Plam Oil Production, Utilization and Update of the Nutritional attributes

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Plam oil is one of the major 17 oils and fats in the world. Latest projection by oil world indicates that production of plam oil has been increasing at a higher rate compared to other oils and fats. Production is projected to increase by two folds from a sizable annual average of 11 million tonnes in 1988/1992 to about 23 million tonnes by year 2003/2007. On the demand side, domestic disappearance is expected to increase from 80 million tonnes to an annual average of 121 millioon tonnes by 2003/2007. It is therefore obvious that plam oil is expected to be in high demand. In addition, growth is expected to be in high demand. In addition, growth is expected to be more prominent in developng countries like China, South Asia, and the Middle-East compared to developed countries. This paper deals with the current situation and prospects for plam oil in two major aspects : supply and demand. In addition the recent developments in scientific research and oleochemical industries will be highlighted.

Palm Oil and Blood Cholesterol

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Introduction

Palm oil is one of the three oils referred to as 'tropical oils'. This is an unfortunate grouping, as the fatty acid composition of palm oil is quite different to that of coconut and palm kernel oil—the other two oils referred to as 'tropical oils'. Palm oil from the fruit of the oil palm tree has been a traditional source of food in West Africa for over 5000 years. Palm oil is now the largest selling edible oil in the export trade of oils and fats, 90% of which is used in food applications. The higher level of saturated fatty acids(approximately 50%) not only makes palm oil an extremely good candidate for processed foods but also makes the oil a source of nutritional controversy. This controversy arose from early nutritional advice, now shown to be not entirely correct, that all saturated fats raise blood cholesterol and polyunsaturated fats lower blood cholesterol. The controversy was fuelled by self-interests of individuals and organisations.

Coronary heart disease and atherosclerosis have, for some time, been linked to concentrations of blood cholesterol, particularly low density lipoprotein cholesterol. Analysis of a large number of studies on coronary heart disease has shown that, in general 'a 1% fall in serum cholesterol is associated with at least a 2% fall in coronary heart disease' and that there is a graded relationship between serum cholesterol concentration and the incidence of the disease(Palca, 1990). His study also concluded that there will be a considerable reduction in heart disease if plasma cholesterol is lowered in the whole community, rather than just those adults with a particularly high plasma cholesterol.

Information like that referred to above increases consumer awareness of cholesterol and dietary fats. Almost everyone in western societies knows their blood cholesterol concentration. Nutritional information on fats and oils, or at least the interpretation of this information, may not always be correct and this does affect consumer awareness which in turn influences the types of fats and oils marketed in a country. Often scientific discussion, particularly when it relates to a controversial topic, tends to become perceived as a fact in the general community once it hits the headlines in the popular press. This is unfortunate. Sadly incorrect messages are often published for commercial advantage or by ignorance on the part of the writer. Palm oil was one commodity that fell victim to misleading representations in the late eighties due to commercially motivated advertising in the United States.

Fatty Acid Composition of Palm Oil

Fruit of the oil palm tree is unique because one fruit produces two types of oil with different fatty acid compositions. The predominant oil in palm oil which comes from the fleshy fibrous mesocarp, whereas the inner white layer(seed or kernel) produces palm kernel oil. In addition to the difference in composition between the two oils, palm oil(and its more liquid fraction, palm olein) is rich in β-carotene and tocols(tocopherols and tocotrienols). The fatty acid composition and the content of natural antioxidants confer exceptional stability to palm oil at high temperatures.

Table 1 documents the fatty acid composition of 'tropical oils'(palm oil, palm kernel oil and coconut oil) in comparison to other oils. Palm oil, is quite different in composition to palm kernel oil and coconut oil ; the latter two containing 82% and 84% saturated fatty acids. The composition of the shorter chain saturated fatty acids is also quite different. Palm oil has approximately 1% of its fatty acids with 14 carbons or less whereas in palm kernel and coconut oils approximately 70% of the fatty acids are in this category. This is an important consideration as lauric and myristic acids with 12 and 14 carbons respectively are the most atherogenic saturated fatty acids.

Also the amount of monoene fatty acids is different between the three 'tropical' oils, palm oil has 40% oleic(C18 : 1), whereas palm kernel oil (15%) and coconut(10%) are significantly lower in monoenes. Oils(canola, olive) rich in monoenes are in favour because they have been shown to lower blood cholesterol without lowering high-density lipoproteins('good cholesterol'). The level of polyunsaturated is also higher in palm oil but not as high as found in oils like soyabean or safflower. The fatty acid composition of palm oil is predictable and constant because it is produced by similar high-yielding hybrid oil palm trees, whereas other commercial vegetable oils(e.g., olive) can vary considerably in their fatty acid composition.

Besides the differences in functional properties of fats with different fatty acid compositions, we are also interested in fatty acid composition in relation to blood cholesterol because of the relationship between blood cholesterol and coronary heart disease. With such differing patterns of fatty acids, the physiological effects of palm oil are likely to be quite different to those of coconut and palm kernel oil.

Replacement of saturated animal fats by polyunsaturated fats in the diets of both animals and humans has resulted in reduced blood cholesterol in a number of studies. However, two vegetable fats with a high content of saturated fats, cocoa butter and palm oil(palm olein), do not cause blood cholesterol concentrations to rise. Kris-Etherton et al(1984) fed diets containing 10% safflower oil, corn oil, olive oil and palm oil and found that palm oil, although more saturated, did not raise blood cholesterol. Sundram et al(1990)

Table 1. Major fatty acids(percent) in selected oils

	Palm kernel oil	Coconut oil	Palm oil	Palm olein	Soyabean oil
C 8 : 0	3.5	3.9			
C 10 : 0	3.2	6.0			
C 12 : 0	47.5	47.6		0.1	
C 14 : 0	16.5	15.7	1.0	1.0	
C 16 : 0	8.8	8.6	44.2	39.8	10.3
C 18 : 0	2.1	2.0	4.4	4.4	3.8
C 18 : 1	14.8	10.2	39.6	42.5	22.8
C 18 : 2	2.4	2.6	10.5	11.2	51.0
C 18 : 3					6.8

fed 20% corn oil, soyabean oil and palm olein to male rats for 15 weeks. The soyabean oil fed rats were lower in blood cholesterol than the other two groups, however, the palm olein group had *a 10.6 mg/dl greater concentration of 'good'* HDL-cholesterol than did the soyabean oil group. Studies with mice and monkeys(Schouten et al, 1989) support earlier observations that the saturated fatty acids of palm oil or palm olein, like those of cocoa butter, do not raise blood cholesterol as predicted by the early equations of Keys et al(1957 ; 1965) and Hegsted et al(1965).

