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Effects of Dietary Prosomillet on Cholesterol and Fatty Acid Metabolism in Rats Fed High Cholesterol Diets

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ABSTRACT

To study the effect of prosomillet (*Panicum milaceum*) on lipid metabolism, male Sprague-Dawley rats weighing 190±8 g were fed six experimental diets for four weeks. The six diets based on AIN-76 composition consisted of one cholesterol-free (normal) and five 1% (w/w) cholesterol diets, i.e. control, two diets containing additional 0.3 and 0 6%(w/w) methanol extracts of prosomillet and another two diets containing 15 and 30%(w/w) prosomillet powder. There was no difference in weight gains between the groups but relative liver weights increased under the cholesterol diets Plasma levels of total cholesterol and triglyceride (TG) decreased by 23 – 27% and by 37 – 52%, respectively, in the four prosomillet diet groups compared to those of the normal and control groups Whereas in the liver, only TG levels decreased in the prosomillet diet groups. Fecal excretions of bile acid and cholesterol increased 5 - 10 times with cholesterol feeding and further increased with prosomillet powder in the diets. They did not increase significantly with methanol extracts of prosomillet. There was a significant increase in the activity of hepatic microsomal cholesterol 7α-hydroxylase when feeding 1% cholesterol, but prosomillet in the diet, either as in the form of powder or methanol extract, appeared to have only slight additional effects, namely increases in enzyme activity. The activity of liver cytosolic glucose-6-phophate dehydrogenase (G6PDH) tended to be reduced with high cholesterol diets and dropped markedly by 15% using additional prosomillet powder. Those of the liver cytosolic malic enzyme had a similar tendency to those of G6PDH. The results indicate that certain active components in prosmillet other than fiber have the potential to exert hypolipidemic effects via regulating cholesterol excretions and lipogenesis.

KEY WORDS: prosomillet, cholesterol, triglyceride, cholesterol 7α-hydroxylase, G6PDH

INTRODUCTION

Among plant foods, grains are particularly important to public health since they supply a considerable amount of energy and a few other nutrients to humans. Increased consumption of whole grain products has been recommended to prevent coronary heart disease (CHD) but it is only in recent years that an inverse relation was shown specifically between intakes of whole grain and CHD risk[1,2]. The effects of the cereals are attributed mainly to dietary fiber, which plays a role in reducing serum cholesterol. With regard to types of dietary fiber, those with high content of water-soluble -glucans are believed to decrease absorption of dietary lipids and increase fecal excretion of bile acids and neutral sterols through their viscosity in aqueous solutions. But there are other data suggesting that the hypocholesterolemic effect of cereal is not solely due to viscosity resulting from soluble fibers. Zhang *et al.*[3] have shown that feeding brewer's spent grain that was low in water-soluble -glucan decreased plasma cholesterol and increased fecal steroid loss in human subjects with ileostomies. Reports from Topping *et al.*[4-6] have supported the results of Zhang *et al.*[3] and also conceded the findings of Qureshi *et al.*[7] that lipid components from barley were involved in the hypocholesterolemic effects of cereals via inhibitory on hepatic 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase (EC 1.1.1.34). In their subsequent works, Qureshi *et al.*[8,9] have identified α-tocotrienol as one of the active constituents and later showed that α-tocotrienol is as potent as α-isomer in humans, although Pearce *et al.*[10] have argued that α-isomer has much greater inhibitory activity toward cholesterol biosynthesis in HepG2 cell *in vitro*. It is well known that cereal grains contain various types of polyphenolic compounds other than tocotrienols.[11] Among them tannic acid and morin[12] have been reported to reduce serum levels of total cholesterol and triglyceride.

Cereals consumed in Korea are of various kinds and some of them have been reported to have hypocholesterolemic effects.[13,14] But active materials other than dietary fibers for the effects have been rarely investigated. In our

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recent work, we showed both *in vitro*[15] and *in vivo*[16] inhibitory effects of methanol extract of prosomillet on the activity of rat liver microsomal HMG-CoA reductase. In the present study, using rats fed a high cholesterol diet, we report hypolipidemic effects of prosomillet in the form of methanol extract and powder as well as changes in bile acid excretion and activities in hepatic cholesterol 7α-hydroxylase and glucose-6-phosphate dehydrogenase.

