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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 6 (6): 580-586, 2003
ISSN 1028-8880

Comparison Between the Effects of Saturated and Unsaturated Oils on Serum Cholesterol of Jordanian Volunteers

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Abstract: The effect of palm oil (PO), olive oil (OO), corn oil (CO) and soybean oil (SO) on the serum lipid profile was studied in 24 healthy persons (12 males, aged 35-43 y; 12 females, aged 26-34 y). The subjects ate their habitual diet using one type of oil in food preparation for 4 weeks with 4 weeks interval between the four oil periods. The SO, CO and OO-diets were significantly ($P<0.05$) reduced levels of serum total cholesterol, low and high density lipoprotein cholesterol, whereas PO diet caused slight increase in this levels. However, SO-diet caused comparatively higher reduction in these levels (-11, -9.5, -2 mg dl^{-1}, respectively). Triglycerides level was increased after SO, CO and OO periods, while PO diet reduced this level.

Key words: Oils, cholesterol, LDL-c, HDL-c, triglycerides

Introduction

Clear relation has been evident between blood cholesterol concentration and individual risk of coronary heart disease (CHD) (Cottrell, 1991). Most CHD is due to the blockages in arteries supplying blood to the heart muscle, as a result of depositing more fat and cholesterol over the years. The arteries become narrower and narrower, this process is known as atherosclerosis (Williams, 1993). Severe disability from all forms of CHD are responsible for the highest incidence of morbidity and mortality recorded for any disease state in many developed nations (Hetzel *et al*., 1989). Cholesterol like other fatty substances cannot mix with water. Therefore, to carry cholesterol and other lipids in the blood, the body wraps them in protein packages. This combination is called a lipoprotein. Blood cholesterol is found in all lipoproteins, including the low density lipoproteins (LDLs) and high density lipoproteins (HDLs) (Williams, 1993). LDLs contain the greatest amount of blood cholesterol and may be responsible for depositing cholesterol in the artery walls. These lipoproteins are atherogenic (Wang, 1987). HDLs contain the greatest amount of protein and small amount of cholesterol. HDLs can acquire cholesterol from cells and transport it to the liver for the reprocessing or bile acid formation (Koo *et al*., 1985). These lipoproteins are appearing to be antiatherogenic (Wang, 1987).

Blood cholesterol concentration can be changed in individuals by alterations in the fatty acid content of their dietary fat (Raiser, 1973). An increase in saturated fatty acids in the diet may lead to an increase in blood cholesterol content (Banamon and Grundy, 1988). The longer chain fatty acids ($\geq C_{18}$) seem to have little effect, whereas the medium chain fatty acid (C_{10}-C_{16}) have a hypercholesterolemic effect (Dziezak, 1989; Elson, 1992; Sundram and Basiron, 1994). The monounsaturated fatty acids (MUFAs) like oleic acid, which preponderant in olive oil, may reduce the blood cholesterol level (Baggio *et al*., 1988). The Polyunsaturated fatty acids (PUFAs), including the essential fatty acids (EFAs), are thought to have a blood cholesterol lowering effect when taken in the diet (Tany *et al*., 1991; Jones, 1994). Besides that, the PUFAs, may reduce the concentration of blood LDL-cholesterol (LDL-c) and HDL-cholesterol (HDL-c) (Nestel, 1987). More specific, dietary n-3 PUFA are more potent than n-6 PUFA in reducing the serum cholesterol (Hearn *et al*., 1987). N-3 PUFA have several beneficial cardiovascular properties (Stone, 1996), including antiatherothrombogenic, antiarrythmic and antihypertensive effects (Grundt *et al*., 1995).

The aim of this study was to determine the effect of four different types of oil, saturated oil such as palm oil (PO), monounsaturated oil such as olive oil (OO), polyunsaturated oil such as corn oil (CO) and soybean oil (SO), on Jordanian blood lipid profile.

