Composition and Related Nutritional and Organoleptic Aspects of Palm Oil

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ABSTRACT

Palm oil is a fruit-coat fat that is low in sterols and rich in vitamins A and E. Up to 50% of its fatty acids are unsaturated, and linoleic acid constitutes up to 11% of the total acids. Its composition makes it an edible oil of nutritional importance and endows it with an inherent stability to oxidation, which has important organoleptic connotations. Variations in composition can occur for a number of reasons but, in general, oils produced in plantation countries have reasonably consistent properties.

INTRODUCTION

Palm oil is extracted from the fruit-coat (pericarp) of the fruit of the oil palm.

There are two species of oil palm, but all of the world's commercial palm oil is produced from the species *Elaeis guineensis* which originated on the West Coast of Africa, where since early times the crude oil expressed from the fruit pericarp has made an important contribution of fat and vitamins to the local diet.

Trade in palm oil started early in the 18th century and grew under the stimulus of the industrial revolution, which gave rise to technical uses for the oil. The two greatest influences on the further development of trade, however, were the advent and growth of the margarine industry in the late 19th century followed by the establishment of oil palms as a plantation crop in Southeast Asia and elsewhere in the early 20th century. This resulted in consistent supplies of edible palm oil which could be readily absorbed in the rapidly expanding edible oil industry.

The traditional outlets for palm oil were in Europe, where its use in the edible oil industry increased steadily as the result of continued improvements in oil quality and steady advances in the technology of refining and utilization.

Today palm oil is a major tropical product of great economic importance to a large number of developing countries and of considerable versatility within the edible oil industry. Total world exports in 1971 were close to one million tons, most of which was consumed in margarine and other edible products.

This review discusses the value of the oil in edible products, in light of its chemistry and composition. Particular reference is made to the consistent properties of plantation-produced oils.

VITAMINS AND STEROLS

Carotenoids and Vitamin A

Palm oil owes its deep red color to the presence of carotenoids. The carotenoid content of the oil varies with the degree of ripeness and the genotype of the fruit from which it is extracted. Typical values for a number of different genotypes found in Malaysia are as follows: dura nigrescens, 700-1000 ppm; dura virescens, 200-500 ppm; tenera nigrescens, 500-800 ppm; and tenera virescens, 400-600 ppm. The names of these genotypes are descriptive of fruit appearance, in particular fruit color, and variations occur within the genotype shown.

Carotenoid content also varies with the country of origin of the oil (Table I). It is probable that a large part of this variation is the result of genetic variations and variations of the ripeness standards for harvesting within and between the different countries, although climate and other geographical factors may also be involved. In countries where plantation production predominates, there is good control of the uniformity of genotype and degree of ripeness resulting in less variable carotenoid content. Typical values for plantation oils are in the range 400-700 ppm, the average being near 600 ppm. Carotenes (α and β) constitute 85-90% of the total carotenoids (Table II).

Both α- and β-carotene possess provitamin A activity; 1 μg of β-carotene is equivalent to 1.66 IU of vitamin A, and 1 μg of α-carotene, to 0.9 IU of vitamin A (6). Palm oil is therefore a rich source of vitamin A.

From the data in Tables I and II and the vitamin A activities of α- and β-carotene, it can be shown that plantation palm oil has an overall vitamin A activity between 430 and 760 IU/g. Thus the oil can be used to impart vitamin A activity to edible fat blends, provided that it is not deodorized or bleached and is neutralized at low temperatures (7).

Vitamin E

Good quality palm oil contains 500-800 ppm tocopherols (1), with α- and γ-tocopherols predominating. Their nutritional importance lies in their marked vitamin E activity (Table III).

No cases of marked vitamin E deficiency have been observed in humans, but the vitamin is known to be an antisterility vitamin, and deficiency symptoms are well known in animals. It has been suggested that ingestion of vitamin E at levels in excess of those required to prevent deficiency symptoms may have benefits, in terms of increased stability of cell membranes, which could be important in preventing certain types of heart disease. The role of the vitamin in preventing certain aging processes is

TABLE I

Geographic Variation in Carotenoid Content of Palm Oil

Country of origin	Carotenoids, ppm
Plantation oils	
Malaysia	500 – 700
Indonesia	400 – 600
Zaire (1)	500 – 700
Ivory Coast (2)	390 – 610
Palm grove oils	
Nigeria (3)	800 – 1600
Ivory Coast (2)	790 – 1480
Togo (2)	1310 – 1480
Dahomey (2)	910 – 1520

TABLE II

Composition of Palm Oil Carotenoids

Carotenoid	Percentage of total carotenoids		
	Zaire (4)	Dahomey (5)	Togo (5)
α-Carotene	36.2 }	85 }	87
β-Carotene	54.4 }		
γ-Carotene	3.3 }		
Lycopene	3.8 }	15 }	13
Xanthophyll	2.2 }		

TABLE III

Composition and Vitamin E Activity of Palm Oil Tocopherols

Tocopherol type	Percentage of total tocopherols (4)	Vitamin E activity, IU/g (6)
α	35	1.1 – 1.49
γ	36	0.12 – 0.15
δ	10	0.012 – 0.016
ε + η	10	–

also being investigated.