In a study to compare the different effects of saturated fatty acids in processed foods, Heber and Alfin-Slater(1991) devised a study to compare coconut oil with palm oil and with hydrogenated soyabean oil. The fats were incorporated into muffins and biscuits and made up so that 50% of the calories were derived from fat. Fasting plasma cholesterol concentrations changed significantly($p<0.05$) only after the men were given the coconut oil diet(Table 2). HDL-cholesterol was elevated more in the group given palm oil and palm oil caused the greatest reduction in blood triglycerides.

In a double blind cross-over trial in which 70% of the fat of normal Dutch diet of 38 men was replaced by palm oil, no effect was observed on total serum cholesterol, however HDL-cholesterol increased by 11% in the palm oil group(Sundram et al, 1992). Similar results were obtained when men were fed a palm oil enriched diet(Heber et al, 1992). Other studies that show either a hypocholesterolemic or neutral effect of palm oil in human trials include those of Truswell et al(1992), Ng et al(1991, 1992), Hornstra et al(1991), and Marzuki et al(1991).

Lipoprotein(a) is a distinct type of plasma lipoprotein that strongly predicts risk of coronary heart disease. Although its concentration is largely genetically controlled, recent reports by Nestel et al(1992) and Mensink et al(1992) suggest that lipoprotein(a) can be influenced by diet. Hornstra et al(1991) noted that lipoprotein(a) was significantly reduced when palm oil comprised most of the fat in the experimental diet.

Palm Oil and Thrombosis

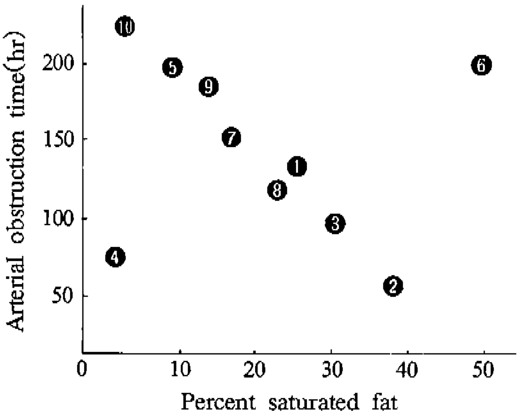
Aspects of the role of fats on coronary heart disease and thrombosis have been reviewed(Nutr. Rev. 1987 ; Elson, 1992). Using an aortic loop technique Hornstra(1988) demonstrated that palm oil does not fit the pattern of other saturated fatty acids in promoting thrombus formation(Fig. 1). Rand et al(1988) have also shown that, although palm oil contains about 50% saturated fatty acids it did not increase arterial thrombosis tendency and tended to decrease platelet aggregation, as compared with highly polyunsaturated sunflower seed oil. The potential of blood platelets to synthesise a prothrombotic compound, thromboxane, and of the arterial wall to generate the antithrombotic substance prostacyclin partly determines the risk of arterial thrombosis.

Sugano(1987) fed rats either palm oil or olive oil at 50% of dietary energy. Although palm oil contained twice as much palmitic acid as olive oil, serum cholesterol in rats fed on palm oil was lower and the linoleic acid(10% in palm oil) ap-

Table 2. Effects of feeding palm(PO), coconut(CNO) and hydrogenated soyabean oils(HSBO) on plasma cholesterol and lipoproteins in healthy male volunteers

Oil	Cholesterol(mg/dL)			HDL-cholesterol(mg/dL)			Triglycerides(mg/dL)		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
PO	176	172	−4	37	41	+4	94	79	−15
CNO	165	195	+30	40	42	+2	93	110	+17
HSBO	170	168	−2	37	39	+2	91	103	+12

Heber and Alfin-Slater(1991)



1. Coconut oil
2. Triglyceride mixture
3. Hydrogenated coconut oil
4. Medium chain triglycerides
5. Rapeseed oil, new
6. Palm oil
7. Olive oil
8. Hydrogenated soyabean oil
9. Linseed oil
10. Rapeseed oil, old

Fig. 1. Arterial obstruction time as influenced by the amount of saturated fat in different oils.

peared to have effectively suppressed any elevating effect of palmitic acid. The prostacyclin/thromboxane ratio was 3 times higher with palm oil and created a favourable environment for the suppression of thrombus formation.

Palm Oil is not Hypercholesterolemic

Although palm oil has a relatively high content of saturates, it does not influence blood cholesterol the way that might be expected. Hayes and colleagues from Brandeis University have gained a good understanding of the role of individual fatty acids on cholesterol metabolism. Their data explains why palm oil is not an oil that raises blood cholesterol.

Cholesterol is transported from the liver to the peripheral tissues in low density lipoproteins (LDL). LDL-cholesterol promotes coronary heart disease(Brown and Goldstein, 1984). Receptors on the surface of heptacytes control the rate at which LDL-cholesterol is taken up by the liver where it can be catabolized for excretion. The risk of coronary heart disease will be reduced if more receptors are available to increase the uptake of LDL-cholesterol by liver cells. High density lipoprotein(HDL) is also able to take up excessive cholesterol from peripheral tissues and return it to the liver for catabolism.

Hayes et al(1991) have reported in monkeys that dietary palmitic acid(C16 : 0) and myristic acid(C14 : 0) have different effects on blood cholesterol ; myristic acid being hypercholesterolemic. This result was reported as early as 1965(Hegsted et al), however the observation was overlooked. Hayes and Khosla(1992), Khosla and Hayes (1992) and Hayes et al(1992) have proposed a hypothesis(summarised in Fig. 2) to explain the differing effects of dietary fatty acids on plasma cholesterol, particularly LDL-cholesterol. Hayes' group propose that linoleic acid(C18 : 2) 'up-regulates' or activates LDL-receptors enabling LDL-cholesterol to be cleared from blood plasma, while myristic acid(C14 : 0) 'down-regulates' the receptors causing LDL-cholesterol to rise. Their data suggests that C12 : 0 and C16 : 0 are equal and neutral in affecting blood cholesterol and that the dietary requirement of C18 : 2 depends on the dietary C14 : 0 present. Above a threshold of 3% energy as C18 : 2, all fatty acids, except C14 : 0, have little effect on blood cholesterol(Fig. 2). When C18 : 2 is between 3% and 6.5% of energy the only fatty acid to increase plasma LDL-cholesterol was C14 : 0. Below 3% of energy, C14 : 0 is very hypercholesterolemic and C16 : 0 only slightly able to elevate blood cholesterol. Palm oil has about 10% C18 : 2 and only 1% C14 : 0 and for this reason behaves like a neutral fat, showing a limited cholesterol response.

