *et al*., 2007; Kelly, 1999) • Inhibition of cholesterol synthesis (Kelly, 1999; Chan *et al*., 1996) • Anti-cancer (Rao *et al*., 1998; Smith *et al*., 1998; Murakoshi *et al*., 1992)
Phospholipids	• Brain development (Suzuki *et al*., 2001) • Energy endurance (Starks *et al*., *2008;* Jager *et al*., 2007) • Eases digestion and nutrition absorption (Lochmann & Brown, 1997)
Co-enzyme Q10	• Antioxidative defence mechanism (Niklowitz *et al*., 2007) • Cardioprotection effects (Verma *et al*., 2007) • Anti-cancer (Portakal *et al*., 2000)
Polyphenolics	• Cholesterol inhibition (Frankel *et al*., 1993) • Anti-cancer (Fink *et al*., 2007; Nair *et al*., 2004; Guthrie *et al*., 1997)

VITAMIN E

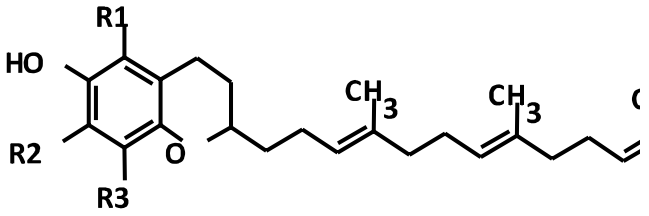
Vitamin E is a complex mixture consisting of two main groups, tocopherols and tocotrienols. Each subfamily of vitamin E is composed of four isomers (α, β, γ, and δ). The high amount of vitamin E in palm oil gives it a strong antioxidant property (see Table 2). Hence, there are a total of eight isomers or vitamers of vitamin E, that is, four (α, β, γ, and δ) tocopherol and four (α, β, γ, and δ) tocotrienol isomers. The composition of the various isomers of vitamin E in palm oil is shown in Table 3. Palm oil is a rich source of tocotrienols consisting mainly of gamma-, alpha- and delta-tocotrienols.

Tocopherols have a long saturated carbon side chain with chiral centres, and are generally present in common vegetable oils namely corn and soybean oils. Tocotrienols, on the other hand, are structurally similar to tocopherols except

a) Alpha-tocopherol



b) Tocotrienols



Isomers of Tocotrienols	*R1*	*R2*	*R3*
Alpha-Tocotrienol	CH_3	CH_3	CH_3
Gamma-Tocotrienol	H	CH_3	CH_3
Delta-Tocotrienol	H	H	CH_3

Figure 1. Chemical structure of alpha-tocopherol and the main isomers of tocotrienols

that they have three unsaturated bonds in the carbon side chain with only one chiral centre (see Figure 1). This unique property enables tocotrienols to penetrate tissues with saturated fatty layers freely and perform a more efficient metabolic function compared to tocopherols. Accumulation of tocotrienols in tissues has been reported to be beneficial to health (Das *et al*., 2008).

Anti-cancer effects

There are a number of studies on vitamin E that have provided convincing and compelling evidence of their anti-cancer properties. Studies on the relationship between palm tocotrienols and breast cancer have shown that individual fractions of tocotrienols could inhibit growth of human breast cancer cells regardless of oestrogen status; however α-tocopherol had no inhibitory effect on these cell lines (Nesaretnam *et al.,* 2004). In addition, preneoplastic, neoplastic and highly malignant mouse mammary epithelial cells have been reported to posses a greater biopotency of tocotrienols compared to tocopherols (McIntyre *et al*. 2000). These studies provide compelling evidence that tocotrienols have higher anti-cancer activity compared to α-tocopherols.

A natural potent antioxidant

Lipid peroxidation is a chain reaction that provides a continuous supply of free radicals. This reaction is not only the cause of food rancidity but is also responsible for the damage of tissues *in vivo* leading to cancer, inflammatory diseases, atherosclerosis and aging. Antioxidants are substances that have the ability to scavenge free radicals or reactive oxygen species and protect cells against oxidative damage. Palm α-tocopherol and γ-tocotrienol were observed to protect against lipid

peroxidation (Suzana *et al.,* 2005). Lipid peroxidation of low-density-lipoproteins (LDL) in the blood is postulated to have a role in initiating the pathogenesis of arteriosclerosis, which is mainly due to the ability of macrophages to recognise the modified or oxidised LDL through their scavenger receptors found on their surface. Both tocotrienols and α-tocopherol have been shown to be able to prevent LDL peroxidation (Suarna *et al*., 1993).