There is therefore a growing interest in the role of vitamin E in the diet, and high vitamin E levels in foodstuffs are obviously desirable. Palm oil has a vitamin E activity between 210 and 460 IU/g. Since neutralization, deodorization, bleaching and hydrogenation result in only slight tocopherol losses (21,22), the oil can make valuable contributions to the vitamin E level in edible products, even after refining.

Tocopherols, particularly α- and γ-tocopherols, are also powerful antioxidants. Their protection of unsaturated fatty acid chains results in the retardation of oxidative rancidity. Palm oil and products in which it is used are therefore stabilized to a large degree against the rapid development of organoleptically undesirable oxidation products.

Sterols

Values reported for the sterol content of palm oil show it to be as low as 0.03% of the oil (8,9). The major sterols present are β-sitosterol (63% of total sterols), stigmasterol (21%) and campesterol (21%); cholesterol comprises ca. 4% of the total sterols (4), or ca. 0.001% of the oil.

Alkali refining of oils reduces their sterol content (10,11), which may be further reduced during deodorization (12); so it is probable that the cholesterol content of refined palm oil is considerably lower than the 0.001% indicated.

In light of the growing concern over the relationship between atherosclerosis and high cholesterol diets, the near absence of cholesterol in palm oil is of considerable importance to the nutritional character of oil.

FATTY ACIDS

Fatty Acid Composition of Oil from *Elaeis guineensis*

Synthesis of lipids within the fruit pericarp commences ca. 19 weeks after pollination and proceeds very rapidly, the major part of the total lipids being formed within 1 week (13).

Palmitic and linoleic acids predominate in the small amount of lipids present before the major synthetic effort, but once synthesis starts the percentage of both these acids drops markedly and the drop is accompanied by a dramatic increase in the percentage of oleic acid. The change in fatty acid composition of the lipids between the 16th, 19th and 20th weeks from pollination is shown in Table IV.

Commercially produced palm oil has the fatty acid composition range shown in Table V, which takes into account palm oil from all sources. The considerable variation reflected may arise from differences in fruit type and ripeness standards or from geographical factors such as soil type and climate.

Analyses of samples of Malaysian and Indonesian palm oil, performed by the author, have demonstrated good consistency in fatty acid composition within oils produced in the same country, and analyses of samples from Zaire, by Loncin and Jacobsberg (9), gave similar findings (Table V). It thus appears that, while the fatty acid composition of palm oil may vary with the country of origin, oils from the same country are reasonably consistent, particularly where the oil production is plantation-based and maximum benefit is obtained from control of ripeness at time of harvesting, and genetic uniformity of the fruit.

Fatty Acid Composition of Oil from Other Species

Another species of the oil palm *Elaeis oleifera* (*Elaeis melanococca*) occurs wild in South America. The oil from the fruit of this palm has a fatty acid composition somewhat different from that of *E. guineensis* (Table VI). The higher percentage of unsaturated acids in *E. oleifera* oil may have certain nutritional advantages, but the palm gives lower yields than *E. guineensis*. The two species are, however, interfertile and *E. guineensis* x *E. oleifera* hybrids have been produced (14). The oil yield and oil properties of these palms are intermediate between those of the parents.

TABLE IV

Changes in Fatty Acid Composition of Lipids during Maturing of Fruit Pericarp in *E. Guineensis* (13)

Weeks after pollination	Percentage composition						
	Saturated acids				Unsaturated acids		
	C_{14}	C_{16}	C_{18}	C_{20}	Oleic	Linoleic	Linolenic
16	2.8	67.0	7.6	1.0	0.0	20.3	1.5
19	0.2	55.7	5.6	0.5	28.2	9.7	0.0
20	0.4	45.5	7.8	0.6	34.0	11.8	0.0

TABLE V

Fatty Acid Composition of Palm Oil

Fatty acid	Percentage of total acids					
	Commercial product (all sources)	Zaire (9)	Indonesia (11 samples)		Malaysia (11 samples)	
			Range	Mean	Range	Mean
Lauric	Trace	0	0-Trace	Trace	0-Trace	Trace
Myristic	0.5-5.9	1.2-2.4	0.4-0.8	0.7	0.5-0.8	0.6
Palmitic	32-51	41-43	46-50	48.6	46-51	49.2
Stearic	2-8	4.4-6.3	2-4	3.1	1.5-3.5	2.2
Oleic	38-52	38-40.2	38-42	39.8	40-42	40.2
Linoleic	5-11	9.9-11.2	6-8	7.8	6-8	7.6
Iodine value	44-54	—	49-53	51	50-54	52

TABLE VI

Fatty Acid Composition of Oil from *E. Oleifera* and *E. Guineensis* x *E. Oleifera* Hybrids (14)