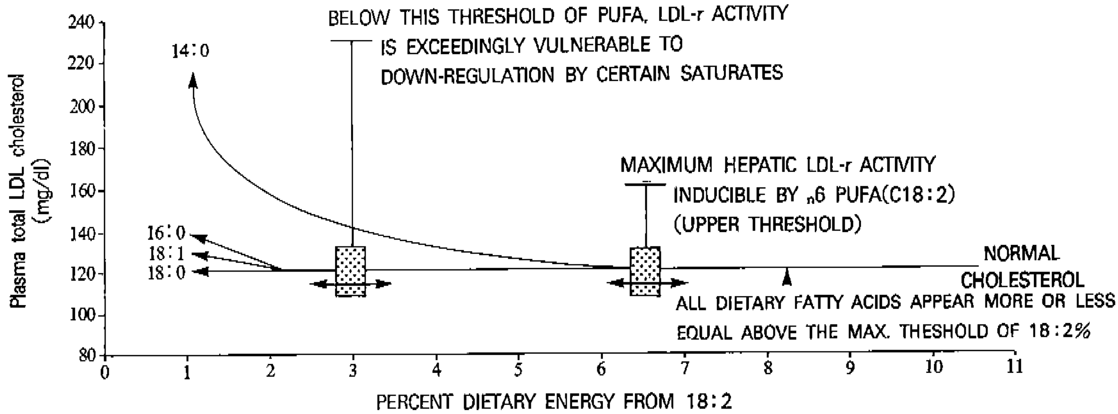


Fig. 2. Dietary thresholds of individual fatty acids.

Trans Fatty Acids

In its natural state, palm oil is semi-solid and is used in foods without partial hydrogenation. For the production of many processed foods, a harder, more solid fat must be prepared by hydrogenation ; a process whereby hydrogen atoms are added to mono-and polyunsaturated fatty acids. Many vegetable oils require hydrogenation to improve their stability and shelf life by decreasing the rate of development of rancidity. In the hydrogenation process unusual *cis* and *trans* isomers of fatty acids are formed.

Fig. 3 shows the double bond positions of *cis* and *trans* isomers of monoene fatty acids in a commercially hydrogenated fat. Before hydrogenation essentially all monounsaturated fatty acids have the double bond at the *cis*-9, 10(Δ9) position (Fig. 3b). However, partial hydrogenation causes the position of the double bond to move along the carbon chain(Fig. 3a, Fig. 3b). Monoenes with a *trans* double bond are straight chain molecules similar in structure to that of a saturated fatty acid.

Trans fats can occur in nature through hydrogenation of unsaturated, particularly polyunsaturated, fatty acids. They are found in small quantities in ruminant products(e.g., milk, beef and lamb). Most *trans* fatty acids in the diet are derived from partially hydrogenated vegetable oil(e.g., soyabean oil) that are used to prepare margarines

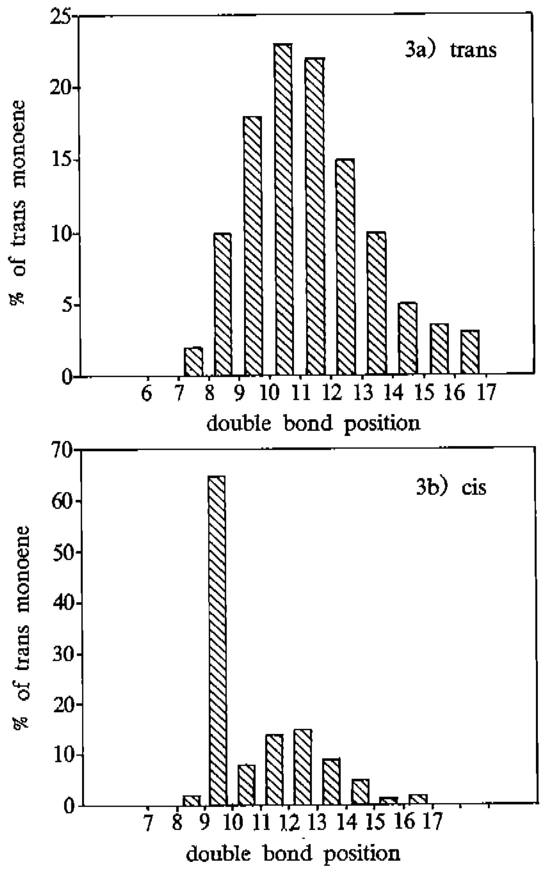


Fig. 3. Double bond positions in cis and trans monoene fractions of a commercially hydrogenated fat product.

and frying oils that have improved stability and functional properties than the natural oils. Rather than partially hydrogenating a polyunsaturated oil, a more reasonable approach would be to use a fat, like palm oil, that has the functional characteristics we require in the end product. By hydrogenating an oil we lose the nutritional advantage of a polyunsaturated oil due to the presence of unusual *trans* fatty acids. Recent studies suggest that *trans* fatty acids adversely affect cholesterol metabolism.

Judd et al(1993) gave a carefully controlled diet for 6 weeks to 29 men and 20 women. The diets used were 1) oleic acid rich, 2) moderately high in *trans* fatty acids(similar to that in the United States diet), 3) high *trans* fatty acids(about twice the United States average) and 4) saturated fatty acids(C12 : 0, C14 : 0, C16 : 0). *Trans* acids caused plasma total and LDL-cholesterol elevations similar in direction to the diet high in saturated fatty acids. The first three diets are all rich in monounsaturated fatty acids, however the *cis* form of the double bond(diet 1) behaves differently to the *trans* form. Diet 4 was rich in C12 : 0 and C14 : 0 fatty acids ; two of the most hypercholesterolemic fatty acids.

In another study mildly hypercholesterolemic men were given diets shown in Table 3(Nestel et al, 1993). The *trans* acid used was elaidic acid and resulted in the highest LDL-cholesterol particularly when compared to oleic acid, the *cis* form of the acid. The elaidic acid(*trans*) diet caused an increase in lipoprotein(a), the best known predictor of coronary heart disease. The palmitic acid-rich diet contained a lot of palm oil and caused an elevation in protective HDL-cholesterol.

Table 3. Effect of dietary fat on blood cholesterol

Diet	HDL-cholesterol (mg/dL)	Comment
Butter fat		
enriched	163	
Oleic acid-rich	151	
Elaidic acid-rich	165	↑ Lp(a)
Palmitic acid-rich	161	↑↑ HDL chol

Lp(a) = lipoprotein(a)
Nestel et al.(1993)

In another major study involving over 85,000 American women, Willett et al(1993) found a direct relationship between intake of *trans* fatty acids and the risk of heart attack. After an eight year follow-up 431 of the women had died of coronary heart disease and all had consumed high levels of *trans* fatty acids from processed foods such as margarine, cakes and biscuits. A clear indication that *trans* fatty acids do increase the risk of coronary heart disease. The nutritional problems of *trans* fatty acids were first written about by Katan's group in the Netherlands(Mensink and Katan, 1989, 1990). He recently summarised his work by stating that the effect of partially hydrogenated vegetable oils on serum lipoproteins is decidedly less favourable than that of unhardened oils(Katan, 1993). This is similar to a position statement put out by the National Heart Foundation of Australia that stated that 'the action of *trans* acids is similar to that of saturated fatty acids'.