Materials and Methods

Participants in this study were selected from different locations in Jordan (Amman, Karak) from Apr. to Nov., 2001. Twelve males averaged 36 years old (ranged 35-43 y.) and twelve females averaged 28 years old (ranged 26 -34 y.) were included in this study. Body weight and body mass index of males were 63 Kg and 21.8, respectively and of females were 56 Kg and 21.3, respectively. All subjects were healthy, normocholesterol

level (< 200 mg dl^{-1}), normotensive, non diabetic and free from cardiac, renal, hepatic or bleeding disorders. However, this study was depended on the families (husband and wife) and they were supplied the mentioned oils and asked to maintain their dietary habits with changing only in the oil type used in food preparation.

Diets: Bread (twice a day) and rice (four times a week) were contributing as the main source of carbohydrates, while chicken (twice a week) and eggs (three eggs a week) were contributing as the main source of protein. Milk and its products (three times a week) and meat were eaten once a week. Different green vegetables and fruits were eaten four times and twice a week, respectively. Daily meals were based on a seven days rotation menu; the same menu was maintained throughout the study. The only variable was the type of oil used in cooking or dipping. PO, Crude OO, CO and SO were used in the preparation of participant diets. Fatty acid composition of these oils were shown in Table 1. Three-day-diet-record for individual dietary intake was used in this study (Table 2), macronutrients and energy were calculated using food composition tables (Pellet and Shadarvian, 1970). Current study was noted that Jordanians consumed OO more than any other oil or fat. It is usually used at least twice a day, consistently for breakfast and lunch especially with chickpea and thyme and sometimes used for cooking.

Study design: Before the beginning of the study the nutritional status of subjects was studied, this work showed that no worth mentioned different in food intake of individuals from week to week and they asked to maintain their traditional 7-days rotation menu. The 24-persons were eating their food with PO or OO or CO or SO as the sole source of fat type for 4wk with 4wk interval between the four diets. However, the period of 4wk was chosen as it has previously been shown that plasma lipid levels stabilize within 2-3 wk after initiating a change in dietary fat intake (Bonamon and Grundy, 1988). Fasting venous blood samples (10 ml) were collected at the entry and at the end of each dietary period for next analysis.

Chemical analysis:

Fatty acids composition (FA): Oil samples were saponified and the free fatty acids were methylated following the procedure of Morrison and Smith (1962). Fatty acid methylesters were separated by Hamlet Packard gas chromotography model 5710a equipped with flame ionization detectors and column of 10% DEGS on chromosorb WDMCS (Supelco, Inc.). The flow rate of carrier gas was 24 ml of N_2/min, of detectors were 30 ml of H_2/min and 300ml/min of air. The initial columns temperature was 150°C then raised to 180°C @ 6°C /min, the injector and detector temperature were 200 and 250°C, respectively. The identification of individual FA was made using FA-methyl ester standards to establish relative retention time. The relative content of each FA-methyl ester was reported as percent area of total FA- methyl ester.

Serum total cholesterol was determined using the enzymatic method from Arab Company for medical diagnostic, (Jordan). Triglycerides were determined by the enzymatic technique from Biocon, (Germany). HDL-c was analyzed by the precipitation technique using magnesium chloride and phosphotungestic acid from Biocon, (Germany). LDL-c was calculated using the formula.

Statistical analysis: The Completely Randomized Design was used for each parameter. Differences between means were determined using Duncan's multiple range test at $p < 0.05$ by SAS (1986).

Results and Discussion

Food consumption: The fatty acid compositions of PO, OO, CO and SO are presented in Table 1. PO contained the more SFA (52.1%) than the other oils. It contained 45.4% palmitic acid. OO was highly MUFA (67.2%) in comparison with other oils. It contained 66.4% oleic acid. CO and SO contained higher PUFA (54.4 and 63.1%, respectively). They contained more than 50% linoleic acid, which is considered nutritionally an essential and adequate for human requirements. The ratios of PUFA : SFA (*p:s*) and MUFA + PUFA (*m+p*):*s* have been used by nutritionists to interpret the effect of dietary oil and fat on the level of blood cholesterol (Hodson *et al.*, 2001). The

Table 1: Fatty acid profile of palm oil (PO), olive oil (OO) , corn oil (CO) and soybean oil (SO)

