Review Article

Phytonutrient deficiency: the place of palm fruit*

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The oil palm (*Elaeis guineensis*) is native to many West African countries, where local populations have used its oil for culinary and other purposes. Large-scale plantations, established principally in tropical regions (Asia, Africa and Latin America), are mostly aimed at the production of oil, which is extracted from the fleshy mesocarp of the palm fruit, and endosperm or kernel oil. Palm oil is different from other plant and animal oils in that it contains 50% saturated fatty acids, 40% unsaturated fatty acids, and 10% polyunsaturated fatty acids. The fruit also contains components that can endow the oil with nutritional and health beneficial properties. These phytonutrients include carotenoids (α-, β- and γ-carotenes), vitamin E (tocopherols and tocotrienols), sterols (sitosterol, stigmasterol and campesterol), phospholipids, glycolipids and squalene. In addition, it is recently reported that certain water-soluble powerful antioxidants, phenolic acids and flavonoids, can be recovered from palm oil mill effluent. Owing to its high content of phytonutrients with antioxidant properties, the possibility exists that palm fruit offers some health advantages by reducing lipid oxidation, oxidative stress and free radical damage. Accordingly, use of palm fruit or its phytonutrient-rich fractions, particularly water-soluble antioxidants, may confer some protection against a number of disorders or diseases including cardiovascular disease, cancers, cataracts and macular degeneration, cognitive impairment and Alzheimer's disease. However, whilst prevention of disease through use of these phytonutrients as in either food ingredients or nutraceuticals may be a worthwhile objective, dose response data are required to evaluate their pharmacologic and toxicologic effects. In addition, one area of concern about use of antioxidant phytonutrients is how much suppression of oxidation may be compatible with good health, as toxic free radicals are required for defence mechanisms. These food-health concepts would probably spur the large-scale oil palm (and monoculture) plantations, which are already seen to be a major cause of deforestation and replacement of diverse ecosystems in many countries. However, the environmental advantages of palm phytonutrients are that they are prepared from the readily available raw material from palm oil milling processes. Palm fruit, one of only a few fatty fruits, is likely to have an increasingly substantiated place in human health, not only through the provision of acceptable dietary fats, but also its characteristic protective phytonutrients.

Key Words: palm fruit, phytonutrient, antioxidant, polyphenol, flavonoid, cardiovascular disease, cancer, diabetes, cataracts, age-related macular degeneration, phytochemicals

Introduction

There has been a growing research interest in palm, especially palm oil, which is one of the major edible plant oils in the tropical countries. The oil palm (*Elaeis guineensis*) is native to many West African countries, where local populations have used its oil for culinary and other purposes. Large-scale plantations, established principally in tropical regions (Asia, Africa and Latin America), are mostly aimed at the production of oil, which is extracted from the fleshy mesocarp of the palm fruit, and endosperm or kernel oil. Palm oil is different from other plant and animal oils in that it contains 50% saturated fatty acids, 40% unsaturated fatty acids, and 10% polyunsaturated fatty acids. The fruit also contains components that can endow the oil with nutritional and health beneficial properties. These phytonutrients include carotenoids (α-, β- and γ-carotenes), vitamin E (tocopherols and tocotrienols), sterols (sitosterol, stigmasterol and campesterol), phospholipids, glycolipids and squalene. In addition, it is recently reported that certain water-soluble powerful antioxidants, phenolic acids and flavonoids, can be recovered from palm oil mill effluent.

Phytonutrients in the lipid fraction of palm fruit

Palm oil is one of the most widely used cooking oils in West and Central Africa. It is obtained from the mesocarp of the fruits, and composed of 50% saturated fatty acids, 40% monounsaturated fatty acids and 10% polyunsaturated fatty acids. The saturated fat components are trace amounts of lauric and myristic acids, which are cholesterol-raising fatty acids, and a large amount of palmitic acid, which has

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a minimal effect on cholesterol elevation. The principal triglyceride species in palm oil have palmitic acid at the alpha-position of the molecule, and this location confers the non-hypercholesterolaemic property to the oil.

Palm oil is used directly in a variety of food processes without undergoing a hydrogenation process, in which some of the *cis*- double bonds are transformed to the *trans*-configuration. Therefore, it is worth noting that palm oil does not contain any *trans*- unsaturated fatty acid isomers. The minor components of fresh palm oil are carotenes, vitamin E, sterols, phospholipids, glycolipids and squalene.

a) Carotenes found in palm oil are α-, β- and γ-carotenes. They are precursors of vitamin A, which prevents night blindness, aids maintenance of tissues and promotes growth.
b) Phytosterols present in palm oil are sitosterol, stigmasterol and campesterol. These lipophilic sterols are easily absorbed in the gastrointestinal tract, and then converted through a series of enzymatic reactions into cholesterol, which is a major precursor of steroid hormones.
c) Squalene, present in palm oil, when in excess amounts has been found to possess a negative feedback inhibition activity on the function of HMG-CoA reductase, an enzyme involved in the production of cholesterol in the liver.
d) Vitamin E found in palm oil is composed mainly of tocopherols and tocotrienols. They act as potent antioxidants that make it relatively stable to oxidation. Both animal and human studies show that tocotrienols could reduce plasma cholesterol, apolipoprotein B, thromboxane B2, and platelet factor IV. They could also inhibit or delay the oxidative deterioration of cellular membranes.