The nutritional attributes of *trans* fatty acids are questionable, therefore, it does not make nutritional or economic sense to chemically modify, by hydrogenation, expensive polyunsaturated oils to achieve a partly solid fat when cheaper oils are available that do not require chemical modification.

Tocotrienols and Lipid Metabolism

Refined palm oil and its commercial fractions (e.g. palm olein) are rich sources of Vitamin E and compounds with Vitamin E activity. The tocopherols and tocotrienols(Table 4) are natural antioxidants and palm oil is the richest source of tocotrienols. Palm is the only commercial vegetable oil to contain significant amounts of tocot-

Table 4. Tocol content of vegetable oils

	Tocopherol				Tocotrienol			
	α	β	λ	δ	α	β	λ	δ
Soybean oil	101		593	264				
Safflower oil	387		14	240				
Corn oil	112	50	602	18				
Cottonseed oil	389		387					
Sunflower oil	487		51	8				
Peanut oil	130		216	21				
Cocoa butter	11	170	7					
Olive oil	51							
Coconut oil	13							
Lard				7				
Palm oil	164				174		313	80
Palm olein	196				201		372	96
Palm stearin	79				81		168	44

Elson(1992)

rienols ; the tocol content of palm oil is typically between 500−750 ppm. Tocotrienols are found, however, as constituents of oat bran oil, rice bran oil and barley oil. Unrefined palm oil is also a rich source of carotenoids(Goh et al, 1985).

The link between tocotrienols and lipid metabolism started in 1986 when Qureshi et al, reported that tocotrienols inhibited the activity of 3-hydroxy-3-methyl glutaryl coenzyme A reductase (HMGCoAR), the rate limiting enzyme in cholesterol synthesis. Qureshi supplemented hypercholesterolemic men with a tocotrienol rich fraction from palm oil(palmvitee capsules) and reported a 15% reduction in serum cholesterol in those individuals fed palmvitee capsules(Qureshi et al, 1991).

Qureshi chose the chicken to confirm the observation that tocotrienols lowered blood cholesterol. Qureshi et al(1988), added a mixture of tocotrienols(palmvitee) and purified tocotrienols at 20 ppm. Total serum cholesterol decreased in the treated birds : δ-tocotrienol being the most effective with a 39% reduction in blood cholesterol. Their study also reported a concomitant reduction in the activity of HMGCoAR.

The effect of dietary fibre(α-cellulose or guar gum) and tocotrienols from palm oil were studied in both young(9 weeks) and mature(51 weeks) Japanese quail(Hood and Sidhu 1992). The diets were based on ingredients of vegetable origin with equal amounts of saturated and unsaturated fatty acids. In young quail, dietary guar gum plus tocotrienols was effective in reducing plasma cholesterol and liver size in comparison to quail fed α-cellulose(Table 5). Tocotrienol had no effect on cholesterol metabolism when included in the α-cellulose treatment. Rates of hepatic cholesterol synthesis from ^{14}C-mevalonate were similar for all treatment groups. In mature quail tocotrienols were not effective in reducing blood cholesterol. Tocotrienols were also not effective in altering the propensity of Japanese quail to develop atherosclerosis in the aortic arch.

The studies of Hood and Sidhu gave no clear result on the effectiveness of tocotrienols as hypocholesterolemic agents. Therefore additional studies were done with male Japanese quail and male Wistar rats that were fed either 0, 50, 250, or 1000 ppm of palmvitee(60% tocotrienols). After 6 weeks on the diets there was no effect, attributable to tocotrienols, seen on liver weight, liver cholesterol, blood cholesterol or hepatic choleste-

Table 5. Cholesterol status of young Japanese quail after 4 weeks on diets containing α-cellulose or guar gum with added tocotrienols in the form of a tocotrienol-rich fraction(TRF) from palm oil

	α-Cellulose		Guar gum	
	−TRF	+TRF	−TRF	+TRF
Live wt(g)	214 ± 3	219 ± 7	199 ± 6	214 ± 10
Liver wt(g)	3.4^a ± 0.2	3.4^a ± 0.2	3.0 ± 0.2	2.7^b ± 0.1
Liver lipid(%)	7.0 ± 0.8	6.7 ± 0.3	6.0 ± 0.5	4.8 ± 0.3
Liver cholesterol(mg/liver)	7.3 ± 0.5	6.9 ± 0.8	7.4 ± 1.1	6.5 ± 0.5
Total plasma cholesterol(mmol/L)	4.83^a± 0.31	4.92^a± 0.29	4.44^a± 0.33	3.59^b± 0.20
HDL plasma cholesterol(mmol/L)	4.00^a± 0.28	3.96^a± 0.30	3.63^a± 0.33	2.55^b± 0.30
Cholesterol synthesis[1)]	451 ± 37	456 ± 29	538 ± 26	499 ± 20

[1)] Nanomoles of mevalonate converted to cholesterol per liver per hr
[a,b] Different superscripts indicates significant differences $p<0.05$
Hood and Sidhu(1992)

rol synthesis(Hood, unpublished). In a further study(Hood and Kneale, unpublished), Japanese quail were fed varying levels(0.75, 1.50, 3.00 and 6.00%) of dietary vegetable fat with palmvitee (2000 ppm) or without palmvitee. Once again no significant differences were seen in the blood cholesterol fractions nor in the activity of HMG-CoAR. The reported inhibitory role of tocotrienols on HMGCoAR as demonstrated by Qureshi's group could not be repeated.

Tocotrienols as Antioxidants

The antioxidant properties of tocotrienols from palm as reported by a number of research workers are very exciting. Tocopherols and tocotrienols are natural antioxidants and act as scavengers of damaging oxygen free radicals that have been suggested as playing a role in cellular aging, atherosclerosis and cancer. Tocopherols are well understood antioxidants and free-radical scavengers however recent evidence predicts that tocotrienols are even more effective.

When the unsaturated fatty acids and cholesterol of low density lipoproteins(LDL) become oxidised the formation of atherosclerotic lesions may be exacerbated. Both α-tocopherol and α-tocotrienol protected human LDL against oxidative modification induced by lipoxygenase, UV-irradiation or an azo-initiator of peroxyl radicals(Packer 1993). The recycling efficiency for α-tocotrienol, as measured by transient disappearance of chromanoxyl radicals, was higher than for α-tocopherol. This led Packer to conclude that, in model systems, α-tocopherol should have higher physiological activity than α-tocopherol under conditions of oxidative stress because of its greater antioxidant potency.

Tocotrienols and Cancer

Palm oil, when fed to rats has caused a reduction in the frequency of chemically induced tumours when compared to diets containing a number of other edible oils(Sylvester et al, 1986 ; Nesaretnam et al, 1991 ; Elson 1992). Breast cancer is a major cause of death of women in western societies(e.g. one in fourteen Australian women will develop breast cancer). As Asian societies become more affluent and change to a higher fat diet it is likely the incidence of breast cancer will increase. In a study using a strain of breast cancer cells, Nesaretnam et al(1993), concluded that a tocotrienol rich fraction from palm oil at a concentration of 180 μg/ml caused a 50% inhibition of growth of human breast cancer cells whereas α-tocopherol(180 μg/ml) had no effect on cancer growth. Palm oil does not appear to promote mammary carcinogenesis like other unsaturated vegetable oils and this may be related to a protective effect of palm oil tocotrienols deposited in mammary adipose tissue.