MATERIALS AND METHODS

1. Animals and diets

Male Sprague-Dawley rats weighing about 190±8 g were obtained from Korea Research Institute of Bioscience and Biotechnology (Taejon, Korea) and acclimated to the facility for 1 week. The rats were divided into six groups, each group comprising 8−9 rats in stainless steel cages with wire mesh bottoms in an environment of constant temperature (22±1℃) and lighting (light on, 08 : 00−20 : 00 h). They were allowed free access to test diets and water for 4 weeks. Food intake was measured daily and body weight every three days; feces were collected during the last week and kept frozen at −50℃. The experiment was done under guidelines for animal experiments provided by the Catholic University of Taegu-Hyosung.

The six test diets were one cholesterol-free diet (normal) and five kinds of 1.0% (w/w) cholesterol diets, all of which were based on AIN-76 diet[17] as shown in Table 1. Casein, cholesterol and vitamin and mineral mixtures (AIN-76) were purchased from Teklad Test Diets (Madison, WI, USA) and cellulose, DL-methionine, choline bitartarate and Na-taurocholate from Sigma-Aldrich Chemical (St. Louis, MO, USA). Corn starch, sucrose and lard were obtained from a local supermarket. The clean prosomillet harvested in Chung-buk, Korea were ground into 40 mesh powder and added to diet either as such or as methanol extract (MeOH-ext). The MeOH-ext was prepared using 80% methanol and ten times volume of prosomillet powder for 16 hours with continuous shaking. The resultant extract was filtered, concentrated under vacuum at 60℃ and finally freeze-dried to remove solvent before being added to the diets. The MeOH-ext was added to the rosomillet diets at levels of 0.3 or 0.6% (w/w) and prosomillet powder at levels of 15 or 30% (w/w), respectively. Contents of starch, cellulose and soybean oil in the prosomillet powder diets were adjusted as shown in Table 1. The contents of starch, protein, fat and fiber was 76.1%, 11.3%, 2.2% and 1.8%, respectively, in the prosomillet[18] in order for all diets to have 20% protein, 60% carbohydrate and 10% fat by weight. Since 2.8 g of the methanol extract was obtained from 100 g dry prosomillet powder, 15 and 30% (w/w) powder in the diets were assumed to have methanol extractable components at the level of 0.42 and 0.84% (w/w), which were slightly higher than two levels of MeOH-ext in the respective diets.

Table 1. Composition of experimental diets (g/~1000 g Diet)

	Normal	Control	Prosomillet 0.3% MeOH-ext	0.6% MeOH-ext	15% Powder	30% Powder
Casein[a]	200	200	200	200	183	166
DL-Methionine[b]	3	3	3	3	3	3
Starch[c]	150	150	150	150	36	0
Sucrose[c]	450	450	450	450	450	372
Cellulose[b]	50	50	50	50	47	45
Lard[c]	100	100	100	100	97	93
Mineral mix[a]	35	35	35	35	35	35
Vitamin mix[a]	10	10	10	10	10	10
Choline[b]	2	2	2	2	2	2
Cholesterol[a]		10	10	10	10	10
Na taurocholate[b]		3	3	3	3	3
Prosomillet[d]						
MeOH-ext			3	6		
Powder					150	300
kcal/1000g	4100	4047	4035	4023	3996	3766

a: Teklad Test Diets, Madison, WI, USA
b. Sigma-Aldrich Chemical, St. Louis, MO, USA
c. Obtained from local mart
d. Harvested in Chung-buk, Korea

2. Biochemical analysis

After 4 weeks of the experimental diets the rats were anesthetized with ether, blood was drawn from abdominal *vena cava* into heparinized tube and plasma was prepared by centrifugation and stored at −50℃ before lipid determination. The liver was excised after removing blood by passing saline through portal vein, blotted dry and one part of it quickly frozen in liquid nitrogen for subsequent measurements of lipids. Another part of the liver was homogenized and subjected to differential centrifugation to prepare microsomal factions which were stored under −70℃ before measuring enzyme activities.

