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Differential Effect of n6 and n3 Polyunsaturated Fatty Acids on Plasma Lipids in Rats Fed Low and High Fat Diets

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= ABSTRACT =

To compare the hypolipidemic effects of n6 and n3 PUFA at different fat levels, male Sprague Dawley rats were fed either low fat (LF, 10% Cal) or high fat (HF, 40% Cal) diet which was different only in fatty acid composition for 6 weeks. Dietary fats were beef tallow, corn oil, perilla oil, and fish oil concentrate as a source of saturated fatty acid, n6 linoleic acid(LA), n3 α-linolenic acid(LL) and n3 eicosapentaenoic acid(EPA)+docosahexaenoic acid(DHA), respectively. VLDL fraction was separated by ultracentrifugation and chemical composition was determined by thin layer chromatography.

Plasma cholesterol level was increased by n6 LA but decreased by n3 LL and n3 EPA in LF and HF diets, and the hypocholesterolemic effect of n3 EPA was most significant in HF diet. HDL-Chol level was raised by n6 LA in LF and HF diets, but significantly reduced by n3 EPA in HF. Plasma TG level was reduced by n6 LA, n3 LL and EPA in LF and HF with the reduction of lipogenic enzyme activity only by n3 PUFAs. The proportion of TG in VLDL fraction was significantly lowered by n3 EPA in LF and HF. The proportion of apo-B in VLDL fraction was not changed in LF, but was significantly decreased in HF by n3 EPA. Therefore, the hypotriglyceridemic effect of n3 PUFA could be from the reduced lipogenesis in liver and resulted in the depressed secretion of TG as VLDL in LF and HF with significant lower production of apoB in HF diet.

KEY WORDS : hypolipidemic effect · n3 fatty acids · α-linolenic acid · eicosapentaenoic acid · perilla oil · fish oil.

Introduction

Epidemiological studies revealed unusually lower incidence of CHD among Greenland Eskimos who traditionally consumed abundant amount of seal, whale and fish, rich in n3 eicosapentaenoic acid(EPA) and docosahexaenoic acid (DHA) and low in n6 linoleic acid(LA) and saturated fatty acid(SFA) than in western population[1)2)]. Although the large amount of polyunsa-

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turated fatty acids(PUFA) in diet has a pronounced hypolipidemic effect, there seem significantly different metabolic effects between fish oil and vegetable oil. Both vegetable oil and fish oil reduced plasma total Chol and LDL-Chol levels in a similar manner, but only fish oils appear to be particularly effective in lowering triglyceride (TG) and very low density lipoprotein(VLDL) levels, being lowered by 50% in normolipidemic individuals and up to 85% in hypertriglyceridemic patients[3-6].

The hypolipidemic effect by dietary PUFA is also appeared to be influenced by the total dietary fat level[7]. In case of high CHO diets, transient hypertriglyceridemia have been observed and this rise in plasma TG was reported to be resulted from the stimulation of VLDL synthesis[8][9]. Therefore, a high CHO diet can be regarded as one of risk factors for CHD and atherosclerosis, if not as much as a high fat diet. It has been shown that the elevated TG and VLDL induced by a high CHO diet were prevented by fish oils but not by vegetable oils[4]. Thus, it seems that the occurrence of CHO-induced hypertriglyceridemia very common in Korea can be reduced if dietary n3 PUFA are included in Korean high CHO diets.

The one of widely used vegetable oil in Korea, perilla oil, has been suggested to have beneficial effects similar to fish oils on serum lipids, since n3 LL, the major fatty acid in perilla oil, is metabolically converted to EPA and DHA by desaturation and chain elongation[10-12]. Therefore, the present study attempts to clarify the hypolipidemic effect of fish oil and perilla oil compared to beef tallow or corn oil in rats fed high CHO or high fat diets.

Materials and Methods

1. Animals and Diets

Male Sprague Dawley rats weighing average 350g (17 weeks old) were fed experimental diets, for 6 weeks, of different dietary fat levels, low fat (LF, 10% Cal) and high fat (HF, 40% Cal), and 5 different dietary fats. The composition of experimental diet is shown in Table 1. The dietary fats were beef tallow(BT), corn oil(CO-I & CO-II), perilla oil(PO) and fish oil concentrate(FO) as a source of SFA, n6 LA, n3 EPA+DHA, respectively. Coconut oil was added to CO-I, CO-II, PO and FO diets to give the total amount of SFA and monoenoic acid at almost constant levels in all dietary groups (Table 2). Corn oil was also added to FO diet to supply enough essential fatty acids. Because fish oil concentrate was commercially fortified with dl-α-tocopherol was added to other dietary groups.