Fatty acids	PO	OO	CO	SO%
12:0	0.20	-	-	-
14:0	1.30	-	-	-
16:0	45.40	14.80	12.30	10.60
16:1	0.30	0.80	0.20	0.90
18:0	4.90	5.30	2.40	0.30
18:1	37.20	66.40	30.20	24.70
18:2 (n-6)	10.20	12.10	53.50	54.60
18:3 (n-3)	0.20	0.60	0.90	8.50
20:0	0.30	-	0.50	0.40
SFA% (s) *	52.10	20.10	15.20	11.30
MUFA% (m)	37.50	67.20	30.40	25.60
PUFA% (p)	10.40	12.70	54.40	63.10
m+ p:s	0.92	3.98	5.58	7.85
p:s	0.20	0.63	3.58	5.58

*SFA, saturated fatty acids; MUFA, mono unsaturated fatty acids; PUFA, polyunsaturated fatty acids.

Table 2: Food consumption of subjects

Dietary oil type*	Gender	Energy Cal	Carbohydrates g	Carbohydrates Cal%	Fats g	Fats Cal%	Proteins g	Proteins Cal%
PO	Males	1920±100	307±25	64.0	56.1±10	26.3	46.7±7	9.7
	Females	1811±90	296±18	65.4	51.3±8	25.5	41.4±6	9.1
	Total	1866	302.0	64.6	53.7	25.9	44.1	9.5
OO	Males	1977±80	312±22	63.1	59.1±11	26.9	49.3±8	10.0
	Females	1761±75	287±23	65.2	49.3±9	25.2	42.4±7	9.6
	Total	1869	300.0	64.1	54.2	26.1	45.9	9.8
CO	Males	1943±70	309±17	63.6	57.4±8	26.6	47.6±9	9.8
	Females	1778±65	293±15	65.9	48.1±9	24.3	43.2±10	9.7
	Total	1860	301.0	64.7	52.8	25.5	45.4	9.8
SO	Males	1891±95	306±16	64.7	52.5±7	25.0	48.5±11	10.2
	Females	1813±100	302±17	66.6	48.5±6	24.1	42.1±8	9.3
	Total	1852	304.0	65.7	50.5	24.5	45.3	9.8
Means of totals		1862	302.0	64.7	52.8	25.5	45.18	9.7

* PO, palm oil; OO, olive oil; CO, corn oil; SO, soybean oil.

Table 3: Effects of dietary palm oil (PO), olive oil (OO), corn oil (CO) and soybean oil (SO) on concentrations of serum lipids of males and females(1)

Lipids	PO		OO		CO		SO	
Serum (2)	Initial	Final	Initial	Final	Initial	Final	Initial	Final
TC (mg dl^{-1})								
Males	171±15	173±14	169±16	164±13*	174±14	165±12*	185±17	173±15*
Females	158±12	159±11	155±10	152±9*	156±12	150±11*	167±14	157±12*
Total	165	166	162	158	165	158	176	165
LDL-c(mg dl^{-1})								
Males	110±11	112±10	112±9	107±8*	115±13	106±9*	121±14	110±9*
Females	104±10	105±11	104±8	101±9*	103±10	97±7*	113±11	105±8*
Total	107	108	108	104	109	102	117	108
HDL-c(mg dl^{-1})								
Males	38±5	39±6	35±7	35±8	36±6	35±4	40±7	38±5*
Females	32±5	32±6	30±4	29±5	33±6	32±7	34±4	32±3*
Total	35.0	35.5	32.5	32.0	34.5	33.5	37.0	35.0
TC/HDL-c								
Males	4.50±0.6	4.44±0.4	4.83±0.5	4.69±0.7*	4.83±0.8	4.71±0.5*	4.63±0.6	4.55±0.4
Felames	4.94±0.8	4.97±0.7	5.17±0.9	5.24±0.6	4.73±0.5	4.69±0.4	4.91±0.6	4.91±0.7
Total	4.7	4.68	4.98	4.94	4.78	4.70	4.76	4.71
LDL-c/HDL-c								
Males	2.89±0.3	2.86±0.2	3.20±0.4	3.05±0.2*	3.19±0.4	3.04±0.2*	3.03±0.3	2.91±0.2*
Females	3.25±0.4	3.28±0.4	3.47±0.3	3.49±0.5	3.11±0.2	3.04±0.3*	3.32±0.4	3.27±0.3
Total	3.06	3.05	3.32	3.25	3.15	3.04	3.16	3.07
TG (mg dl^{-1})								
Males	115±7	112±6*	110±5	112±6	116±8	118±7	120±7	123±6
Felames	110±5	111±7	105±4	108±7*	102±5	104±6	100±5	102±4
Total	113	111	108	110	109	111	110	113