Plasma total cholesterol, HDL-cholesterol and triglyceride were measured by using enzymatic kit (Shinyang Chemical Co. Seoul, Korea). Hepatic lipids were extracted by the method of Folch *et al.*[19] Cholesterol[20] was measured colorimetrically, and triglyceride was measured by using the enzymatic kit (Shinyang Chemical Co.) with the aid of detergent, triton X-100.[21] Bile acid from dry feces was extracted by the method of Crowell and Macdonald[22] and determined by using enzymatic kit (Sigma).

Activity of cholesterol 7α-hydroxylase was measured using incorporation of liposome solublized cholesterol isotope ([4-14C] cholesterol, Amersham, Buckinghamshire, England) into microsomal preparations[23] but azolectin for liposome was prepared from phosphatidylcholine.[16] Activities of glucose-6-phosphate dehydrogenase and malic enzyme in cytosol were measured by recording NADP reduction.[21)25]

3. Statistical analysis

Data were analyzed by analysis of variances and group differences were considered statistically significant at $p < 0.05$ by Tukey's test.

RESULTS

1. Growth and liver weight

As shown in Table 2, there was no significant difference in feed efficiencies among the six experimental groups, although feed efficiency was somewhat lower in rats fed 30% prosomillet powder. Relative liver weights were higher in the five high-cholesterol fed groups than the normal group fed a cholesterol-free diet. However, increases in body and liver weights were smaller in the group fed a diet containing 30% prosomillet powder compared to the control and the other three prosomillet groups.

2. Effects of dietary prosomillet on plasma and liver lipids and fecal excretion of bile acid

Table 3 shows plasma lipid levels of experimental groups. Levels of total cholesterol were increased 2.8 times with the 1% cholesterol diet (control) compared to the normal cholesterol-free diet. But the cholestrol levels were reduced significantly (23 – 27%) with diets containing 0.3% and 0.6% methanol extract of prosmillet and 30% prosmillet powder, while they tended to decrease in the group fed 15% prosomillet powder. Plasma levels of HDL-cholesterol and HDL-cholesterol/total cholesterol ratios decreased, on the other hand, in the control and four prosmillet groups but they did not differ among these five groups. Plasma triglyceride levels, which tended to be higher in the control group with the 1% cholesterol diet, was significantly (37 – 52%) lower in the four prosomillet groups than in the control group.

Hepatic cholesterol and triglyceride concentrations were elevated about 1.5 and 2.5 times respectively using the 1% cholesterol diet, as shown in Table 4. In contrast to those observed in plasma, cholesterol levels in the liver were not reduced in all prosomillet groups compared with the control group, although they exhibited a tendency to decrease. Liver triglyceride levels were significantly (15 – 21%) reduced only in groups fed 0.3% prosomillet methanol extract and 15% prosomillet powder.

3. Fecal excretions of bile acid and cholesterol

Fecal excretions of bile acid and cholesterol were three to five times higher in the control group fed 1% cho-

Table 2. Effects of dietary prosomillet on growth of rats on high cholesterol diet

	Initial body weight (g)	Body weight gain (g)	Feed efficiency (g/100 g diet)	Relative liver weight (g/100 g bw)
Normal	197 3 ± 3 7[NS]	116.5 ± 4.2[NS]	22 ± 2[NS]	2.67 ± 0.56[b]
Control	193.0 ± 3.5	127.0 ± 2.4	25±1	4.02 ± 1.01[a]
MeOH-ext				
0.3%	190.5 ± 2.8	130 1 ± 1.9	23±2	4.17 ± 1.98[a]
0.6%	193.5 ± 3.1	120.3 ± 4.8	25 ± 2	4.20 ± 0 60[a]
Powder				
15%	187.9 ± 2.7	120.9 ± 5.0	24 ± 2	4.15 ± 1 00[a]
30%	188 9 ± 3.2	111.8 ± 2.5	19 ± 2	3.80 ± 0 44[ab]