2. Biochemical Analysis

Fasting blood was collected from inferior vena cava under anesthesia with ethylether, and was treated with sodium citrate (3.8%) to prepare plasma. HDL fraction was immediately separated by polyanionic precipitation method of Burnstein et al[13], and then total Chol in plasma and HDL fraction were determined by cholesterol oxidase method using commercialized enzyme kit T-Choles 5 (Dong A Pharmacy). VLDL fraction was immediately separated by ultracentrifugation method of Hatch and Lees[14] and dialyzed against 0.15 M NaCl containing 1mM EDTA at 4℃ for 48 hrs, and protein contents of VLDL fraction were determined by the method of Lowry et al[15]. Neutral lipids of dialized VLDL fraction were separated on silica gel plate by thin layer chromatography (TLC) which was developed in petroleum ether : diethyl ether : acetic acid (90 : 10 : 1, v/v/v) solvent system. Free Chol(FC) and Chol ester(CE) were analyzed by the method of McDougal and Farmer[16], and TG by the method of Fletcher[17]. Phosphorus of phospholipid was assayed by Fiske and SubbaRow method[18] and multip-

Table 1. Composition of experimental diets

Constituents(g)			Low Fat	High Fat
Corn starch			67.4	46.8
Casein			19.3	23.4
DL-Methionine			0.3	0.3
Fat or Oil 1)			4.3	20.8
BT	group	bt	4.3	bt 20.8
CO-I	group	co	2.2	co 10.2
		cc	2.1	cc 10.6
CO-II	group	co	4.3	co 20.8
PO	group	po	2.0	po 9.7
		co	0.2	co 0.5
		cc	2.1	cc 10.6
FO	group	fo	2.0	fo 9.7
		co	0.3	co 0.8
		cc	2.0	cc 10.3
Salt mixture2)			3.2	3.2
Zinc mixture3)			0.8	0.8
Vitamin mixture4)			1.0	1.0
α-Cellulose			3.7	3.7

1) 3mg vitamin A and 1.5mg vitamin D were dissolved in 150g oil.
2) Hubble Mendel Wakeman Mixture (per 100g) Calcium carbonate 54.3 ; Magnesium carbonate 2.50 ; Magnesium sulfate. $7H_2O$ 1.60 ; Sodium chloride 6.90 ; Potassium chloride 11.20 ; Potassium phosphate monobasic 21.20 ; Ferric phosphate 2.05 ; Potassium iodide 0.008 ; Manganese sulfate.H_2O 0.035 ; Sodium fluoride 0.1 ; Aluminium potassium sulfate 0.017 ; Copper sulfate. $5H_2O$ 0.09
3) Zine mixture : 1.67g Zn-acetate/kg corn starch
4) Vitamin mixture (per 100g)
Thiamine-HCl 0.04 ; Riboflavin 0.08 ; Pyridoxine-HCl 0.05 ; Ca-pantothenate 0.40 ; Inositol 2.00 ; Menadione 0.04 ; Niacin 0.40 ; Choline dihydrogen citrate 42.38 ; Biotin premix(1%) 0.30 ; Vitamin B_{12} premix(0.2%) 1.00 ; Corn starch 53.27 ; Folic acid 0.04
bt : beef tallow co : corn oil po : perilla oil
fo : fish oil cc : coconut oil

lied by the factor 25. VLDL fraction was delipidated with the mixture of ethanol and diethyl ether (3 : 1, v/v), by the method of Bersot et al[19], and apoprotein composition in VLDL fraction was measured by sodium dodesyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) of Hames [20]. The delipidated VLDL fraction was applied at 11% slab gel and run on a LKB vertical apparatus at 30 mA at 5-6 hrs and protein bands were stained with 0.1% coommassie blue. Apoprotein concentrations were estimated by scanning the stained gels at 650 nm with LKB densitometer.

Liver cytosol fraction was separated by the method of Geller and Winge[21], and glucose-6-phosphate dehydrogenase(G6PDH), 6-phosphogluconate dehydrogenase(6PGDH) activities were measured by the method of Glock and McLean [22], and malic enzyme(ME) activity was determined by the method of O'choa[23]. Enzyme activities are expressed as specific activities of enzyme unit per milligram protein, and one unit is the amount of enzyme which produced 1 μmole NADPH per min. All data were subjected to analysis of variance and Scheffe's test at $p<0.05$.