Sundram and colleagues (2003) have described the chemistry of palm oil in more detail in this issue.[1]

Phytonutrients in the water fraction of palm fruit

Unlike the lipid fraction, only limited information is available on the water fraction of palm fruit. The first report was presented by Sundram and colleagues of the Malaysian Palm Oil Board at the PIPOC International Palm Oil Congress in 2001.[2] Large amounts of various phenolic acids and flavonoids are retained in the palm oil mill effluent resulting from the heat inactivation of polyphenol oxidase enzyme during the milling process. Many phenolic compounds are effective antioxidants because of their free radical scavenging properties and because they are chelators of metal ions; thus, they may protect tissues against free oxygen radical and lipid peroxidation.[3] It is believed that these water-soluble polyphenols are produced by plants in order to protect against autoxidation.[4]

Dietary polyphenols

Polyphenols are present in all plants, and, thus, are in the diet. There are more than 8,000 phenolic structures that have been identified that vary structurally from being a simple molecule (e.g phenolic acids with a C6 ring structure) to being highly polymerised compounds (such as tannins). The main classes of polyphenols are phenolic acids, flavonoids and the less common stilbenes and lignans.

Phenolic acids

The major class of phenolic acids is the hydroxy cinnamic acids, which are found in almost every plant. The major representative of hydroxy cinnamic acids is caffeic acid, which occurs in foods mainly as chlorogenic acid, an ester with quinic acid. Coffee is a major source of chlorogenic acid in the human diet. Chlorogenic and caffeic acids are antioxidants in vitro, and they might inhibit the formation of mutagenic and carcinogenic *N*-nitroso compounds[5], and chlorogenic acid can inhibit DNA damage.[6] The inverse association between coffee intake and colon cancer in some epidemiologic studies might be explained in part by the chlorogenic acid present in coffee.[7,8]

Flavonoids

Flavonoids are polyphenolic compounds that occur ubiquitously in plant foods and have structural variations in the one of three rings (C6-C3-C6 backbone structure) that characterises the different types namely, flavonols, flavones, isoflavones, flavanols (catechins), flavanones and anthocyanins (see Table 1).

Polyphenols in palm fruit: their possible role in the prevention of chronic diseases

Sundram and colleagues evaluated the antioxidant activity of the flavonoid-phenolic rich crude extract against Trolox (a water-soluble analogue of vitamin E), and found it to have a substantial antioxidant activity.[2] It was also tested against gallic acid in a 2, 2-diphenyl-1-picrylhydrazyl (DPPH) free radical generating system, and was found to have free radical scavenging activity superior to that of green tea extract on an equivalent weight basis. Furthermore, it was also demonstrated that this palm extract protected against Cu^{2+} induced human LDL oxidation, as effective as α-tocopherol and α-tocotrienol.

Owing to its high content of phytonutrients with demon-strable antioxidant properties, the possibility exists that palm fruit offers some health advantages by reducing lipid oxidation, oxidative stress and free radical damage. Mounting evidence indicates protective effects of high consumption of polyphenol-rich foods, such as fruits, vegetables and beverages (tea and red wine) reported to play a role in a number of age-related diseases, such as cardiovascular disease, certain cancers, cataracts and macular degeneration, cognitive impairment and Alzheimer's disease.[9-15] Furthermore, flavonoids may also be operative by mechanisms that apparently are not directly dependent upon their antioxidant properties. A wide range of different biological activities, including anti-bacterial, anti-inflammatory and anti-carcinogenic effects mediated by different mechanisms, are associated with flavonoid compounds.[16] Therefore, it is likely that use of palm fruit or its phytonutrient-rich fractions may confer some protection against these disorders or diseases.