Mean ± SE of 8 rats per group
Values in the same column not sharing common superscript letters are significantly different at $p < 0.05$ by Tukey's test

Table 3. Effects of dietary prosomillet on concentrations of plasma cholesterol and triglyceride of rats on high cholesterol diet

	Total cholesterol (mg/100 mL)	HDL-cholesterol	HDLc/TChol	Triglyceride (mg/100 mL)
Normal	86.4 ± 6.6[c]	45.1 ± 2.0[a]	0.522 ± 0.06[a]	34.1 ± 7.5[ab]
Control	238.9 ± 20.1[a]	19.4 ± 2.4[b]	0.081 ± 0.06[b]	42.6 ± 6.8[a]
MeOH-ext				
0.3%	172 7 ± 6 8[b]	16 5 ± 1.5[bc]	0.096 ± 0.06[b]	20.4 ± 2 4[b]
0.6%	184.5 ± 7.2[b]	13.6 ± 1.1[c]	0.074 ± 0.06[b]	26 9 ± 6.0[b]
Powder				
15%	199.8 ± 11.2[ab]	18.3 ± 1.5[bc]	0.092 ± 0.06[b]	22.1 ± 3.4[b]
30%	174.6 ± 13.5[b]	15 7 ± 1 9[bc]	0.090 ± 0.06[b]	23.5 ± 2.8[b]

Mean ± SE of 8 rats per group
Values in the same column not sharing common superscript letters are significantly different at $p < 0.05$ by Tukey's test

Table 4. Effects of dietary prosomillet on concentrations of liver cholesterol and triglyceride of rats on high cholesterol diet

	Cholesterol (mg/g liver)	Triglyceride
Normal	1.90 ± 0.31[b]	14.82 ± 1.24[c]
Control	27.88 ± 4.39[a]	37.91 ± 4.8[a]
MeOH-ext		
0.3%	22.88 ± 4.02[a]	32.06 ± 2.97[b]
0.6%	24.42 ± 2.25[a]	34.31 ± 4.10[ab]
Powder		
15%	25 06 ± 3.68[a]	29.97 ± 3.19[b]
30%	25.28 ± 3 20[c]	35 62 ± 3.15[ab]

Mean ± SE of 8 rats per group
Values in the same column not sharing common superscript letters are significantly different at $p < 0.05$ by Tukey's test

Table 5. Effects of dietary prosomillet on fecal excretions of bile acids and cholesterol of rats on high cholesterol diets

	Fecal bile acid	Cholesterol	Bile acid + Cholesterol
mg/day			
Normal	11.18 ± 1.32^{c}	11.50 ± 1.20^{c}	22.68 ± 1.70^{c}
Control	51.22 ± 3.26^{ab}	92.70 ± 15.33^{b}	143.9 ± 15.49^{b}
MeOH-ext			
0.3%	56.13 ± 2.88^{ab}	109.68 ± 4.97^{ab}	165.8 ± 13.85^{ab}
0.6%	48.72 ± 2.90^{b}	104.52 ± 8.15^{ab}	151.4 ± 11.47^{ab}
Powder			
15%	59.56 ± 2.10^{a}	118.90 ± 4.28^{a}	178.51 ± 8.50^{a}
30%	61.55 ± 9.30^{a}	114.09 ± 9.20^{ab}	175.62 ± 24.25^{a}

Mean ± SE of 8 rats per group
Values in the same column not sharing common superscript letters are significantly different at $p < 0.05$ by Tukey's test