Results and Discussion

1. Plasma Cholesterol

Plasma cholesterol was higher in corn oil fed rats than in fish oil or perilla oil fed rats regardless of dietary fat level (Table 3). At LF diet, plasma Chol levels of PO and FO were significantly lowered compared to that of corn oil groups and n3 LL was as much powerful as n3 EPA+DHA in hypocholesterolemic effect. At HF diet, however, n3 EPA+DHA was more effective than n3 LL. Therefore, it could be suggested that plasma cholesterol-lowering effect was in the order of n3 EPA+DHA>n3 LL>n6 LA at both fat levels in this study.

There were several reports[24-26] in which plasma Chol was significantly depressed by the supplementation of sardine and mackerel oil. They suggested that n3 EPA in fish oil interfered with the

Table 2. Fatty acid composition of experimental diets(g/100g diet)

Dietary Groups	SFA[1)]	MFA	PUFA	LA	LL	EPA+DHA[2)]
LF groups						
BT	2.14	1.80	0.17	0.13	0.03	–
CO-I	1.88	0.84	1.15	1.12	0.03	–
CO-II	0.70	1.41	2.18	2.12	0.06	–
PO	1.72	0.54	1.62	0.44	1.18	–
FO	2.01	0.79	1.01	0.19	–	0.74
HF groups						
BT	10.36	8.69	0.83	0.65	0.13	–
CO-I	9.32	3.97	5.35	5.22	0.14	–
CO-II	3.37	6.83	10.52	10.25	0.28	–
PO	8.57	2.50	7.60	1.89	5.71	–
FO	10.06	3.61	4.59	0.58	0.01	3.59

BT : Beef Tallow(Control Group) CO-I & II : Corn Oil Group
PO : Perilla Oil Group FO : Fish Oil Group
SFA : Saturated Fatty Acid MFA : Monounsaturated Fatty Acid
PUFA : Polyunsaturated Fatty Acid LA : Linoleic Acid (n6)
LL : α-Linolenic Acid (n3) EPA : Eicosapentaenoic Acid (n3)
DHA : Docosahexaenoic Acid (n3)
1) Saturated fatty acid ≥ C12 : 0
2) Fish oil concentrate contains EPA 25% and DHA 12%.

Table 3. Effect of dietary fats on plasma cholesterol, HDL-Chol and triglyceride in rats

Parameters (mg/dl)	Dietary Groups				
	BT	CO-I	CO-II	PO	FO
LF group					
T-Chol	58.5± 16.6^{ab} (10)	61.1± 9.0^{ab} (10)	68.3± 12.7^{a} (10)	45.1± 7.8^{b} (10)	45.2± 8.8^{b} (10)
HDL-Chol	36.2± 10.2^{ab} (10)	43.1± 5.8^{ab} (9)	48.5± 11.0^{a} (9)	30.6± 5.1^{b} (9)	29.2± 8.8^{b} (8)
TG	88.9± 15.0^{a} (9)	80.6± 24.0^{a} (10)	92.4± 30.0^{a} (10)	46.1± 16.8^{b} (10)	43.1± 13.9^{b} (10)
HF group					
T-Chol	55.0± 11.4 (10)	57.5± 13.4 (10)	57.2± 7.0 (10)	51.6± 15.5 (10)	42.6± 6.8 (10)
HDL-Chol	32.3± 7.4^{ab} (8)	45.1± 8.4^{a} (9)	44.3± 7.8^{a} (9)	33.8± 4.8^{ab} (9)	27.0± 4.7^{b} (8)
TG	68.8± 13.0^{a} (10)	63.1± 19.3^{ab} (10)	50.0± 8.5^{ab} (10)	40.7± 8.1^{b} (10)	32.6± 10.1^{b} (10)

Values are Mean± S.D.
( ) : Number of rats
T-Chol : Total cholesterol TG : Triglyceride HDL-Chol : High density lipoprotein-Cholesterol
Superscript a or b : Values with different alphabet were significantly different at $p<0.05$ by Scheffe' test

absorption of exogenous Chol. Reduction in plasma Chol level may be accompained by an increased excretion of sterols and bile acids in the feces. Such a phenomenon has been observed in both normal subjects and subjects with hypertriglyceridemia after consumption of vegetable oil[6]. Balasubramaniam et al.[27] have also noted increased fecal steroid excretion after consumption of fish oil. The hypocholesterolemic effect of n3 PUFA in the present study may be due to the increase of fecal steroid excretion and or the decrease of exogenous cholesterol absorption even though they were not determined.