(1) Mean ± SD, (2) :TC, total cholesterol; LDL-c, low density lipoprotein cholesterol; HDL-c, high density lipoprotein cholesterol ; TG, triglycerides. * Significantly different from initial value $P < 0.05$.

Table 4: Serum lipid responses (mg/dl and %) from the base line of males and females fed dietary Palm oil (PO), olive oil (OO), corn oil (CO) and soybean oil (SO)

Dietary fattype	Gender	*TC mg dl^{-1}	*TC %	LDL-C mg dl^{-1}	LDL-C %	HDL-C Mg dl^{-1}	HDL-C %	Triglycerides Mg dl^{-1}	Triglycerides %
PO	Males	$+2^{g}$	+1.0	$+2^{e}$	+1.8	$+1^{a}$	+2.6	-3^{a}	-2.6
	Females	$+1^{g}$	+0.6	$+1^{e}$	+0.1	-Ü	--	$+1^{b}$	+0.9
	Total	+1.5	+0.8	+1.5	+1.0	+0.5	+1.3	-1	-0.8
OO	Males	-5^{e}	-2.9	-8^{b}	-7.41	--	--	$+2^{bc}$	+1.8
	Females	-3^{f}	-1.9	-8^{b}	-8.08	-1	-3. 3	$+3^{c}$	+2.9
	Total	-4	-2.4	-8	-7.77	-0.5	-1.5	+2.5	+2.3
CO	Males	-9^{c}	-5.2	-10^{a}	-9.17	-1	-2.8	$+2^{bc}$	+1.7
	Females	-6^{d}	-3.8	-8^{b}	-7.69	-1	-3.0	$+2^{bc}$	+1.9
	Total	-7.5	-4.5	-8.92	-8.37	-1	-2.9	+2	+1.8
SO	Males	-12^{a}	-6.5	-11^{a}	-9.1	-2	-5.0	$+3^{c}$	+2.5
	Females	-10^{b}	-5.9	-8^{b}	-7.1	-2	-5.9	$+2^{bc}$	+2.0
	Total	-11	-6.3	-9.5	-8.1	-2	-5.5	+2.5	+2.3

* TC, total cholesterol; LDL-c, low-density lipoprotein cholesterol; HDL-c, high-density lipoprotein cholesterol.
Values in columns with different superscripts differ significantly, $P<0.05$.

results showed that the *p:s* ratios of PO, OO, CO and SO were 0.2, 0.63, 3.58 and 5.58, respectively and the *m+p:s* ratios of these oils were 0.92, 3.98, 5.58 and 7.85, respectively.

The three-days-diet-record of dietary intake of participants showed no big difference in food intake between the pretrial period and the period of study and no worth mentioned difference between periods of the study. Food consumption of four diets was compared for both sexes (Table 2). It was generally higher in males than that for females. However, investigated oils formed about 60%, but SO formed about 55%, of the dietary fat intake.

Serum lipids: The consumption of OO, CO and SO significantly lowered the serum cholesterol level under the initial level, whereas PO feeding caused slight increase in this level above the initial level. However, SO resulted in more reduction in serum cholesterol level (-11mg/l) than CO (7.5 mg l^{-1}) and OO (-4mg l^{-1}) (Table 3). By comparison with initial concentration, OO, CO and SO significantly lowered LDL-c and caused slight reduction in HDL-c, whereas PO caused slight increase in these levels. When the responses in serum total cholesterol in the males and females were considered separately for the four diets, the reduction was greater in males than in females. The level of triglycerides (TG) was increased in serum of both sexes fed OO, CO and SO diets and in females fed PO diet, whereas decreased in males fed PO diet (Table 4).