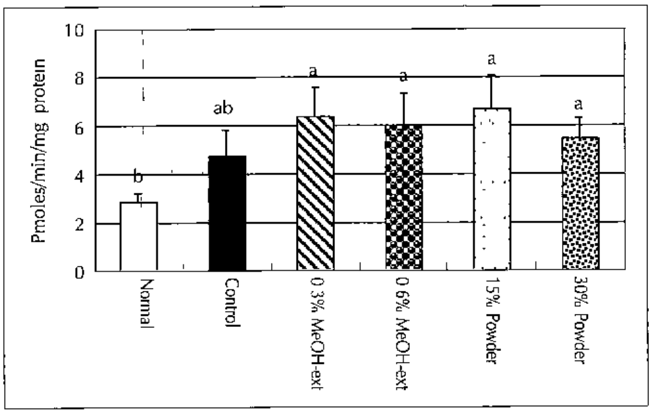

Fig. 1. Changes in activities of hepatic cholesterol 7α-hydroxylase of rats on high cholesterol diets by prosomillet extract and powder. 1pmoles of [14C] cholesterol into [14C] 7α-hydroxycholesterol/min/mg microsomal protein, Mean ± SE of 8 rats per group, Different alphabet letters in cholesterol 7α-hydroxylase activities denotes significant difference among groups.

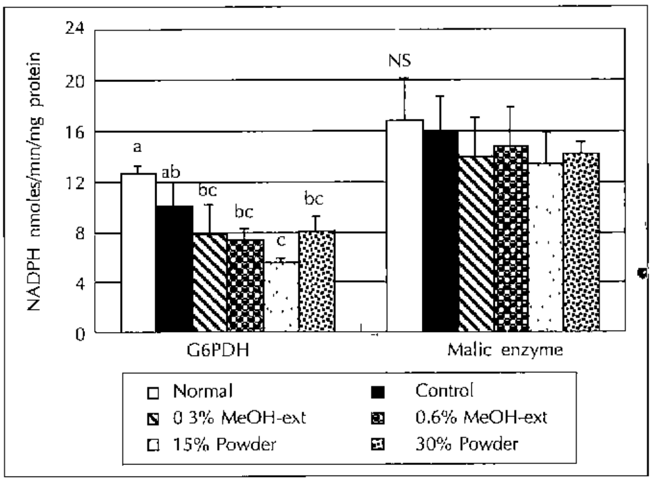

Fig. 2. Changes in activities of hepatic lipogenic enzymes of rats on high cholesterol diets by prosomillet extract and powder.
Mean ± SE of 8 rats per group, Different alphabet letters in the same enzyme activities denotes significant difference among groups, NS, not significant.

lesterol than in the normal group fed a cholesterol-free diet, as seen in Table 5. Feeding 0.3 and 0.6% prosomillet methanol extract did not signigicantly increase excretions of either bile acid or cholesterol but 15 and 30% prosomillet powder did, although bile acid and cholesterol excretions tended to be higher in the two groups fed prosomillet methanol extract than the control group.

4. Hepatic activities of cholesterol 7α-hydroxylase and lipogenic enzymes

As shown in Fig. 1, there was a significant increase in the activity of liver microsomal cholesterol 7α-hydroxylase when using 1% cholesterol in the diets for the control and four prosomillet groups. But neither prosomillet methanol extract nor powder in the diet further elevated the level of enzyme activity, although there were increasing tendencies of the enzyme activities in the four prosomillet groups compared with the control.

The activities of liver cytosolic glucose-6-phosphate dehydrogenase (G6PDH) and malic enzyme are shown in Fig. 2. G6PDH activities were significantly (20–40%) reduced and malic enzyme activities appeared also to be lowered by dietary cholesterol. Methanol extract of prosomillet or powder in the diets seemed to suppress the activities of both enzymes further.

DISCUSSION

In the present study, hypocholesterolemic effect was clearly shown by either methanol extract of prosomillet or by prosomillet powder, whereas the effect was not observed in the previous study using cholesterol-free diets.[16] This means that prosomillet can exert a cholesterol-lowering effect above a certain level of plasma cholesterol. The present experimental conditions were comparable to those of many other studies[5,26,28] in which test materials exerted hypocholesterolemic effects only in diet-induced hypercholesterolemia. The hypotriglyceridemic effect of a prosomillet diet without added cholesterol[16] was more pronounced in the present study using 1% cholesterol in the diet.