Inhibition of the biosynthesis of cholesterol

Human trial have shown that daily consumption of tocotrienols-rich fractions (TRF) from palm oil (200 mg/day) by hypercholesterolemic subjects has resulted in a significant reduction in serum cholesterol, LDL cholesterol, Apo B, tromboxane, platelet factor 4, and glucose levels within four weeks of initial study period (Qureshi *et al*., 1991). This study showed γ-tocotrienol to be the most potent cholesterol inhibitor. In addition, the reduction of various plasma lipids observed in a human pilot study was also found to be consistent with the observations in animal models (Qureshi *et al*., 1991). These findings suggest that tocotrienols could confer multiple cardiovascular benefits.

Tocotrienols, in particular *g*-tocotrienol, was found to decrease hepatic cholesterol production and thus reduce plasma cholesterol levels in animals. It has been suggested that the γ-tocotrienol acts on the mevalonate pathway by post-transcriptional suppression of the 3-hydroxy-3-methl-glutaryl-coenzyme-A (HMG-CoA) reductase which results in lower cholesterol production by the liver. Recently, it has been shown that only δ- and γ-tocotrienols can induce the direct ubiquination of the HMG-Co A reductase (Song & Boyd, 2006). The δ- and γ-tocotrienols are also known as desmethyl tocotrienols as these vitamin E isomers have less methyl groups. Desmethyl tocotrienols are believed to be the only two isomers that can inhibit the activity of the HMG-Co A reductase (Song & Boyd, 2006). In addition, the desmethyl tocotrienols can also block the processing of sterol regulatory element binding proteins (SREBPs) that control the genes encoding the enzymes responsible for the biosynthesis of cholesterol and the LDL receptor. In contrast, tocopherols do not have the advantageous molecular structure that can inhibit the activity of the HMG-CoA reductase.

Cardio-protection effects

Recent evidence show that daily supplementation of tocotrienol-rich fraction (TRF) can confer cardio-protection in rats (Das *et al*., 2008). The isomer that provided the highest level of cardio-protection was γ-tocotrienol followed by α- and δ-tocotrienols. The main mechanism that provided the cardio-protective properties of TRF was its ability to inhibit the activation of C-Src activation and stabilisation of proteosomes (Das *et al*., 2008). The antioxidant vitamins in palm oil have also been shown to play a vital role in protecting the heart of rats from injuries due to oxidative stress induced by ischemic-reperfusion injury (Narang *et al*., 2004).

Anti-diabetic effect

Palm vitamin E has been reported to have the ability to recover the glycaemic status of streptozotocin-induced diabetic rats (Budin *et al.,* 2006). It is postulated that the mechanism by which vitamin E helps to restore the glycaemic status of the streptozotocin-induced diabetic rats is by inhibiting the production of malon-dialdehyde, which is associated with oxidative damage and prevent DNA damage in streptozotocin-induced diabetic rats. In addition, it was also shown that TRF supplementation could effectively prevent advanced glycosylation of protein in the serum of streptozotocin-induced diabetic rats, leading to a decrease in the serum blood sugar and glycated haemoglobin in these diabetic rats (Nazaimoon & Khalid, 2002).

CAROTENOIDS

Crude palm oil is considered to be one of the world's richest natural plant sources of carotenoids, which are responsible for the brilliant orange-red feature of crude palm oil and fruits. There are about 600 types of naturally occurring carotenoids. There are thirteen different types of carotenoids found in palm oil. Among them are the phytoene, phytofluene, cis-β-carotene, β-carotene, α-carotene, cis-α-carotene, γ-carotene, δ-carotene, neurosporene, β-zeacarotene, α-zeacarotene and lycopene (Rao, 2000). The major carotenes in the palm oil are the α- and β- carotenes, which account for 35% and 56% respectively of the total carotenoids present in crude palm oil (Rao, 2000). The carotenoids in plants largely serve as a constituent of chromoplast for photo-synthesis as well as protection against photo-oxidation processes. These orange-red pigments can quench singlet oxygen and free radicals via the triplet state. Palm oil has 15 times more retinol (provitamin A) equivalents than carrots and 300 times more than tomatoes (Nagendran *et al*., 2000).

Pro-vitamin A activity

To date, there are many types of carotenoids identified. Of these, only 10% are shown to have pro-vitamin A activity. The α-, β- and γ-carotenes are the only carotenes found in red palm oil that have the pro-vitamin A activity (Rao, 2000). Pro-vitamin A can be cleaved to yield retinaldehyde and then retinol and retinoic acid. The total amount of vitamin A in food is expressed as micrograms of retinol equivalents. Carotenoids are fat soluble pigments which require fat for conversion into vitamin A. Thus red palm oil is a perfect solution for the treatment of vitamin A deficiency (Rao, 2000).