	Percentage of total fatty acids			
Fatty acid	*E. oleifera*	*E. oleifera*	x	*E. guineensis*
Lauric	0.05	0.01	0.1	0.07
Myristic	0.3	0.47	0.9	0.77
Palmitic	25.0	31.7	32.5	27.3
Stearic	1.2	4.1	3.4	6.1
Arachidic	0.1	0.11	0.1	0
Palmitoleic	1.4	0.05	0.2	0.45
Oleic	68.6	49.5	48.0	58.5
Linoleic	2.1	13.4	13.8	11.35
Linolenic	0.9	0.5	0.4	1.3
Iodine value	81.3	70.7	62.0	69.8

The fatty acid composition of oil from hybrid fruit is shown in Table VI. Possibilities therefore exist for the production of high yielding interspecific hybrids, which give an oil higher in unsaturated acids than that presently obtained from *E. guineensis*.

Essential Fatty Acids

Plantation oil fatty acids consist of up to 11% linoleic acid (Table V), which is a polyunsaturated acid known to be essential to growth and health in animals and humans. Deficiency symptoms in humans include skin diseases, loss of weight and increased metabolic rate.

Linoleic acid reserves in humans are high, the half-life of linoleate in adults being on the order of 2 years (15), and deficiency symptoms are difficult to induce even in controlled experiments where prolonged periods of fat-free diet are necessary to reduce linoleate reserves to a critical level. Thus, while regular ingestion of relatively small amounts of linoleic acid may be beneficial in preventing depletion of linoleate reserves, it does not appear necessary to maintain high linoleic acid diets to prevent essential fatty acid deficiency.

Other Nutritional Considerations

While the relationship between the nature of dietary fats and the incidence of various cardiovascular ailments is still largely unresolved, it is generally felt that fats that maintain relatively low blood serum cholesterol levels will be effective in preventing atherosclerosis resulting from abnormal deposition of cholesterol in the arteries.

It is reasonably well established that fats containing predominantly polyunsaturated acids reduce serum cholesterol levels, while fats containing predominantly saturated acids have the opposite effect, even though such fats may themselves contain no cholesterol. Oleic acid (monounsaturated) appears neutral in this respect (16,17) neither raising nor lowering the serum cholesterol level.

Plantation palm oil contains up to 42% oleic acid and is therefore probably best considered as a neutral fat in terms of effect on serum cholesterol levels, although benefits may result from the linoleic acid present.

Fatty acids present in normal dietary fats have also been shown to have an influence on blood clotting. In experiments in which rats were maintained on a diet designed to induce thrombosis, mortality was reduced by supplementing the diet with oleic, linoleic or linolenic acid (18), although linolenic acid was more effective in reversing or preventing certain blood clotting phenomena than linoleic or oleic acids.

Experiments performed in vitro (19) have shown that saturated acids of long chain length (stearic acid and above) promoted certain clotting phenomena, while short chain saturated acids (palmitic acid and below) did not. Linoleic acid behaved as a short chain saturated acid in this respect, and oleic acid was intermediate between stearic and palmitic acid.

Therefore the inference is that palm oil, containing predominantly oleic, linoleic and palmitic acids, occupies a neutral position in this respect also.

Organoleptic Considerations

Most crude oils have natural "nutty" or "fruity" flavors, but these can be removed with comparative ease during refining and will not reoccur later. However oxidative spoilage of the oil can result in the production of off-flavors, which may occur in both crude and refined oil. While such flavors can be removed during refining, the rate of their appearance, or reappearance, in refined oil is an important factor governing the shelf-life of the product in which the refined oils are used.

Since this type of oxidative rancidity is the result of free radical autoxidation of fatty acid chains, and free radical formation depends on abstraction of hydrogen from the active methylene group adjacent to the olefinic center in the fatty acid chain, only unsaturated acids oxidize at a significant rate. Polyunsaturated acids, with more active methylene groups, oxidize much more rapidly than monounsaturated acids. The relative rates of oxidation for oleic, linoleic and linolenic acid chains are 1, 15 and 30, respectively. Free radicle formation is also catalyzed by heavy metal contaminants such as iron or copper.

Plantation palm oil contains no linolenic acid and the linoleic acid content is lower than that of many other polyunsaturated oils. Also the heavy metal content of plantation oils is very low (copper, ca. 0.2 ppm; iron, ca. 5 ppm). These oils are therefore inherently stable.

Further stability is obtained from the presence of tocopherol, which appears to be a free radical acceptor capable of accelerating the chain termination step. Carotene acts synergistically with tocopherol in this respect (20), and early flavor problems associated with palm oil, although poorly documented, appear to have been connected with the production of β-ionone as the result of excessive oxidation of carotene in the crude oil. This particular problem has now disappeared as a result of care taken during the production of plantation oils, and for similar reasons bleachability problems associated with the reaction of oxidized fatty acid chains with carotene (9) are not severe in plantation oils.

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