2. HDL-Cholesterol

Plasma HDL-Chol level was increased in CO-I and CO-II groups but was slightly lowered in PO and FO groups than in BT group at both fat levels(Table 3). However, HDL-Chol level was significantly lowered n3 fatty acids (LL and EPA) compared to n6 LA.

Similar findings were observed in the reports of Harris et al[26] and Sanders and Roshanai[28]. In contrast, there are some reports that HDL-Chol level was increased by feeding marine oil in human[29][30]and was decreased by the addition of linseed or perilla oil and which was not affected by vegetable oil[31][32]. Thus, the effects of different kinds of PUFA upon HDL-Chol are not consistent and seems to be related to the absolute amount of PUFA and the duration of dietary treatment.

3. Liver Cholesterol

Liver Chol level was slightly decreased in CO-I and CO-II groups and increased in PO and FO groups compared to BT group at LF diet with no significance(Table 4). Compared to CO-I group, liver Chol level was higher in CO-II, PO, and FO diet which contain the higher degree of fat unsaturation(Table 4). The increase of liver Chol by PUFA was similar in HF diets. It seems that n3 PUFA lowers plasma cholesterol, but has no effect on liver cholesterol. It has been shown than n3 PUFA induced acyl Co-A : cholesterol acyltransferase (ACAT) in liver compared to SFA diet[33]. These observations would be consistent with the accumulation of cholesteryl ester by the liver and the secretion of cholesteryl ester-enriched VLDL with n3 fatty acid feeding. In the present study, the increase of liver Chol by n3 PUFA could be from the result of the increased uptake of Chol from plasma to liver by ACAT.

4. Plasma Triglyceride

It has been well documented that the substitution of n3 PUFA in diet results in a significant reduction in plasma TG levels and this effect has not been clearly observed with n6 LA[34-36]. High carbohydrate-low fat diet increases the concentration of plasma TG in both normal and hypertriglyceridemic subjects. These diets cause protracted elevations of blood glucose and insulin which in turn lead to an increased synthesis and release of TG-rich VLDL by the liver[37]. On the contrary, feeding the high fat diets to growing chicks induced an increase in plasma free fatty acids with a marked reduction in fatty acid synthesis in the liver[38].

In the present study, plasma TG concentration was not significantly changed in CO-I and CO-II groups compared to BT group at LF diet (Table 3). Liver TG level in CO-II group was significantly higher than BT group at LF diet (Table 4), but there was no significant effect on lipogenic enzyme activity by n6 LA compared to BT group (Table 5), and this may imply that the lipogenesis in liver was not affected by dietary n6 LA (Table 6). Therefore, the higher content of liver TG by n6 LA in LF diet was thought to be the result of the stimulated production of insulin which leads to the induction of lipoprotein lipase(LPL)

Table 4. Effect of dietary fats on total cholesterol and triglyceride levels in liver

Parameters	Dietary Groups				
	BT	CO-I	CO-II	PO	FO
LF group					
Chol	3.7± 1.4 (10)	3.2± 1.2 (10)	3.5± 1.2 (10)	4.1± 1.3 (10)	4.6± 1.9 (10)
TG	11.2± 4.6[b] (9)	12.3± 2.7[ab] (9)	17.6± 6.6[a] (8)	9.8± 3.6[b] (7)	9.8± 3.6[b] (7)
HF group					
Chol	3.5± 0.8 (10)	3.4± 1.2 (10)	4.3± 1.6 (10)	4.1± 1.1 (10)	4.1± 1.1 (10)
TG	15.6± 5.6 (9)	13.4± 2.7 (10)	17.2± 9.8 (9)	13.8± 5.0 (8)	15.3± 6.4 (7)

Values are Mean± S.D., and expressed in mg/g wet liver.
( ) : Number of rats
Superscript a or b : Values with different alphabet were significantly different at $P<0.05$ by Scheff e test

Table 5. Effect of dietary fats on lipogenic enzyme activities in liver cytosol of rats