Cardio-protection effects

Like tocotrienols, carotenoids are also reported to have various protective and therapeutic effects on cardiovascular diseases. Though the incorporation of carotenoids into LDL was found to be far lower than vitamin E, the β-carotene can also significantly protect LDL from oxidation (Packer, 1993). Lipid peroxidation, as we know is one of the major culprits in the development of coronary heart disease. A clinical trial involving 19 healthy human subjects conducted in Canada showed daily supplementation of lycopene from tomato could significantly decrease serum lipid peroxidation and LDL oxidation (Agarwal & Rao, 1998). However, this approach has no effect on serum cholesterol levels.

Anti-cancer properties

There is growing evidence on the ability of carotenoids to confer protection against certain forms of cancer (Prakash *et al*., 2002). In a case-control study involving 270 human subjects, it was shown that a lower plasma level of carotenoids (α-carotene, β-carotene, β-cryptoxanthin, lutein, and total carotenoids) is associated with increased incidence of breast cancer (Toniola *et al*., 2001). However, a similar beneficial effect was not observed with plasma lycopene levels. More recent clinical studies showed that there was a 35% reduction in breast cancer risk for women with the highest quintile of α-carotene (Tamimi *et al*., 2005).

PHYTOSTEROLS

Phytosterols are naturally occurring substances found in many plants and plant-based raw materials in food. The richest sources of phytosterols are unrefined plant oils, seeds, nuts and legumes. The major phytosterols in crude palm oil are the β-sitosterol (60%), campasterol (13%), stigmasterol (24%) and cholesterol (3%). These phytosterols are structurally similar to that of cholesterol, the difference being the side-chains, which contains additional double bond and/or with methyl or ethyl groups. Sterols are essential components of

cell membranes for both plants and animals. A typical Asian diet contains between 350 to 400 mg of phytosterols/day, whereas a vegetarian diet contains 600 to 800 mg of phytosterols/day.

Cholesterol-lowering properties

The main focus of interest in palm phytosterols has been their cholesterol-lowering property. Phytosterols have been incorporated into margarines, spreads and other high fat foods to reduce total cholesterol and LDL-cholesterol. A study on colectomised patients has shown that margarines fortified with stanol ester can reduce the absorption and serum concentrations of cholesterol and plant sterols. Plant sterols are readily absorbed but these would be effectively eliminated in bile without the formation of gallstones (Miettinen *et al*., 2000). Dietary intake of more than 2 g/day of phytosterols or phytostanols has been shown to effectively decrease cholesterol absorption from the gut, reduce plasma cholesterol about 10%, LDL cholesterol around 10% to 15%, with minimal change in HDL cholesterol (Zadak *et al*., 2006). This means that the cholesterol-lowering property of phytosterols may be due to its ability to suppress absorption of cholesterol in the intestines and cholesterol biosynthesis

SQUALENE

Squalene ($C_{30}H_{50}$) is a naturally occurring triterpene with a highly unsaturated aliphatic hydrocarbon. It is primarily found in shark liver oil (*Squalus spp*.) but could also be obtained from various plant sources like olive oil, palm oil, wheat germ oil, amaranth oil, and rice bran oil (Kelly, 1999). Squalene, like other isoprenoids (namely carotenes, vitamin A, vitamin K, vitamin D, vitamin E, cyclic terpenoids compounds and dolichol), is a lipophilic antioxidant having unique characteristics to anchor itself to cell membrane. To stabilise itself, squalene binds to hydrogen ions from water and acids in the body and this process produces oxygen for the body (Kelly, 1999). Appropriate amounts of oxygen is very important for the maintenance of good health.

Inhibition of cholesterol synthesis

Daily supplementation of squalene for one-month has been shown to provide beneficial effect on the cardiovascular health. About 60% of the squalene is absorbed leading to a 17-fold increase in serum squalene without any significant changes observed in serum triglycerides and cholesterol. Possibly, this is a result of a concomitant increase in faecal elimination. In addition, as squalene was incorporated potentially into tissues, it eventually becomes a metabolic precursor of cholesterol and other steroids (Kelly, 1999). In a clinical study, volunteers were asked to take 860 mg of squalene and/or 10 mg of pravastatin for the treatment of hypercholesterolemia (Chan *et al*, 1996). This study showed that pravastatin was more efficient than squalene in reducing total cholesterol, LDL-cholesterol, triglyceride as well as increasing HDL-cholesterol levels. However the combination of pravastatin and squalene was found to be most efficacious in reducing total and LDL cholesterol, besides increasing HDL cholesterol (Chan *et al*, 1996).