Summary

The fatty acid composition and the content of tocopherols and tocotrienols of palm oil are quite different to that of coconut and palm kernel oil, hence it is not surprising that the physiological effects of palm oil are quite different to those of coconut and palm kernel oil. The grouping of palm oil with the other two 'tropical oils' is unfortunate since palm oil is hypocholesterolemic compared to coconut and palm kernel oils. Although palm oil contains fifty percent fatty acids, the balance of fatty acids in this oil is not conducive to elevating blood cholesterol, particularly since palm oil contains adequate linoleic acid and is very low in myristic acid : a hypercholesterolemic fatty acid. Palm oil should be considered normocholesterolemic, as in the majority of animal and human studies it does not elevate blood cholesterol. Palm oil is semi-solid, has good oxidative stability and can be used in many food products without partial hydrogenation : a process resulting in unnatural cis and trans isomers of monoenic fatty acids. Trans fatty acids(e.g., elaidic) tend to raise blood cholesterol in comparison to their cis isomers(e.g., oleic acid), therefore it is not nutritionally nor economically rational to chemically modify, by partial hydrogenation, expensive polyunsaturated oils to achieve a semi-solid fat when semi-solid fats are currently available as natural oils.

Palm oil is the richest source of tocotrienols, potent natural antioxidants that reduce biological oxidation(e.g., protect human low density lipoproteins against oxidative modification hence reducing the formation of atherosclerotic lesions). Preliminary results also suggest that tocotrienols have a protective effect on the development of human breast cancer when compared to other vegetable oils. Studies have shown that tocotrienols from palm oil inhibits hepatic cholesterol synthesis and decreases blood cholesterol, however, this biological effect of tocotrienols has not been reproducible, hence the role of tocotrienols on cholesterol metabolism has yet to be clarified.

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한국인의 식이지방과 팜유의 영양 비교

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서 론

1. Palm oil은 어떤 oil인가?

동물성 지방에는 포화지방산이 많이 함유되어 있고 식물성 지방에는 불포화 지방산이 많이 함유되어 있다는 것이 일반인의 통념이다. 그러나 조금 전문적으로 각 지방의 급원에 따라서 관찰해 보면 식물성 지방인 coconut oil은 동물성 지방에 못지 않게 포화 지방산을 대량 함유하고 있다. 그런데 palm과 coconut이 비슷한 열매이므로 많은 사람들이 coconut과 palm을 잘 구분하지 못하는 것도 사실이다. Palm oil은 사실상 1945년 2차 세계대전까지는 technical oil로만 사용되었다. 그러나 1952년 이후에 palm oil의 생산과 가공에 대한 많은 연구가 진행되면서 식용으로 palm oil이 이용되는 가능성이 제시되었다. 그리하여 그 이후에 생산되는 palm oil 전량의 90% 이상이 식용으로 이용되기 시작하였고 이 양은 인간이 섭취하는 fat과 oil 전량의 13% 정도 점하게 되었다. 그래서 palm oil은 oil/fat의 세계 생산의 2번째 위치를 차지하게 되었다[1].

Palm oil은 많은 가공식품에 이용되고 있다. Magarine, baked product, frying media, 많은 confectionary fat에 이용된다. Palm oil이 이와 같이 많은 가공식품에 이용될 수 있는 것은 그 palm oil이 가지고 있는 다음의 특성들이 있기에 가능하다[1]; 1) Palm oil은 그 자체가 등황색 빛깔을 가지고 있어 magarine의 노란색과 일치하는 색을 제공한다. 2) Palm oil을 구성하고 있는 지방산은 저장과 열에 불안정한 불포화 지방산인 linoleic acid과 linolenic acid량이 낮아서 oil 자체에 안정감을 제공한다. 3) 가수분해에 민감한 short fatty acid를 포함한 중성지방의 양이 적어서 미생물의 작용에 의해서 발생할 수 있는 악취를 최소화할 수 있다. 4) Palm oil은 10℃에서 작은 solid을 함유함과 더불어서 높은 융점의 특징을 가진 TG 함유량이 높기에 더운 기후와 산업에 응용할 수 있는 범위가 넓다. 특히 고형형태의 생산품을 형성하는 범위가 넓을 수 있다(wide range of plastic product).

Palm oil의 영양적 가치는 이를 구성하는 지방산 성분에 의해 설명될 수 있으며 지방산 이외에 함유되어 있는 지용성 물질 특히 carotene과 vitamin E의 함량에 의해 설명할 수 있다. 다음의 Table 1은 palm oil의 지방산의 조성을 다른 주요 oil들의 지방산 조성과 비교한 것이다(Table 1)[2]. Palm oil의 지방산 조성을 조사해 보면 palmitic acid와 oleic acid의 함량이 높아 beef fat과 유사한 지방산 조성을 나타내고 있다. Crude palm oil과 palm kernel oil을 비교하면 palm kernel oil은 coconut과 유사한 지방산 조성을 보인다. 다른 식물성 유지는 crude palm oil에 비해 oleic acid와 linoleic acid 함량이 높고 palmitic acid 함량은 낮다.

그리하여 crude palm oil을 식용으로 하기보다는 palm oil을 지방산 fraction에 따라 분리하여서 생산하고 있다. 융점이 낮은 palm olein과 융점이 높은 palm stearin으로 나누어서 palm olein을 식용으로 권장하며 palm stearin은 technical oil로 사용하도록 권장한다.

다음의 Table 2는 palm olein과 palm stearin의 지방산 조성을 비교한 것이다[2]. Palm olein는 주로 oleic acid와 linoleic acid 함량을 가능한 한 증가시키고 palmitic acid 함량을 감소시켜서 융점을 낮게 만든 oil이다. 이에 비해 palm stearin은 oleic acid와 linoleic acid 함량이 plam olein보다 50%정도 적어서

Table 1. Fatty acid composition of major edible oils

Fatty acid	Palm	Palm Kernel	Coconut	Soybean	Cotton seed	Corn	Beef fat
6 : 0	–	0.2	0.4	–	–	–	–
8 : 0	–	3.3	7.3	–	–	–	–
10 : 0	–	3.5	6.6	–	–	–	0.0– 0.1
12 : 0	0.1	47.8	47.8	–	Tr	0.1	0.1
14 : 0	1.0	16.3	18.1	0.1	0.8	0.1	2.7– 4.8
16 : 0	43.8	8.5	8.9	11.2	23.7	12.1	20.9–28.9
16 : 1	0.1	–	–	0.1	0.8	0.2	2.3– 9.1
18 : 0	4.8	2.4	2.7	0.4	2.6	2.4	7.0–26.5
18 : 1	38.9	15.4	6.4	22.0	18.4	32.1	30.4–48.0
18 : 2	10.6	2.4	1.6	53.8	53.0	50.9	0.6– 1.8
18 : 3	0.3	–	–	7.5	0.1	0.9	0.3– 0.7
20 : 0	0.3	0.1	0.1	0.4	0.3	0.5	Tr– 0.9