Enzyme Activities	Dietary Groups				
	BT	CO-I	CO-II	PO	FO
LF group					
G6PDH	25.8± 4.7 (9)	22.4± 4.0 (10)	24.4± 8.1 (10)	25.3± 12.6 (7)	15.9± 6.0 (10)
6PGDH	39.0± 15.0 (10)	30.7± 6.0 (10)	37.6± 16.1 (10)	29.7± 7.7 (7)	28.6± 11.0 (10)
ME	2.0± 1.3 (10)	1.7± 0.8 (10)	1.2± 0.5 (9)	1.6± 1.2 (10)	0.9± 0.4 (10)
HF group					
G6PDH	18.9± 4.9 (10)	20.3± 6.4 (10)	22.8± 10.0 (8)	18.7± 6.2 (7)	11.0± 4.3 (9)
6PGDH	27.6± 9.0 (10)	29.6± 10.3 (10)	37.1± 17.5 (8)	31.5± 10.4 (7)	19.8± 5.4 (9)
ME	1.4± 1.3 (10)	1.3± 0.5 (8)	1.2± 0.5 (8)	1.8± 0.9 (10)	0.6± 0.3 (9)

Values are Mean± S.D. and expressed as specific activity in μmole NADPH/min/mg protein
( ) : Number of rats
G6PDH : Glucose 6-Phosphate Dehydrogenase 6PGDH : 6-Phosphogluconate Dehydrogenase
ME : Malic Enzyme

and so plasma TG was effectively taken up to the liver. The relative proportions of TG in VLDL fraction was not significantly different in CO-I and CO-II from BT group (Table 6). Therefore, it seems that corn oil did not suppress the incorporation of TG into VLDL to a degree caused by fish oil or perilla oil in LF diet.

On the other hand, plasma TG level in HF

was lowered compared to that in LF and lipogenic enzyme activities were decreased in CO-I and CO-II groups compared to BT group. The relative proprotion of TG in VLDL fraction was not significantly changed but liver TG level was increased by n6 LA in HF. Haug and Hostmark[39] reported that LPL activity was increased to approximately 50% after fed dietary fat at 42% Cal. In the present study, the increase of liver TG in HF seems to be that chylomicron level was elevated by high fat diet and lead to the increase of LPL activity as their report[39].

Plasma TG concentrations in PO and FO groups were significantly lowered at both LF and HF. Liver TG level and the relative proportion of TG in VLDL fraction were also decreased by PO and FO groups of n3 fatty acids at LF and HF and those effects were more significant by n3 EPA. Total activities of lipogenic enzymes were lower in FO group. Plasma TG level and VLDL-TG were significantly decreased and lipogenic enzyme activities were also decreased in FO group at LF and HF. To compare the effects of n6 LA to those of n3 LL and EPA, n6 LA was major PUFA in CO-I and CO-II groups, are pooled together and n3 LL and EPA were the major n3 series PUFA in PO and FO groups, are pooled together. Therefore, plasma TG was decreased by n3 PUFA at both fat levels which may be resulted from the reduced lipogenesis in liver and then lower secretion of TG into plasma (Table 7-8).

At LF, Liver TG concentration was decreased but Apo-B level was not changed by n3 PUFA (Table 9). However, in HF diet, liver TG level was not influenced by the reduction of lipogenic enzyme activity, but Apo-B level was lowered and VLDL synthesis was lowered by n3 PUFA (EPA) which resulted in the reduction of liver TG secretion into plasma. Iritani and Fujikawa[40] observed that the lipogenic enzyme activities in liver and

Table 6. Effect of dietary fats on chemical composition of VLDL fraction in low and high fat diets

VLDL Composition (%)	Dietary Groups				
	BT	CO-I	CO-II	PO	FO
LF group					
FC	9.4± 1.5^{ab}	8.1± 0.8^{a}	7.8± 1.8^{a}	9.4± 0.5^{ab}	11.2± 3.4^{b}
CE	11.6± 1.0	11.3± 1.7	13.2± 2.4	11.2± 2.2	14.0± 3.9
TG	63.4± 3.5^{a}	68.0± 2.2^{a}	66.7± 5.5^{a}	62.4± 2.6^{ab}	54.1± 6.8^{b}
PL	8.3± 2.3^{a}	7.4± 0.7^{a}	7.5± 3.9^{a}	11.9± 1.8^{b}	12.9± 1.1^{b}
PR	5.6± 1.2^{ab}	5.2± 1.1^{ab}	4.9± 0.8^{a}	5.1± 0.7^{a}	7.8± 2.2^{b}
HF group					
FC	7.8± 0.8	7.9± 0.7	7.1± 1.6	9.2± 1.9	10.2± 2.1
CE	13.0± 3.6	11.7± 2.6	9.2± 1.2	12.2± 0.7	12.5± 1.1
TG	68.1± 3.7^{a}	67.8± 3.1^{a}	68.8± 5.1^{a}	62.8± 4.1^{ab}	55.8± 5.2^{b}
PL	6.0± 1.9^{a}	8.5± 2.1^{ab}	7.3± 1.6^{ab}	11.1± 2.5^{b}	12.2± 3.9^{b}
PR	5.2± 1.8^{a}	4.2± 1.2^{a}	6.7± 3.2^{ab}	4.8± 1.3^{a}	9.3± 2.2^{b}