This study had maintained the habitual diet of volunteers, for that no change in habitual diet items, but the type of dietary oil was changed to assess the effects of PO, OO, CO and SO feeding on serum lipid profile. The volunteers were able to maintain their body wieght for the study period which indicated that there was no any change in their energy balance, that was presumably due to that the subjects might have adapted their diets.

Looking back to the data in Table 1, the results indicate that all samples which show hypocholesterolemic effect have high PUFAs (specially SO) and possess high *p:s* and *m+ p:s* ratios as compared with effect of PO which contained high SFA. Among the four oils, effect of SO on serum cholesterol was more pronounced. This oil comes the first hypocholesterolemic effect, may be due to its high *p:s* ratio (Lee *et al*., 1989). It is possible that the high content of total PUFAs in SO works as an inhibitor for hepatic hydroxy-methyl-glutarate (HMG)-Co A reductase, the rate limiting enzyme in cholesterol biosynthesis (Yaquoob *et al*., 1995). It seems that n-3 PUFAs have high inhibition effect of this enzyme (Elson, 1992). One of n-3 PUFAs the linolenic acid which formed 8.5% of SO. Philipson *et al*. (1985) stated that ingesting n-3 PUFAs reduced human serum cholesterol. Therrien (1989) reported normal blood cholesterol level of Eskimo population who are famous in consuming highly marine fish diet (high n-3 PUFAs). Recently, Hodson *et al*. (2001) stated that n-6 PUFAs reduced serum cholesterol in human. One of these fatty acids, the linoleic acid which formed 54.6% in SO and 53.5% in CO. Chanmugan *et al*. (1986) and Hearn *et al*. (1987) mentioned that the concentration of serum cholesterol tended to increase linearly with the increase in n-6 PUFAs/n-3 PUFAs (n-6/n-3) ratios. Furthermore, Elson (1992) showed that with the decrease in n-6/n-3 ratios, the serum cholesterol and hepatic HMG-CoA reductase activities were also lowered. These explanations may presumably explain the hypocholesterolemic effect of all PUFA and at the same time emphasize the high effect of n-3 PUFA. However, these explanations may also enhance the idea about imaginable role of SO in reducing the serum cholesterol of human being, specially SO that contains high percentage of linolenic acid. CO diet which has high PUFAs comes the second in reducing effect of serum cholesterol following SO diet and this may be due to its lower content of linolenic acid (0.9 %) compared with SO.

Linoleic acid may act as a hypocholesterolemic agent in human and the same observation was found in rats (Lacono and Dougherty, 1991) in cebus monkeys (Fine *et al*., 1981). The SO and CO diets, resulted in decreasing the occurrence of enterohepatic circulation of bile acids and less feed back inhibition of bile acid synthesis (Bjorkhom *et al*., 1978). The effects of CO and SO on serum cholesterol concentration are in agree-ment with results found in human (Hodson *et al*., 2001; Nilsen *et al*., 2001), OO occupied the third in lowering effect of serum cholesterol following CO and SO. The hypocholesterolemic effect of OO diet may be attributed to its high oleic acid content, (Grundy 1989). The effect of OO diet on serum cholesterol is in agreement with results of Hodson *et al*., (2001). The moderate effect of PO (normocholesterolemic effect), inspite of its high SFA content and low *p:s* ratio, may be due to its high palmitic acid content (Sundram and Basiron, 1994). However, the slight increase in serum cholesterol after PO period may be attributed to the small amount of meyristic acid (1.3%) in PO. This type of fatty acid works as raising factor for serum cholesterol (Elson, 1992). The results of PO effects on serum cholesterol came in agreement with those obtained by Sugano and Imaizumi, (1991), whereas in disagreement with the results of Jian *et al*., (1997) who mentioned that PO significantly reduced serum cholesterol of human.