Nishizawa and Fudamoto[29] reported that feeding mice protein from prosomillet at a level of 25% increased HDL-cholesterol. In the present study, the 30% prosomillet powder diet contained only 3% protein from prosomillet and methanol extract diets had no prosomillet protein. Therefore, the fact that HDL-cholesterol levels relative to total cholesterol (HDL/TChol) were higher in prosomillet diet groups than in the control group may have to be explained by factors other than protein.

Extracts from green tea,[30] garlic,[31] pepper,[32] persimmon leaf,[33] some parts of plants used in oriental medicine,[28] and a few types of cereals[6)8)13)14)] have been reported to show hypolipidemic action in animals. However, most of the extracts were prepared using hot water or more hydrophillic solvents such as ethanol and ethyl acetate.

In the present study, prosomillet extract was extracted with 80% methanol, but hexane extractable components comprised 55.6% of the total when a second extraction was carried out using several kinds of solvents serially.[34] Moreover, it was the hexane extractable fraction that inhibited rat liver microsomal hydroxymethyl glutaryl CoA reductase.[16] Therefore, the effective components for hypolipidemic action by prosomillet in the present study are more likely to be lipophillic, although hydrophillic components cannot be excluded. Qureshi et al reported the hypocholesterolmic effects of various lipid soluble fractions from barley[7] and later concluded that one of major active materials was α-tocotrienol.[8)9)] Recently, Gerhardt and Gallo[35] reported that full-fat rice bran containing minimal soluble fiber reduced LDL-cholesterol by 13.7% when added to the prudent diet of hyperlipidemic adults but they have not identified the active components.

Among lipophillic plant components, β-carotene and lycopene have been shown to reduce LDL-cholesterol level in humans and been related to suppression of cholesterol-synthesis and augmentation of LDL receptor activity in macrophage.[36] Capsaicin of red pepper[37] as well as tannic acid and morin[12] were earlier recognized to have a hypotriglyceridemic effect. It is not elucidated which components in methanol extract of prosomillet exerted the lipid lowering effect.

Intake of dietary fiber from grains have been reported to increase fecal bile acid exceretion.[4] In the present study, fecal excretions of both bile acid and cholesterol were highest in the two prosomillet powder groups, although amounts of total dietary fiber were adjusted to be same in all six experimental diets. Different types of dietary fiber from prosomillet may have influenced the increase in fecal bile acid excretion, even though minute in quantity (6–10% of total dietary fiber. But prosomillet methanol extract devoid of the special type of fiber also seemed to increase the fecal excretion of bile acid and cholesterol. This indicates that certain constituents present in the extract were responsible for the effect, the mechanism of which probably differs from that of dietary fiber. The mechanism appears to be related to the activity of hepatic cholesterol 7α-hydroxylase. The enzyme activity was not significantly enhanced by any of the prosomillet diets, but the activity positively correlated with the sum of fecal bile acid and cholesterol excretions, although correlation was weak ($r = 0.32$, $p = 0.056$). As for barley, however, both lipid and water soluble fractions were shown to decrease the activity of cholesterol 7α-hydroxylase.[7)8)] The hypocholesterolmic effect by prosomillet is therefore due to enhanced activity of cholesterol 7α-hydroxylase as well as decreased *de novo* synthesis of cholesterol,[16] although the latter may have been considerably suppressed by dietary cholesterol in the present study. Low activities of G6PDH and malic enzyme may play a role in reducing serum and liver levels of triglyceride in groups fed prosomillet, either as methanol extract or as powder, as observed in previous study using a cholesterol-free diet.[16] The present results can be compared with those of Qureshi *et al.*,[7] which showed the different effects on the activity of the fatty acid synthetase of two active compounds isolated from petroleum extracts of barley powder.

It is concluded that prosomillet contains potential hypolipidemic component(s), apart from dietary fiber and probably different from those found in barley.[7)8)] Hexane extractable constituents of prosomillet, comprising more than half of total methanol extract of prosomillet, are likely to have active materials. They were composed of six different components separated by thin layer chromatography (unpublished observation).

Identification of active component(s) derived from them needs to be done and other polar components that were 28% of total methanol extract also have to be examined to shed light on the hypolipidemic effect of prosomillet in a future study.