Values are Mean± S.D. of 5 pooeed, and expressed in the relative % of total contents of VLDL fraction.

VLDL : Very Low Density Lipoprotein LDL : Low Density Lipoprotein
HDL : High Density Lipoprotein FC : Free Cholesterol CE : Cholesteryl Ester
TG : Triglyceride PL : Phospholipid PR : Protein
Superscript a or b : Values with different alphabet were significantly different at $p<0.05$.

Table 7. Comparison of the effect of n6 and n3 PUFA on chemical composition of VLDL fractions in low and high fat groups

VLDL Composition(%)	SFA (BT)	n6 (CO-I + CO-II)	n3 (PO+FO)
LF group			
FC	9.4± 1.5^{ab}	8.0± 1.3^{a}	10.3± 2.5^{b}
CE	11.6± 1.0	12.3± 2.2	12.6± 3.3
TG	63.4± 3.5^{ab}	67.3± 4.0^{a}	58.3± 6.5^{b}
PL	8.3± 2.3^{ab}	7.4± 2.6^{a}	12.4± 1.5^{b}
PR	5.6± 1.2	5.0± 0.9	6.4± 2.1
HG group			
FC	7.8± 0.8^{ab}	7.5± 1.2^{a}	9.7± 2.0^{b}
CE	13.0± 3.6	10.4± 2.3	12.4± 0.9
TG	68.1± 3.7^{a}	68.3± 3.9^{a}	59.3± 5.8^{b}
PL	6.0± 1.9^{a}	7.9± 1.9^{a}	11.7± 3.1^{b}
PR	5.2± 1.8	5.5± 2.6	7.1± 3.0

Values are Mean± S.D. and expressed in the relative % of total contents of VLDL fraction.
Superscript a or b : Values with different alphabet were significantly different at $p<0.05$.

Table 8. Comparison of the effect of n6 and n3 PUFA on lipogenic enzyme activities in liver cytosol of rets fed low and high fat diet

Parameters	SFA (BT)	n6 (CO-I + CO-II)	n3 (PO+FO)
LF group			
G6PDH	25.8± 4.7^{a} (9)	23.4± 6.3^{a} (20)	17.4± 5.7^{b} (17)
6PGDH	39.0± 15.0 (10)	34.1± 12.3 (20)	29.1± 9.5 (17)
Malic Enzyme	2.0± 1.3 (10)	1.4± 0.7 (19)	1.3± 0.9 (20)
HF group			
G6PDH	18.9± 4.9^{ab} (10)	21.4± 8.1^{a} (18)	14.4± 6.4^{b} (16)
6PGDH	27.6± 9.0 (10)	32.9± 14.0 (18)	24.9± 9.7 (16)
Malic Enzyme	1.4± 1.3 (10)	1.3± 0.5 (16)	1.2± 0.9 (19)

( ) : Number of rats
Values are Mean± S.D. and expressed as specific activity in μmole NADPH/min/㎎ protein.
Superscript a or b : Values with different alphabet were significantly different at $p<0.05$.
G6PDH : Glucose 6-Phosphate Dehydrogenase
6PGDH : 6-Phosphogluconate Dehydrogenase

Table 9. Comparison of apoprotein composition in VLDL fraction in low and high fat diet groups