Anti-cancer properties

Squalene also has an amazing ability to resist cancer. There are numerous studies, which suggest squalene to be the bio-active component in olive oil that provides the olive oil its anti-cancer properties (Rao, Newmark & Reddy, 1998; Owen *et al*., 2000). Topical application of squalene has been reported to inhibit the tumour-promoting effects of 12-0-tetradecanoylphorbol-13-acetate (TPA) on 7,12-dimethylbenz[α]anthracene (DMBA) initiated mouse skin carcinogenesis (Murakoshi *et al*., 1992). Squalene also inhibited the tumour-inducing effect of [3-

(4-amino-2-methyl-5-pyrimidinyl)methyl-1-(2-chloroethyl)-1-nitrosurea (ACNU)) in a mouse model (Yamaguchi *et al*., 1985). In this animal model, it was observed that the administration of squalene resulted in some long term survivors without significant toxicity effect on the host.

PHOSPHOLIPIDS

Phospholipids form the main building block in all living forms as these are essential components of lipoproteins and biological membranes. This phytonutrient is present in small quantities in crude palm oil. The main phospholipids in palm oil are phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol and phosphatidylglycerol.

Brain development

A study conducted by Suzuki *et al.,* (2001) showed that oral administration of phosphatidylcholine (lecithin) resulted in improved performance in the 'Morris water maze' test on aged and memory-impaired rats. The Morris water maze test is used to test long-term spatial memory ability.

Choline is a major building block of phosphatidylcholine, sphingomyelin and choline plasmologens. It is also used by the human body as a precursor to make acetylcholine, a major neurotransmitter that permits neurotransmission. Therefore, an adequate supply of choline is essential for optimal nerve function. Choline is important as a prenatal supplement. During pregnancy, choline intake by women influences memory and brain development in the growing foetus. Pregnant and lactating women as well as their infant and children obtain choline mainly from formula or breast milk and food. Consumption of foods low in phospholipids may lead to depletion of phosphatidylcholine for the brain cells for proper neurotransmission. Phosphatidylserine administration could also improve memory and other brain functions that tend to decline with age (Jager, Puroura & Kingsley, 2007).

Reduces severity of exercise-induced stress

Intense exercise causes a pronounced decrease in choline concentrations in the blood. Thus choline supplementation is important to replenish the plasma choline levels. Phosphatidylcholine has been shown to be twelve times more effective than inorganic choline salts at raising human blood choline levels. Over-training is a natural hazard of competitive sports that can lead to decreased performance, injury, depressed immunity and psychological depression. Studies have also shown that phosphatidylserine administration could lessen the severity of exercise-induced stress while improving mental stress (Jager *et al,* 2007). In addition, phosphatidylserine supplementations could also promote a desired hormonal status by blunting the increase of cortisol levels on the athletes (Starks *et al*., 2008).

Eases digestion and nutrition absorption

Improvement in weight gain and feed efficiency was observed in a study on goldfish using diets supplemented with soybean lecithin (Lochmann & Brown, 1997). Increased phosphatidylcholine and other phospholipid fractions have proven to enhance absorption of dietary lipid and facilitate lipid transportation. Lecithin is able to dispense fat thus aiding its breakdown and preventing accumulation of fat in the liver.

COENZYME Q10

Coenzyme Q10 is a naturally occurring compound that is structurally related to vitamins E and K. Chemically, it is known as 2,3-dimethoxy-5methyl-6-polyisoprene. Commercial red palm olein is reported to contain 18-25 mg kg^{-1} of Coenzyme Q10 (Ng

et al., 2006). It has been reported that Coenzyme Q10 has 10 times greater antioxidant property than vitamin E (Ng *et al*., 2006).

Enhances production of cellular energy

Co-enzyme Q10 is also known as ubiquinone. The most common form of coenzyme Q (quinone) in mammals contains ten isoprene units and is known as Coenzyme Q10. It is a hydrophobic quinone that diffuses rapidly through the lipids of the inner mitochondrial membrane. Coenzyme Q10 plays a vital role in the transport of protons across the inner mitochondrial membrane to assist the synthesis of adenine triphosphate (ATP). There is an abundance of coenzyme Q10 in organs that require a large supply of energy such as the heart, liver, kidney and pancreas (Verma *et al*., 2007). As coenzyme Q10 has a major role to play in the production of energy, it is an inevitable that a low concentration of this micronutrient could be detrimental to health.