Table 2. Fractional fatty acid composition of palm oil

Fatty acid	Palm oil	Palm olein	Palm stearin
12 : 0	0.0– 0.2	0.1– 0.2	0.1– 0.2
14 : 0	0.8– 1.3	0.9– 1.0	1.0– 1.3
16 : 0	43.1–46.3	39.5–40.8	46.5–68.9
16 : 1	Tr– 0.3	Tr– 0.2	Tr– 0.2
18 : 0	4.0– 5.5	3.9– 4.4	4.4– 5.5
18 : 1	36.7–40.8	42.7–43.9	19.9–38.4
18 : 2	9.4– 11.9	10.6–11.4	4.1– 9.3
18 : 3	0.1– 0.4	0.0– 0.4	0.1– 0.2
20 : 0	0.1– 0.4	0.1– 0.3	0.1– 0.3

고체 형태로 존재하는 유지이다.

다음은 palm oil에 함유된 지방이외의 지용성 성분으로 vitamin E와 carotenoids가 있다.

Palm oil의 vitamine E의 함량을 다른 vegetable oil과 비교하면 다음과 같다(Table 3)[3]. Vitamin E의 주요성분인 tocopherol과 불포화 물질인 tocotrienol을 이성체에 따라 α, β, γ, δ로 분류하였다. 다른 식용유에 못지않게 α-tocopherol과 tocotrienol의 함량이 높으며 γ-tocotrienol도 상당히 함유되어 있다.

Crude palm oil의 carotenoids 함량은 500~700 ppm으로 함량범위가 넓다. Palm oil에 함유된 carotenoids의 조성을 분석해 보면 α-carotene과 β-carotene이 각각 36%와 54%을 차지하고, γ-carotene, lycopene, xanthopylls은 소량 함유되어 있다[3].

Table 3. Vitamin E content of vegetable oils

	Tocopherol (ppm)				Tocotrienol (ppm)			
	α	β	γ	δ	α	β	γ	δ
Palm oil	256		316	70	143	32	286	69
Palm oil	279		61		274		398	69
Palm oil	152				205		439	94
Soybean oil	101		593	264				
Safflower oil	387		174	240				
Corn oil	112	50	602	18				
Cottonseed oil	389		387					
Sunflower oil	487		51	8				
Peanut oil	130		216	21				
Cocoa butter	11		170	7				
Olive oil	51							
Coconut oil	13							
Lard	12			7				
Palm oil	164				174		313	80
Palm olein	196				201		372	96
Palm stearin	79				81		168	44

2. 우리나라 주요 식이지방급원과 팜유의 체내 지방 대사 비교

우리나라에서 흔히 식이지방으로 많이 이용되고 있는 참기름, 들기름, 미강유, 그리고 생선 기름의 체내 지방대사, 특히 thrombus 형성, 혈청 성분 변화를 팜유와 비교하였다.

1) 우리나라의 지방섭취현황

우리나라 1991년 국민영양실태조사와 1989년

식품수급표에 의하면 우리나라 지방섭취현황은 전체 에너지 섭취량의 12~15% 섭취하는 실정이다. 지역적으로 차이가 나서 농촌은 12%, 대도시는 15%, 중소도시는 그 중간을 차지하고 있는 실정이다. 그리고 참기름 섭취량은 중소도시가 가장 적은 1.3g이고 농촌과 대도시는 각각 1.7g과 1.6g을 먹는 실정이다. 또한 농촌에서는 들기름 섭취량이 0.2g 정도 나타나 있다. 우리나라의 89년 수급표에 의한 식용유 공급 현황을 보면 콩기름이 34.0%이고 그 다음 팜유가 24.8%을 차지한다. 콩기름은 주로 식용유로 쓰이고 팜유는 과자, 라면 등등 제품에 혼합된 invisuable oil로 사용되고 있는 실정이다. 그러나 우리나라 지방 총 섭취량은 서구사회에 비해 상당히 낮은 편이다.

2) 지방산 구성

참기름의 특성은 거기에 함유된 지방산의 분포로 보아 n-6 지방산인 linoleic acid가 많고 들기름은 n-3인 linolenic acid가 많고 미강유는 n-9인 oleic acid와 linoleic acid가 많다. 그리고 이 3가지 유지는 20 chain의 지방산은 없다. 이에 비해 팜유는 palmitic acid와 n-9인 oleic acid 함량이 높게 함유되어 있고 linoleic acid 함량은 낮다. 이와 함께 어유와 우지의 지방산 조성을 비교하여 높았다(Table 5).

Table 4. Daily intake & Supply of dietary oils

		농 촌	중소도시	대도시
섭취량	총지방섭취량(g)	24.9	29.0	31.2
	(Energy %)	(11.9%)	(13.0%)	(15.2%)
	동물성지방(g)	8.0	11.8	12.5
	식물성지방(g)	16.9	17.2	18.8
	참기름(g)	1.7	1.3	1.6
	들기름(g)	0.2	0.0	0.0
공 급 량		콩기름 34.0% 팜 유 24.8%		

Table 6. Initial and final body weight and body weight gain

Groups	Initial body weight (g)	Final body weight (g)	Body weight gain (g/day)
Sesame oil	134.1±7.9	428.4±15.2	3.68±0.21
Perilla oil	143.9±6.7	436.3±20.4	3.66±0.31
Rice bran oil	137.9±5.4	430.8±19.9	3.66±0.25
Fish oil	131.3±6.8	416.9±15.4	3.63±0.14
Plam oil	131.7±4.5	453.3±15.4	3.96±0.21

3. 우리나라 식이지방과 팜유로 사육한 쥐의 혈청 지방성분 비교

초기체중이 135g내외인 흰쥐들에게 참기름, 들기름, 미강유, 어유, 팜유를 섭취열량의 30%되게, 그리고 corn starch 55%, casein 15%로 동물의 사료를 만든 후 12주간 동안 사육하였다. 그 결과 체중 증가량은 모든 다른 지방군에서 차이가 없었다(Table 6). 또한 식이 섭취량도 1일 19g 내외를 섭취하는 것으로 차이를 보이지 않았다(Table 7). 신체내 축적되는 지방 함량을 알기 위하여 epididymal

Table 5. Fatty acids composition of dietary oils (Unit : %)

Fatty acid \ Oils	Sesame	Perilla	Rice bran	Fish	Beef tallow	Palm
12 : 0						1.2
14 : 0				5.1	2.6	1.3
16 : 0	9.4	8.7	15.2	31.4	25.1	42.0
18 : 0				4.1	23.1	0.1
1(n-9)	30.0	17.1	37.2	10.9	42.4	38.4
2(n-6)	60.5	30.4	46.2	26.1	3.6	16.9
3(n-3)	0.1	43.8	1.4	0.4	–	0.1
20 : 0				0.1	1.8	–
4(n-6)				19.4		–
5(n-3)				2.5		–
n-3/n-6	0.001	1.44	0.03	0.064	–	0.006
P/S ratio	9.64	10.49	5.58	1.21	0.07	1.24

fat pad 무게를 측정하였으나 어유군과 팜유군이 약간 높은 경향이나 큰차이는 없었다(Table 8).