	SFA(5) (BT)	n6(10) (CO-I+CO-II)	n3(10) (PO+FO)
LF group			
Apo C	14.0± 7.3	14.8± 4.5	18.5± 10.8
Apo A-I	24.0± 4.1	25.0± 6.1	26.1± 9.6
Apo E	23.6± 2.8	25.7± 15.1	28.0± 7.0
Apo A-IV	4.5± 2.0	5.1± 2.9	2.5± 1.1
Apo B	36.6± 9.0	32.0± 16.0	38.0± 9.0
HF group			
Apo C	13.9± 2.1	10.1± 7.3	12.5± 1.9
Apo A-I	16.7± 1.1	23.9± 13.1	21.7± 10.6
Apo E	21.3± 8.9	17.5± 6.2	31.7± 11.4
Apo A-IV	2.3± 0.1	7.8± 2.6	12.8± 3.4
Apo B	45.2± 21.3	44.6± 14.6	21.4± 15.1

Values are Mean± S.D. and expressed as the percentage of total apoproteins.
( ) : Number of pooled samples

TG levels of plasma and liver were markedly reduced. They suggested that n3 PUFA was easily incorporated into the tissue phospholipids and some intake of marine oil will bring about a favorable lipid profile for plasma TG level. Nossen et al.[41] and others[42] reported that TG synthesis and lipogenic enzyme activities in liver were both inhibited when rat hepatocytes were incubated with EPA in tissue cultures. Saynor et al.[36] and Iritani et al.[43] also observed that fish oil inhibited liver acetyl CoA carboxylase activity and reduced hepatic lipogenesis which resulted in lower plasma TG levels.

Conclusion

When male Sprague Dawley rats were fed the experimental diets for 6 weeks which composed of different kinds of dietary fats at 10% and 40% Cal with sufficient tocopherol supplement, the following results were obtained.

Plasma total Chol and HDL-Chol levels were significantly lower in fish oil group than in corn oil and perilla oil groups. Plasma cholesterol-lowering effect of PUFA was in the order of n3 EPA+DHA>n3 LL>n6 LA.

Plasma TG was significantly lower in both fish oil and perilla oil groups than in corn oil group. Plasma TG-lowering effect was greater by n3 EPA+DHA and LL than by n6 LA.

In conclusion, because of their higher hypocholesterolemic and hypotriglyceridemic effects, fish oil and perilla oil rich in n3 PUFA may have important nutritional applications in the prevention and treatment of atherosclerotic diseases.

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식이지방 수준에 따라 n6 와 n3 계 불포화지방산이 혈장 지질수준에 미치는 영향에 관한 비교연구

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식이지방의 수준에 따라 n6 와 n3 불포화지방산이 혈장 지질조성에 미치는 영향과 또 그 기전이 다른지를 연구하고자 Sprague Dawley 종 수컷쥐에게 저지방(LF, 10% Cal)식이와 고지방식이(HF, 40% Cal)를 각각 6주동안 투여하였으며, 사용된 기름은 포화지방산 급원으로는 쇠기름, n6 linoleic acid(LA) 급원으로 corn oil, n3 α-linolenic acid(LL) 급원으로 perilla oil, n3 eicosapentaenoic acid(EPA)와 docosahexaenoic acid(DHA) 급원으로 fish oil이었다. Ultracentrifugation 방법으로 VLDL fraction을 분리하여 thin layer chromatography에 의해서 화학적조성을 구하였다.

Plasma cholestere 수준은 LF 와 HF 모두 n6 LA에 의해서는 오히려 증가되었고 n3 LL 과 n3 EPA에 의해서는 감소되었으며, HF 에서 n3 EPA가 가장 cholesterol 저하효과가 있었다. HDL-Chol 농도는 n6 LA에 의해서 증가되었으나, HF 경우 n3 EPA에 의해서 유의성있게 감소되었다. Plasma TG 농도는 n3 EPA에 의해서 가장 감소되었고 간의 lipogenic enzyme 활성을 억제하였으며 VLDL fraction 의 TG 상대적양(%)이 유의성 있게 낮아졌다. 이때 LF 군에서는 VLDL fraction의 apo-B의 상대적 양(%)이 감소되지 않았으나 HF군에서 n3 EPA에 의해서 유의성 있게 낮았다. 그러므로 n3 EPA의 hypotriglyceridemic effect는 간에서 lipogenesis를 억제하여 plasma VLDL로 TG 분비가 억제되었을 것이며, HF일 경우는 간에서 apo-B 생성도 억제되었다. 관상동맥성심장질환의 예방적 차원에서 평상시에도 쇠기름과 corn oil 보다는 n3 PUFA가 풍부한 들기름이나 생선을 더욱 이용하는 것이 바람직하다.