Antioxidative defense mechanism

Clinically, coenzyme Q10 is the first line antioxidant present in our defence system to protect us against excessive oxidative stress. Being the only lipophilic antioxidant synthesised by our body, it is capable of regenerating back to its reduced or oxidised (antioxidant) form with the help of normal cellular enzymes. A recent study showed that intracellular enrichment of coenzyme Q10 in plasma and blood cells had a long lasting anti-oxidative defence mechanism (Niklowitz *et al*., 2007).

Cardio-protection effects

Most of the research on the coenzyme Q10 focuses on the heart where this nutrient is mostly concentrated. The research concerning coenzyme Q10's effects in patients with heart disease is quite remarkable. In Japan, considerable research has been conducted on the safety assessment of coenzyme Q10 in animal and human studies. The Japanese government has been prompted to approve coenzyme Q10 as a drug for the treatment of congestive heart failure way back in 1974. In 2001, coenzyme Q10 was officially approved for use in food and dietary supplements in Japan (Hidaka *et al*., 2008). In a recent study on the protective effect on coenzyme Q10 loaded liposomes in rabbits with an experimental myocardial infarction, it was found that exogenous coenzyme Q10 could provide an effective intracellular delivery of coenzyme Q10 to protect ischemic cells (Verma *et al*., 2007).

Anticancer

Coenzyme Q10 also has anticancer properties of its own. In a study of mitochondrial coenzyme Q10 concentrations in human breast cancer carcinoma tissues from patients who underwent radical mastectomy and diagnosed with infiltrative ductal carcinoma, coenzyme Q10 concentrations in tumour tissues were found to be significantly lower than that in normal tissues. It has been suggested that this reduction may be due to an increase in reactive oxygen species in malignant cells that causes over-expression of antioxidant enzymes and leads to the consumption of coenzyme Q10 (Portakal *et al*., 2000).

POLYPHENOLICS

According to a study conducted by the Malaysian Palm Oil Board (MPOB), palm fruit can serve as a potentially inexpensive source of phenolic antioxidants for the polyphenols market that is currently being monopolised by those extracted from grape seed and tea (Tan *et al*., 2007). While fat soluble components in palm oil have received considerable attention, relatively little importance has been given to the water soluble components. Polyphenols are a large family of natural compounds that can be classified into phenolic acids and flavonoids.

Major components of palm phenolics include *p*-hydroxybenzoic acid, cinnamic acids, ferulic acid, and caumaric acid and the flavonoid rutin hydrate. Flavonoids are touted as some of the most potent free radical scavengers and ion chelators. Phenolics on the other hand act as free radical terminators. Malonyldialdehyde and flavonoids have been claimed to be more powerful than vitamin A, α-tocopherol or β-carotene as antioxidant (Middleton *et al.*, 2000). An interesting research has shown that the free radical scavenging activity of the palm phenolics is equivalent to that of green tea extract (Tan *et al.*, 2007).

Inhibition of lipid peroxidation

Phenolic compounds in red wine have been reported to have the capacity to inhibit copper-catalysed oxidation of LDL (Frankel *et al.*, 1993). These phenolic substances were found to be significantly better in inhibiting the oxidation of LDL compared to α-tocopherol (Frankel *et al.*, 1993).

Anticancer properties

Cell culture studies using various prostate cancer cells showed that quercetin, a flavonoid, significantly inhibited the expression of specific oncogenes and several genes that controlled the G_1, S, G_2, and M phases of the cell cycle (Nair *et al.*, 2004). In addition, quercetin could also reciprocally up-regulate the expression of several tumour suppressor genes (Nair *et al.*, 2004). In a case-control study conducted on humans in the USA, the intake of lignans and flavonoids was found to be associated with a reduction in breast cancer risk (Fink *et al.*, 2007). Another remarkable research suggested that palm tocotrienols and plant flavonoids can act synergistically with each other, and enhance efficacy of tamoxifen in exhibiting anti-proliferative activity of breast cancer cell irrespective of their oestrogen status (Guthrie *et al.*, 1997).

CONCLUSION

There is an immense variety of phytonutrients in palm oil. Knowing the health benefits offered by these phytonutrients will provide us with a better understanding of the nutritional value of palm oil. It does appear from reviewing the literature that palm oil is a wholesome and excellent edible oil. There is an abundant supply of palm oil in Malaysia, and it is important to take note that it is a rich source of many important micronutrients that could help prevent a number of diseases as well as be useful in the treatment of several disorders and ailments.

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