Table 1. The main classes of flavonoids

Class	Basic structure	Compounds	Food sources
Flavonols		Quercetin, myricetin, kaempferol	Apples, onions, tea, berries, olives, broccoli, lettuce, red wine, cocoa, chocolate
Flavones		Apigenin, luteolin	
Isoflavones		Genistein, diadzein	Soy
Flavanols (Catechins)		(–)-epigallo-catechin-3-gallate (EGCG)	Tea, red wine, cocoa/ chocolate
Flavanones		Naringenin, hesperitin	Citrus fruits
Antho-cyanidins		Cyaniding, pelargonidin	Blueberries red cabbage purple sweet potatoes

Cardiovascular disease (CVD)

Several population studies have reported an inverse association between the intake of dietary flavonoids (from a variety of plant foods, such as apples, onions and tea) and risk of coronary heart disease (CHD).[17-21] A protective effect of dietary flavonoid intake on stroke incidence was first demonstrated by the Zutphen Study after 552 men were followed up for 15 years.[20] The consumption of black tea, a good source of catechins, was inversely associated with stroke risk. For those studies that have reported an inverse association, putative mechanism of action include inhibition of LDL oxidation (measured in vitro)[22,23], and reduction of cytotoxicity of modified LDL to the vessel wall.[24,25] LDL is modified by free radicals that oxidise the polyunsaturated fatty acids in the LDL molecule. Modified LDL is easily absorbed by macrophages and is toxic to the vessel endothelium.[26] This may ultimately lead to the formation of atherosclerotic plaques. There is emerging evidence that phenolic compounds have anti-thrombotic effects that appear to be the result of reduced susceptibility of platelet aggregation, reduced synthesis of prothrombotic and pro-inflammatory mediators, decreased expression of adhesion molecules, and tissue factor activity.[27, 28]

Furthermore, antioxidants including polyphenolic compounds may have a role in endothelial-dependent vasodilation by preserving the biological activity of endothelium-derived nitric oxide (NO).[29] NO is an essential molecule in the regulation of vascular tone via the stimulation of vascular smooth muscle cell relaxation and concomitant vasodilation. NO also exerts a number of other anti-atherogenic effects, including inhibition of leukocyte-endothelial interaction, smooth muscle cell proliferation, and platelet aggregation. The increased oxidative stress, particularly increased production of superoxide radicals and elevated levels of oxidised LDL, can attenuate the biological activity of NO. It has been demonstrated that vitamin C, an antioxidant vitamin, can spare intracellular thiols, which in turn can stabilise NO through the formation of biologically active S-nitroso-thiols.[29]

However, while the protective effects of phytonutrients against CVD have been proposed to be attributable to their antioxidant properties, the results of controlled trials using antioxidant vitamins (vitamin E and β-carotene) are inconsistent. In the Physicians' Health Study in which more than 22,000 apparently healthy US male physicians took either 50mg β-carotene or placebo every second day for 12 years, β-carotene had no effect on the incidence of CHD.[30] Amongst the 1862 Alpha Tocopherol Beta Carotene (ATBC) Study participants with a history of myocardial infarction, both vitamin E and β-carotene and their combination decreased the incidence of nonfatal myocardial infarction compared with the placebo group (14%-38%), but increased the incidence of fatal CHD (33%-75%).[31] Similarly, in the Cambridge Heart Antioxidant Study, 2002 patients with angiographically proven coronary atherosclerosis were given vitamin E supplements 400 or 800 IU/day for an average of 17 months.[32] Vitamin E supplementation reduced the risk of nonfatal myocardial infarction by 77%, but there were 29% more deaths, including more fatal myocardial infarctions, in the group who received vitamin E supplements.

Cancer

Epidemiologic studies consistently have demonstrated an inverse relation between flavonoid consumption and risks of certain types of cancer.[33-37] Several in vitro cell culture and in vivo experiments have shown that flavonoids may interrupt various stages of the cancer process.[37] However, in most studies, supplements of vitamins C and E, and β-carotene do not decrease DNA damage.[38,39]

It appears that these phytonutrients may act in a variety of ways beyond their antioxidant properties to interfere with carcinogenesis, such as protecting DNA from oxidative damage, deactivating carcinogens, and inhibiting the expression of mutated genes and the activity of enzymes that promote carcinogenesis, as well as promoting detoxification of xenobiotics.[40-42] Catechins in green tea, particularly the major (–)-epigallocatechin-3-gallate (EGCG), possess significant chemopreventive activity.[43] It is evident that EGCG protects normal cells from genotoxic or carcinogenic assault and is capable of eliminating tumour cells, by eliciting a variety of cellular and molecular responses which include antimutagenic activity[44], suppression of oxidative DNA damage[45], and induction of apoptosis in tumour cells.[46,47]

Diabetes

Non-insulin dependent diabetes mellitus (NIDDM) or type 2 diabetes is increasingly common throughout the world. The World Health Organization (WHO) has predicted that between 1997 and 2025, the number of diabetics will double from 143 million to about 300 million. The leading cause of mortality and morbidity in people with NIDDM is CVD caused by macro- and microvascular degeneration. A number of studies have suggested that enhanced oxidation is the underlying abnormally responsible for some of the complications of diabetes. Studies in human and laboratory animals with NIDDM indicate that vitamin E and lipoic acid supplements lessen the impact of oxidative damage caused by dysregulation of glucose metabolism.[48-50]