The effects four oils on serum TC seemed to be in accordance with their effects on HDL-c and LDL-c concentrations. The SO and CO resulted in more reduction in these concentrations than that caused by OO, whereas PO caused a slight increase in these concentrations. These differences may be attributed to

the difference in fatty acid composition of the four oils. High content of PUFA in SO and CO may result in reducing the LDL-c by altering the LDL composition or by decreasing the concentration of LDL particles (Vega *et al*., 1982). Williams *et al*. (1986) reported that PUFA reduced blood lipoprotein concentrations compared with MUFA and SFA. The same observations were mentioned by Howard *et al.* (1995) and Noakes and Clifton (1998). Current results about the effects of dietary oil type on cholesterol of serum lipoproteins came in agreement with the results of Lu *et al*. (1997) and Hodson *et al*. (2001).

In general, the elevated blood cholesterol is a major risk factor for CVD (NCEP, 1993). Several studies confirmed that the high blood cholesterol in young adults is a predict of CVD risk in later life (Myers *et al*., 1995). Present results showed that replacing PO with SO rather than CO and OO is more efficacious of lowering the predicted risk of CVD due to a larger decline in serum total cholesterol. There is a good evidence that the ratio of TC/HDL-c is a better indicator of CVD risks than either total cholesterol or LDL-c alone (Kinosian *et al*., 1994). Results of this study showed a reduction in TC/HDL-c ratio after SO, CO, OO and PO periods. These reductions were pronounced in males than females. The results also showed that the LDL-c/HDL-c ratio was in accordance with the former ratio.

The results showed that the effect of dietary fat type on the serum TG was reverse of the effect on serum total cholesterol. That is the hypocholesterolemic effect of SO, CO and OO accompanied with an increase in serum TG level whereas PO resulted in reduction in this level. Therefore, these results imply that the differences in fatty acids composition of oil types may result in differences in their effects on secreting and degrading serum TG. PUFA and MUFA may enhance very low density lipoprotein (VLDL)- TG secretion compared with SFA(Heimberg and Wilcox, 1972). Lee *et al*. (1989) Stated that the plasma TG of rats increased with increasing *p:s* ratio. Present results are in agreement with observations of Marzuki *et al*. (1991), whereas in disagreement with the results of Tany *et al*. (1991), who mentioned that the CO reduced plasma TG of volunteers compared with PO.

In conclusion, the current results imply the hypocholesterolemic effect of unsaturated oils and distinguish the effect of n_3-fatty acid (SO), which resulted in more reduction in serum cholesterol and serum cholesterol indices. Finally, this work suggests study effects of mentioned oils on serum lipid of hypercholesterolemic humans.

References

Baggio, G., A. Paguan and M. Muraea, 1988. Olive oil enriched diet: effect on serum lipid levels and biliary cholesterol saturation. Am. J. Clin. Nutr., 47: 960-4.

Bjorkhem, L., R. Blomstrand and L. Svensson, 1978. Effect of different dietary triglycerides on 7α- hydroxylation of cholesterol and other mixed-function oxidations. J. Lipid Res., 19: 359-69.

Bonamon, A. and S.M. Grundy, 1988. Effect of dietary stearic acid on plasma cholesterol and lipoprotein levels. N. Engl. J. Med., 318: 1244-8.

Chanmugan, P., M. Boudreau and D.H. Hwag, 1986. A research note-diferrences in the ω3-fatty acid contents in pond-reared and wild fish and shellfish. J. Food Sci., 51: 1556-57.

Cottrell, R.C., 1991. Introduction: nutritional aspects of palm oil. Am. J. Clin. Nutr., 53: 989-1009.

Dziezak, J.D., 1989. Fats, Oils and Fat Substitues. Food Technology's Innovative, Food Trends, Institute of Food Technologist, Food Technology, July p:65.

Elson, C.E., 1992. Tropical oils: nutritional and scientific issues. Crit Rev. in Food Sci. Nut., 31: 79-102.

Fine, K.M., J. Dupont and M.M. Mathias, 1981. Rat platelet prostaglandin cyclic AMP and lipid response to variations in dietary fat. J. Nutr., 111: 699-707.