Table 9에 나타난 혈청 총지방과 중성지방을 보면, 참기름군과 들기름군에서는 중성지방의 함량이 낮았으며 기타 다른 군들은 중성지방이 높았으며 특히 어유군에서 가장 높았다. 총지방량은 우지군이 가장 높았고 그 다음이 미강유군이였으며 다른 군들은 비슷했다.

Table 10에서 보여주는 것처럼 cholesterol량을 비교해 보면 총 cholesterol은 어유군에서 가장 낮았고 그 다음이 들기름군이었다. HDL-cholesterol은 미강유군이 가장 높았고 그 다음이 들기름군, 팜유군 순이였고 참기름군과 우지군은 그 다음으로 유사한 수치를 보였다. 어유군에서 HDL-cholesterol이 가장 낮았다. 그런데 총 cholesterol에 대한 HDL-cholesterol 비율을 보면 들기름군이 가장 높았고 그 다음이 팜유군이였다. 그리고 그 비례는 우지군이 가장 낮았다. 그러므로 총 cholesterol 함량을 중요시하기 보다는 총 cholesterol에 대한 HDL-cholesterol 비율에 중점을 두면, 확실히 들기름군이 가장 좋았고 그 다음이 팜유군, 어유군, 참기름군, 우지군 순이였다. 혈청내에 총지방 함량이나 중성지방을 보면 참기름군과 들기름군이 유사한 영향을 보였지만 총 cholesterol에 대한 HDL-cholesterol의 비율의 견지에서 보면 들기름이 상당히 유리한 기름임을 알 수 있다.

4. 우리나라 식이지방과 팜유로 사육한 쥐의 항혈전 효과

각군들의 항혈전 효과를 보기 위해 동물들의 혈소판 수와 출혈시간과 전혈응고시간, 혈소판이 만드는 MDA 함량을 측정하였고 혈소판의 지방산 구성을 분석하였다.

혈소판 수(Table 11)는 미강유군과 참기름군이 가장 높았으며 그 다음이 팜유군이였고 들기름군이 가장 낮았다. 그리고 백혈구의 수는 어유군이 가장

Table 7. Daily food intakc and food efficiency ratio

Groups	Daily food intakc (g/day)	Food cfficiency ratio
Scsamc oil	19.1± 0.4	0.18± 0.010
Pcrilla oil	18.7± 0.7	0.20± 0.008
Ricc bran oil	18.7± 0.9	0.19± 0.003
Fish oil	20.2± 0.9	0.18± 0.008
Palm oil	18.3± 0.9	0.19± 0.006

Table 8. Epididymal fat pad weight and EFP indcx

Groups	Epididymal fat pad (g)	EFP index (mg/g BW)
Scsamc oil	7.57± 0.77	17.6± 1.7
Pcrilla oil	8.30± 0.74	18.7± 1.1
Ricc bran oil	8.48± 1.18	17.9± 1.8
Fish oil	8.91± 1.24	21.2± 2.6
Palm oil	9.99± 1.01	21.9± 1.9

Table 9. Scrum total lipid and triglyceride concentrations

Groups	Total lipid (mg/dl scrum)	Triglyceride (mg/dl serum)
Scsamc oil	227.6± 9.1	93.2± 9.2
Pcrilla oil	200.7± 16.9	96.8± 9.8
Ricc bran oil	229.4± 13.6	128.4± 10.8
Fish oil	202.3± 15.2	150.8± 11.1
Becf tallow	315.2± 20.1	124.1± 6.0
Palm oil	216.1± 10.5	136.6± 6.2

Table 10. Scrum total cholesterol, HDL-cholesterol and HDL-Chol/T-Chol Ratio

Groups	Total cholesterol (mg/dl serum)	HDL-cholesterol (mg/dl serum)	HDL-Chol/T-Chol ratio
Sesamc oil	78.9± 8.1	40.3± 5.9	0.51± 0.05
Pcrilla oil	73.6± 5.6	53.2± 5.7	0.73± 0.05
Rice bran oil	97.0± 10.4	64.7± 9.1	0.57± 0.05
Fish oil	59.1± 2.1	30.0± 1.4	0.53± 0.32
Bccf tallow	88.6± 2.8	39.8± 5.7	0.45± 0.10
Palm oil	80.2± 2.1	43.3± 3.4	0.60± 0.49

높았으며 그 다음이 팜유군이였고 그 다음이 들기름군 그리고 참기름군이 가장 낮았다. 혈소판의 수로 보면 들기름군이 낮아 응집 가능성을 낮추어준다는데서 항혈전에 유리한다고 볼 수 있으나 백혈구가 감소한다는 측면에서 면역능력이 낮을 것으로 예상이 된다. 그러나 다음 Table 12에서 참기름, 들기름, 우지와 어유를 식이 kg당 7, 15, 30%정도 제공하고 면역능력을 측정한 결과 고지방일 때에는 기름의 급원에 상관없이 면역능력이 저하되나 중간 정도내지 저지방일 때에는 면역능력이 참기름군과 들기름군에서 비교적 높았다. 또한 참기름군의 경우는 15%에서도 면역 능력의 저하를 보이나 들기름군은 7와 15%에서 면역 능력이 증가되었다.

다음 Table 13에서는 출혈시간과 전혈응고시간을 측정하여 본 결과 어유군과 들기름군이 출혈시간이 가장 길었고 참기름군이 가장 낮았으며 팜유군, 우지군과 유사한 결과를 나타냈다. 그런데 응고시간은 출혈시간 만큼 각각의 지방군에서 차이를 나타내지 않았다. 다음 Table 14에서는 혈소판의 MDA 방출량을 측정하여 본 결과 들기름군이 가장 낮았고 팜유군, 어유군, 참기름군이 유사한 수준을 나타냈으며 미강유군과 우지군은 2~3배 이상 높았다.

이러한 결과를 종합해 보면 확실히 어유와 들기름은 항혈전 효과가 가장 높은 기름이고 그 다음이 팜유의 순으로 생각해 볼 수 있고 참기름과 미강유, 우지는 항혈전 효과에서는 불리한 기름으로 생각할 수 있다.혈소판의 지방산 조성을 보면 역시 n-3/n-6 비례를 보아도 들기름이 가장 높고 우지가 가장 낮은 결과를 보였다(Table 15).