Diseases of the eye

Cataracts, age-related macular degeneration and other eye diseases, such as diabetic retinopathy, are probably linked to the effects of oxygen radicals derived from light or metabolic reactions. Cataracts develop as the protein making up the lens of the eye is damaged by free radicals, oxidants and UV-light.[51] High consumption of fruit and vegetables is associated with delayed development of various forms of cataract. The same beneficial relationship to vision pertains to increased intakes of antioxidants, such as vitamins C, E and β-carotene, and to plasma antioxidant status.[52-54] Thus, it appears that assuring optimal antioxidant intake can extend lens function. In addition to achieving beneficial effects from long-known antioxidant vitamins such as vitamins E and C and folic acid, some protection may be conferred by other antioxidant phytonutrients, such as flavonoids, especially catechin, and other polyphenols.[55]

Similar to cataracts, epidemiological and intervention studies suggest that low antioxidant intake may be associated with the occurrence of neovascular age-related macular degeneration (AMD), the leading cause of irreversible vision loss in the developed world.[56-58] That is because the retina is particularly susceptible to oxidative stress because of its high consumption of oxygen, its high proportion of polyunsaturated fatty acids, and its exposure to visible light. The Age-Related Eye Disease Study (AREDS) Research Group recently reported significant reduction in the progression of certain categories of age-related macular degeneration (AMD) with the use of high-dose antioxidant and zinc supplementation.[59-61]

Alzheimer's disease

The aetiology of Alzheimer's disease (AD) is not well understood; therefore neither prevention strategies nor long-term effective treatments are available for this disease. Based on laboratory and clinical studies, it appears that reactive oxygen species (ROS) and reactive nitrogen species (RNS) that are generated extracellularly and intracellularly by various mechanisms are among the major intermediary risk factors that initiate and promote neurodegeneration in AD. Therefore, it is proposed that antioxidant supplements could be useful in the prevention of AD, and as an adjunct to standard therapy in the treatment of AD. However, results from prospective studies are inconsistent. One study showed that, after 5,395 dementia-free elderly were followed for a mean of 6 years, high dietary intake of vitamin C and vitamin E decreased the risk of AD.[62] In contrast, no relationships were observed between the AD risk and the intake of vitamins C and E and carotenes in supplemental or dietary (non-supplemental) form or in both forms in a study where 980 participants were followed for an average of 4 years.[63] The value of antioxidant phytonutrients present in palm fruit for AD prevention is ambiguous, and will remain so until properly designed human trials have been performed.

Pro-oxidant activities

It is generally accepted that certain components and some plant materials have beneficial antioxidant effects; however, this is often complicated by the realisation that these compounds can have adverse effects. A majority of antioxidants present in plant foods or food additives are capable of stimulating free-radical damage to non-lipid components, carbohydrates and DNA in vitro, and may therefore exert pro-oxidant actions in biological systems.[64] One area of concern about use of antioxidant phytonutrients is how much suppression of oxidation may be compatible with good health, as toxic free radicals are required for defence mechanisms. Like other antioxidant phyto-nutrients, under certain conditions flavonoids may also behave as pro-oxidants.[65] However, if the extent of pro-oxidant activity of these compounds is limited, this could suggest that the effects are unlikely to present a problem in biological systems.

Dietary antioxidants can exert a number of effects in vivo, such as promoting the synthesis of endogenous antioxidant defences by up-regulation of their biosynthesis and/or increased gene expression.[66] For example, the presence of vitamin E in the dietary supplement may preserve the pool of endogenous glutathione, and therefore the glutathione levels were elevated in antioxidant-fed mice. The vitamin E supplements can indeed modify gene expression induced by heat shock in vivo as well as protect animal tissues against oxidative stress by enhancing the level of endogenous antioxidants and inducing heat shock protein-70 gene expression.

Because there are many biological activities attributed to phytonutrients present in palm fruit, especially polyphenols, some of which could be beneficial or detrimental depending on specific circumstances, further studies in both the laboratory and with populations are warranted.

Conclusions

The cultural link between the medicinal values of a plant and its value as food has repercussions on a whole set of studies dealing with the nutritional values of certain edible plants. Knowing the chemical composition is an indispensable precondition for their promotion. The question might be asked as to whether enough consideration has been given to food component contributions to bodily functions and to health protection. These food-health concepts would probably spur the large-scale oil palm (and monoculture) plantations, which are already seen to be a major cause of deforestation and replacement of diverse ecosystems in many countries. However, the

environmental advantages of palm phytonutrients are that they are prepared from the readily available raw material from palm oil milling processes.

In conclusion, palm fruit is likely to have an increasingly substantiated place in human health, not only through the provision of acceptable dietary fats, but also its characteristic protective compounds.

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