Grundt, H., D.W. Nilsen and O. Hetland, 1995. Improvement of serum lipids and blood pressure during intervention with n-3 fatty acids was not associated with changes in insulin levels in subjects with compined hyperlipidaemia. J. Intern. Med., 237: 249-59.

Grundy, S.M., 1989. Monounsaturated fatty acid and cholesterol metabolism: implications for dietary recommendations. J. Nutr., 119: 529 - 33.

Hearn, T.L., S.A. Sgoutas, J.A. Hearn and D.S. Sgoutas, 1987. Polyunsaturated fatty acids and fat in fish flesh for selecting species for health benefits. J. Food Sci., 52: 1209-11.

Heimberg , M. and H. G. Wilcox, 1972. The effect of palmitic and oleic acids on the properties and composition of the very low density lipoprotein secreted by the liver. J. Biol. Chem., 247: 875 - 80.

Hetzel, B.S , J.S. Charnock, T. Dwyer and PL. Mclennan, 1989. Fall in coronary heart disease mortality in USA and Australia due to sudden death : evidence for the role of polyunsaturated fat. J. Clin. Epidemiol., 42: 855-93.

Hodson, L., C.M. Skeaff and W. Chisholm, 2001. The effect of replacing dietary saturated fat with polyunsaturated or monounsaturated fat on plasma lipids in free-living young adults. Europian J. Clin. Nutr., 55 : 908-15.

Howard, B.V. , J.S. Hanna, C.C. Heiser, K.A. Jablonski, M.C. Paidi, L. Alarif, D.C. Robbins and W.J. Howard, 1995. Polyunsaturated fatty acids result in greater cholesterol lowering and less triacylglycerol elevation than do monounsaturated fatty acids in a dose-response comparison in a multi racial study group. Am. J. Clin. Nutr., 62 : 392-402.

Jian, Z., P.Wang, C.Wang, X.S. Chen and K. Ge, 1997. Nonhypercholesterolemic effects of a palm oil diet in Chinese adults. J. Nutr., 127 : 509-13.

Jones, P.J., 1994. Dietary linleic, á-linolenic and oleic acids are oxidized in similar rates in rats fed a diet containing these acids in equal proportions. Lipids, 29: 491-5.

Kinosian, B., H. Glick and G.Garland, 1994. Cholesterol and coronary heart disease: predicting risks by levels and ratios. Ann. Intern. Med., 121: 641-7.

Koo, C., T. Innerarity and R.W. Mahley, 1985. Obligatory role of cholesterol and apolipoprotein-E in the formation of large cholesterol-enriched and receptor-active high density lipoproteins. J. Biol. Chem., 260: 11934 - 43.

Lacono, J. M. and R. M. Dougherty, 1991. Lack of effect of linoleic acid on the high density lipoprotein cholesterol fraction of plasma lipoproteins. Am. J. Clin. Nutr., 53: 660 –4.

Lee, J.H., M. Fukumoto, H. Niahida, R. Ikida and M. Sugano, 1989. The interrelated effects of n-6/n-3 and polyunsaturated/saturated ratios of dietary fats on the regulation of lipid metabolism in rats. J. Nutr., 119 : 1893-99.

Lu, Z., S. Hendrich, N. Shen, P. J. White and L.R. Cook, 1997. Low Linolenate and commercial soybean oils diminish serum HDL cholesterol in young free living adult females. J. Am. College. Nutr., 16 : 562-9.

Marzuki, A., F. Archad, T. Avdurazak and K. Jaarin, 1991. Influence of dietary fat on plasma lipid profiles of Malaysian adolescents. Am. J. Clin. Nutr., 53: 1010 - 14.

Morrison, W.R. and L.M. Smith, 1962. Preparation of fatty acid methyl ester and dimethyl acetals from lipid with boron flourid-methanol. J. Lipid. Res., 5: 600.

Myers, L., S.S. Coughlin, L.S. Webber, S.R. Srinivasan and G.S. Berenson, 1995. Prediction of adult cardiovascular multifactorial risk status from childhood risk factor levels. The Bogalusa Heart Study. Am. J. Epidemiol., 142: 918-24.