5. RBC membrane 지방산 조성과 RBC 칼슘 함량 변화

식이에서 섭취한 식이 지방의 종류에 따라 체내 세포막 지방산 조성이 변화되는 것으로 사려되어 RBC 지방산 조성을 분석하였다. RBC 세포막의 유연성에 따라 세포막을 통과하는 칼슘의 양을 측정함으로써 세포막의 유연성을 감지해 보고자 하였다. 세포막에 결합된 양의 칼슘의 양과 RBC ghost세포내에 trap된 칼슘의 양을 측정함으로써

Table 11. Number of platelets and white blood cells

Groups	Platelet number (unit : 10^6/ml)	White blood cell number (Unit : 10^7/ml)
Sesame oil	227.6± 9.1	93.2± 9.2
Perilla oil	200.7± 16.9	96.8± 9.8
Rice bran oil	229.4± 13.6	128.4± 10.8
Fish oil	202.3± 15.2	150.8± 11.1
Palm oil	216.1± 10.5	136.6± 6.2

Table 12. Mitogen response(Stimulation index/2.5 $\times 10^5$ spleen cell)

Group	Con A	PHA(10μg/10μl)
L-SO	174.74± 63.54	93.39± 29.49
M-SO	88.64± 22.95	69.62± 15.17
H-SO	52.47± 12.00	38.31± 7.65
L-PO	101.39± 24.50	62.28± 14.18
M-PO	105.36± 19.45	70.87± 18.96
H-PO	74.17± 16.85	62.01± 18.87
L-BT	70.89± 9.44	34.20± 9.94
M-BT	68.49± 15.97	53.31± 18.44
H-BT	60.30± 13.22	45.15± 9.79
L-FS	80.57± 19.55	57.77± 15.23
M-FS	82.80± 16.76	53.09± 9.11
H-FS	92.76± 22.74	61.60± 15.39

Table 13. Bleeding time and whole blood clotting time

Groups	Bleeding time (sec.)	Whole blood clotting time (sec.)
Sesame oil	90.1± 6.3	84.6± 10.8
Perilla oil	250.0± 36.8	87.1± 6.4
Rice bran oil	209.9± 26.1	83.8± 2.7
Fish oil	250.0± 28.6	88.0± 5.6
Beef tallow	160.9± 5.8	
Palm oil	153.6± 21.6	90.7± 4.5

Table 14. Malondialdehyde formation content

Group	MDA formation content (unit : n mol/10^9 platelet)
Sesame oil	6.57± 0.99
Perilla oil	4.98± 0.88
Rice bran oil	19.89± 9.35
Fish oil	6.57± 3.27
Beef tallow	13.60± 1.45
Palm oil	5.68± 0.30

세포막의 유연성을 알아보았다. 이는 이혜양의 논문에서 사람의 적혈구의 막의 지방산조성과 세포막의 칼슘과 ghost cell에 trap된 칼슘양이 연령증가에 따라 변화됨을 보여주었다. 연령이 증가함에 따라 막의 지방산 p/s 비율이 감소되며 그에 따라 RBC ghost세포내에 trap된 칼슘의 양이 증가되는 것으로 보고하였다. 이 결과는 적혈구막의 유연성이 감소되는 것으로 해석될 수 있다(Table 16).

본 연구에서 보면 들기름군이 ghost세포내에 trap된 양이 가장 낮았으며 참기름군이 가장 높았고 그 다음이 어유군과 팜유군에서 유사한 양을 나타냈다. 그러나 팜유군은 적혈구막에 함유된 칼슘의 양이 높았다. 이 결과는 들기름군의 경우 막의 유연성이 다른 기름군에 비하여 비교적 높다고 생각할 수 있다(Table 17, 18).

요 약

이상의 모든 결과를 요약해 보면 어유의 경우 항혈전 효과에는 상당히 들기름과 함께 좋으나 막의 유연성과 다른 면에서 들기름은 항혈전과 세포막의 유연성 유지 등에서 상당히 유리한 기름으로 생각할 수 있다. 팜유는 우지나 참기름보다 항혈전 효과나 세포막 유연성 유지에서 좋으나 들기름보다는 떨

Table 15. Bleeding time and whole blood clotting time (Unit : %)

Fatty acid	Sesame	Perilla	Rice bran	Fish	Beef	Palm
16 : 0	31.5	31.3	26.7	19.8	31.8	24.5
18 : 1(w-9)	5.6	7.7	8.1	4.1	11.6	3.5
: 2(w-6)	35.2	33.4	28.5	45.4	12.4	42.4
: 3(w-3)	–	–	–	4.6	1.6	3.3
20 : 0	–	–	–	1.0	2.2	0.4
: 4(w-6)	18.5	15.4	29.3	18.6	20.7	19.3
: 5(w-3)	9.3	10.3	7.4	6.4	0.7	6.3
18+20 w-3/w-6	0.173	0.211	0.128	0.172	0.070	0.155

Table 16. RBC membrane P/S ratio & RBC Ca in three age groups

Age(yr)	20−39	40−59	60+
P/S ratio			
Male	1.38	1.33	1.24
Female	1.37	1.36	1.21
RBC Ca(μmol/l)			
Male	16.68± 1.44	20.32± 1.62	23.93± 1.52
Female	18.32± 2.10	23.08± 1.00	29.49± 4.24

Table 17. Relative fatty acids composition of RBC membrane (Unit : %)

Fatty acid	Sesame	Perilla	Rice bran	Fish	Palm
16 : 0	18.3	17.8	19.3	12.7	6.4
18 : 1(w-9)	1.4	3.6	3.6	0.1	4.5
: 2(w-6)	43.8	51.1	42.8	22.2	54.5
: 3(w-3)	–	–	–	2.2	1.9
20 : 0	–	0.5	–	–	0.1
: 4(w-6)	27.8	13.3	26.1	40.9	23.5
: 5(w-3)	8.7	13.7	8.1	9.2	9.1
18+20 w-3/w-6	0.122	0.213	0.118	0.181	0.141

Table 18. Concentration of red blood cell(RBC) Ca, membrane Ca and trapped Ca

Group	RBC calcium (μg/dl cell)	RBC membrane calcium (μg/dl cell)	Trapped Ca (μg/dl cell)
Sesame oil	112.5±19.1	67.5± 7.2	92.3±23.4
Perilla oil	80.0± 8.2	68.4± 8.0	29.0± 2.8
Rice bran oil	88.3± 9.4	47.4±12.0	54.9±11.2
Fish oil	81.7± 7.1	56.0± 8.0	38.0± 9.0
Palm oil	73.9± 2.5	102.0±25.0	38.0± 5.0

어지는 것으로 생각할 수 있다.

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