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Literature cited

1) Jacobs DR Jr, Meyer KA, Kushi LH, Folsom AR. Whole-grain intake may reduce the risk of ischemic heart disease death in postmenopausal women: the Iowa Women's Health Study. *Am J Clin Nutr* 68: 248-257, 1998

2) Liu S, Stampfer MJ, Hu FB, Giovannucci E, Rimm E, Manson JE, Hennekens CH, Willett WC. Whole-grain consumption and risk of coronary heart disease: results from the Nurses' Health Study. *Am J Clin*

Nutr 70 412-419, 1999

3) Zhang J-X, Lundin E, Andersson H, Bosaeus I, Dahlgren S, Hallmans G, Sterling R, Aman P. Brewer's spent grain, serum lipids and fecal sterol excretion in human subjects with ileostomies. *J Nutr* 121. 778-784, 1991

4) Illman, RJ, Storer GB, Topping DL White wheat flour lowers plasma cholesterol and increases cecal steroids relative to whole wheat flour, wheat bran and wheat pollard in rats. *J Nutr* 123. 1094-1100, 1993

5) Jackson KA, Suter DAI, Topping DL. Oat bran, barley and malted barley lower plasma cholesterol relative to wheat bran but differ in their effects on liver cholesterol in rats fed diets with and without cholesterol. *J Nutr* 124: 1678-1684, 1994

6) Illman RJ, Topping DL, Dowling K, Trimble RP, Russell GR, Storer GB. Effects of solvent extraction on the hypocholesterolemic action of oat bran in the rat. *Br J Nutr* 65 435-443, 1992

7) Qureshi AA, Burger WC, Peterson DM, Elson CE. Suppression of cholesterogenesis by plant constituents review of Wisconsin contribution to NC-167. *Lipids* 20 817-824, 1985

8) Qureshi AA, Burger WC, Peterson DM, Elson CE. The structure of an inhibitior of cholesterol biosynthesis isolated from barley. *J Biol Chem* 23 10544-10550, 1986

9) Qureshi AA, Bradlow BA, Brace L, Manganello J, Peterson DM, Pearce BC, Wright JJ, Gapor A, Elson CE. Response of hypercholesterolemic subjects to administration of tocotrienols. *Lipids* 30 1171-1177, 1995

10) Pearce BC, Parker RA, Deason ME, Quershi AA, Wright JJ Hypocholesterolemic activity of synthetic and natural tocotrienols. *J Med Chem* 35 3595-3606, 1992

11) Salunkhe DK, Jadhav SJ, Kadam SS, Chavan JK. Chemical, biochemical, and biological significance of polyphenols in cereals and legumes. *Crit Rev Food Sci Nutr* 17. 277-305, 1982

12) Yuganari T, Tan BK, Teh M, Das NP Effects of polyphenol natural products on the lipid profiles of rats fed high fat diets. *Lipids* 27: 181-186, 1992

13) Park YJ, Lee YS, Suzuki H. Effect of coix on plasma cholesterol and lipid metabolism in rats (*in Korean*) *Korean J Nutr* 21. 89-98, 1988

14) Choi YS, Ahn C, Shin HH, Choe M, Oh SY, Lee SY. Effect of instant buckewheat noodle on digestibility and lipid profiles of liver and serum in rats (*in Korean*). *J Korean Soc Food Nutr* 21 478-483, 1992

15) Ha TY, Cho IJ, Lee SH Screening of HMG-CoA reductase inhibitory activity of ethanol and methanol extracts from cereals and legumes. (*in Korean*) *Korean J Food Sci Technol* 30. 224-229, 1998

16) Cho S-H, Jung S-E, Lee H-K, Ha T-Y. Effects of methanol extract of prosomillet on cholesterol and fatty acid metabolism in rat. *J Food Sci Nutr* 3 188-192, 1999

17) The American Institute of Nutrtion. Report of the American Institute of Nutrtion Ad Hoc Committee on Standards for Nutritional Studies. *J Nutr* 107 1340-1348, 1977