NCEP, 1993. Summary of the second report of the national cholesterol education program expert panel on detection. Evaluation and treatment of high blood cholesterolin adults (adult Treatment Panel II). J. A. M. A., 269: 3015-23.

Nestel, P.J., 1987. Polyunsaturated fatty acids (n–3, n–6). Am. J. Clin. Nutr., 45: 1161 –7.

Nilsen, D., A. Grethe, L. Knud, M. Solfrid, A. Torbjohn and W. Leik, 2001. Effects of a high-dose concentrate of n–3 fatty acids or corn oil introduced early after an acute myocardial infraction on serum triacylglycerol and HDL cholesterol. Am. J. Clin. Nutr. 74: 50 –6.

Noakes, M. and P.M. Clifton, 1998. Oil blends containing partially hydrogenated or intersterified fats: differential effects on plasma lipids. Am. J. Clin. Nutr., 68: 242-7.

Pellet, P.L. and S. Shadarvian, 1970. Food Composition Tables Use in the Middle East. American Univ. Beirut.

Phillipson, B.E., D.W. Rothrock, W.E. Connor, W.S. Harris and D.R. Illingworth, 1985. Reduction of plasma lipids, lipoprotein and apoproteins by dietary fish oils in patients with hypertriglyceridemia. N. Engl. J. Med., 312: 1210-16.

Raiser, R., 1973. Saturated fat in the diet and serum cholesterol concentration: critical examination of the literature. Am. J. Clin. Nutr., 164: 1912-19.

Sandstrom, B., A. Aro, W. Becker, N. Lyhne, J.I. Pedersen and I. Porsdottir, 1996. Nordiska naringsrekommendationer. (Nordic nutrition recommendations 1996.) Copenhagen: Nordisk Ministrad.

SAS, version, 1986. Statistical Analysis System, SAS Institute Inc., Cary, NC 27512- 8000, USA.

Stone, N.J., 1996. Fish consumption, fish oil, lipids and coronary heart disease. Am. J. Clin. Nutr., 65: 1083-6.

Sugano, M. and K. Imaizumi, 1991. Effect of palm oil on lipid and lipoprotein metabolism and eicosanoid production in rats. Am. J. Clin. Nutr., 53: 1034-8.

Sundram, K. and Y. Basiron, 1994. Modulation of human blood lipids and lipoproteins by palm oil (Abst.) Unesco/ Costam SFRR-Asia workshop on nutrition, lipids, health and disease. Penang/Malaysia.

Tany, K. N., H. Khalid, J.B. Limi, M.S. Lye and L.R. Ishak, 1991. Nonhypercholesterolemic effects of a palm oil diet in Malaysian volunteers. Am. J. Clin. Nutr., 53: 1015-20.

Therrien, M., 1989. The effects of omega-3 fatty acids on total cholesterol and high density lipoprotein cholesterol in humans. Can. Home. Econ. J., 39: 149-52.

Vega, G.L., E. Groszek, R. Wolf and S.M. Grundy, 1982. Influence of polyunsaturated fats on composition of plasma lipoproteins and apoproteins. J. Lipid Res., 23: 811-22.

Wang, C.S., 1987. Classification of Lipids, by Thomas Briggs and Albert M. Chandler. Springer-Verlag, New York Inc.

Williams, P.T., R.M. Krauss, S.J. Kindel, D.M. Dreon, K.M. Vranizen and P.D. Wood, 1986. Relationship of dietary fat, protein, cholesterol and fiber intake to athergenic lipoproteins in men. Am. J. Clin. Nutr., 44: 788 –97.

Williams, S.B., 1993. Nutrition and Diet Therapy, 7th ed., The C.V. Mosby Company, St. Louis.

Yaquoob, P., E. J. Shirington, N. Jeffery, P. Sanderson, D.J. Harvey, E Newsholme and P.C. Calder, 1995. Comparison of the effects of a range of dietary lipids upon serum and tissue lipid composition in the rat. J. Biochem. Cell. Biol., 27: 297-310.