18) Food Composition Table (*in Korean*), National Rural Living Science Institute, Korea, 1996

19) Folch J, Lees M, Sloane-Stanley GH. A simple method for the isolation and purification of total lipids from animal tissues *J Biol Chem* 226. 497-509, 1957

20) Pearson S, Stern S, McGavack TH A rapid accurate method for the determination of total cholesterol in serum *Anal Chem* 25: 813-814, 1953

21) Sale FO, Marchesini S, Fishman PH, Berra B A sensitive enzymatic assay for determination of cholesterol in lipid extracts. *Anal Biochem* 142 347-350, 1984

22) Crowell MJ, Macdonald IA. Enzymatic determination of 3α-, 7α-, and 12-hydroxyl groups of fecal bile salts. *Clin Chem* 26 1298-1300, 1980

23) Junker LH, Story JA. An improved assay for cholesterol 7α-hydroxylase activity using phospholipid liposome solubilized substrate. *Lipids* 20: 712-718, 1985

24) Baginski ES, Foa PP, Zak B Glucose-6-phosphatase. In Methods in Enzymatic Analysis (Bergermeyer HU ed) Vol 2, pp.867-880, Academic Press, New York, 1974

25) Ochoa S. Malic enzyme. In. Methods in Enzymology (Lowenstein JM ed) Vol 13, pp 230-237, Academic Press, New York, 1969

26) Turley SD, Spady DK, Dietschy JM. Regulation of fecal bile acid excretion in male golden Syrian hamsters fed a cereal-based diet with and without added cholesterol. *Hepatology* 25 797-803, 1997

27) Vergara-Jimenez M, Conde K, Erickson SK, Fernandez ML Hypolipidemic mechanisms of pectin and psyllium in guinea pigs fed high fat-sucrose diets alterations on hepatic cholesterol metabolism. *J Lipid Res* 39 1455-1465, 1998

28) Lee H-J, Choi M-S. Changes of lipid metabolism by hot water extracts of Typha Augustifolia, Fagophyrum Rotundatum and Rosa Multiflora in rats fed high-cholesterol diet *Nutr Sci* 2 31-39, 1999

29) Nishizawa N, Fudamoto Y The elevation of plasma conccnetration of high-density lipoprotein cholesterol inmice fed protein from prosomillet. *Biosci Biotech Biochem* 59: 333-335, 1995

30) Chan PT, Fong WP, Cheung YL, Huang Y, Ho WK, Chen ZY Chan PT. Jasmine green tea epicatechins are hypolipidemic in hamsters (Mesocricetus auratus fed a high fat diet) *J Nutr* 129. 1094-101, 1999

31) Gebhardt R, Beck H. Differential inhibitory effects of garlic-derived organosulfur compounds on cholesterol biosynthesis in primary rat hepatocyte cultures *Lipids* 31 1269-1276, 1996

32) Kawada T, Hagihara K, Iwai K. Effects of capsaicin on lipid metabolism in rats fed a high fat diet. *J Nutr* 116 1272-1278, 1986

33) Lee M-S, Kang M-H, Jang H-D, Kim J-I, Park OJ. Effects of persimmon leaf extract supplementation on blood lipid concentrations and antioxidant status in rats fed high-sucrose and high-fat diets. *Nutr Sci* 2: 40-45, 1999

34) Jung SE Effect of dietary prosomillet on cholesterol and fatty acid metabolism in rat. Ph D thesis, Catholic University of Taegu-Hyosung, 1999

35) Gerhardt AL, Gallo NB. Full-fat rice bran and oat bran similarly reduce hypercholesterolemia in humans. *J Nutr* 128: 865-869, 1998

36) Fuhrman B, Elis A, Aviram M. Hypocholesterolemic effect of lycopene and β-carotene is related to suppression of cholesterol synthesis and augmentation of LDL receptor activity in macrophage. *Biochem Biophys Res Comm* 233: 658-662, 1997

37) Kawada T, Hagihara K, Iwai K. Effects of capsaicin on lipid metabolism in rats fed a high fat diet. *J Nutr* 116 1272-1278, 1986