Türk Biyokimya Dergisi [Turkish Journal of Biochemistry–Turk J Biochem] 2009; 34 (2) ; 105–111.

Research Article [Araştırma Makalesi]

Yayın tarihi 24 Haziran, 2009 © TurkJBiochem.com

[Published online 24 June, 2009]

A Diet Rich Fiber Improves Lipid Profile in Rats Fed on High Fat Diet

[Yüksek Yağ İçeren Diyet İle Beslenen Sıçanlarda Lif Bakımından Zengin Diyet Lipid Profilini İyileştirmektedir]

[1]Reem Tourkostani,
[1]Iman Al Balouni,
[2]Said S. Moselhy and
[2]Taha A. Kumosani

[1]Department of Nutrition, Faculty of Education and Home Economic, [2]Biochemistry Department, Faculty of Science, King Abdul-Aziz University, Jeddah, KSA.

Yazışma Adresi
[Correspondence Address]

Said S. Moselhy

Biochemistry Department, Faculty of Science King Abdulaziz University P.
O. Box, 80203, Jeddah, 21589, Saudi Arabia
Tel: 00966566991424.
E-mail: moselhy6@hotmail.com

Registered: 15 December 2008; Accepted: 11 May 2009

[Kayıt tarihi: 15 Aralık 2008; Kabul tarihi: 11 Mayıs 2009]

ABSTRACT

Objective: The objective of this study was to investigate the protective effect of apple peels, Psyllium seeds and celery fibers supplement as hypolipidemic agent in rats fed on high-fat diet. The fiber contents were found to be 91.74%, 85.37% and 86.43% respectively.

Material and methods: This study was conducted on 10 equal rat groups which were fed as follows; standard diet (3 months), standard diet (6 months), standard diet supplemented with 20% coconut oil (3 months), high-fat diet (3 months) followed by a standard diet (3 months), high-fat diet supplemented with 5% apple peels or with 5% psyllium seeds or with 5% celery (3 months), high-fat diet (3 months) followed by standard diet supplemented with 5% apple peels or with 5% psyllium seeds or with 5% celery (3 months). Fasting blood samples were collected and subjected to lipid profile assay and atherogenic index.

Results: Rats fed on coconut oil showed significant elevation in the levels of serum total cholesterol, LDL-c, atherogenic factor while HDL-c level was significantly decreased as compared to control rats. Histological examination revealed a large lipid and cholesterol depositions in livers of rats fed high-fat diet. The potential of apple peels>psyllium seeds>celery in lowering plasma total cholesterol and triacylglycerol levels. Accumulation of hepatic lipid droplets was diminished comparing to the high-fat diet group. These beneficial effects may be due to its high fiber content of the apple peels.

Key Words: Hypolipidemic, apple peels, psyllium, celery, rats

ÖZET

Amaç: Yüksek yağ içeren diyetle beslenen sıçanlarda hipolipidemik ajan olarak elma kabuğu, Psyllium tohumu ve kereviz lifinin koruyucu etkilerinin incelenmesi amaçlanmıştır. Bu maddelerin lif içeriği sırasıyla % 91.74, % 85.37 ve % 86.43 olarak bulunmuştur.

Materyal ve metod: Çalışma için 10 eşit sıçan grubu oluşturuldu: Bunlar; standart diyet ile beslenen sıçanlar (3 ay), standart diyet ile beslenen sıçanlar (6 ay), %20 hindistan cevizi yağı içeren standart diyet ile beslenenler (3 ay), yüksek yağ içeren diyet ile (3 ay) daha sonra ise standart diyet ile beslenenler (3 ay), yüksek yağ içeren diyete ek olarak %5 elma kabuğu, %5 psyllium veya %5 kerevizden biri ile beslenler (3 ay), yüksek yağ içeren diyet (3 ay) ve sonrasında 3 ay süre ile de %5 elma kabuğu, %5 psyllium ya da %5 kerevizden biri ile beslenler şeklindedir. Açlık kan örnekleri toplanarak lipid profilleri ve aterojenik indeksleri incelendi.

Bulgular: Hindistan cevizi yağı ile beslenen sıçanların serum total kolesterol, LDL-c, aterojenik faktör düzeyleri belirgin şekilde yüksek; buna karşılık HDL-c düzeyleri ise kontrol grubuna kıyasla düşük bulunmuştur. Histolojik incelemeler yüksek yağ içeren diyet ile beslenen sıçanların karaciğerinde lipid ve kolesterol depolanmasının olduğunu göstermiştir. Plazma total kolesterol ve trigliserid düzeylerini azaltmadaki potansiyelin elma kabuğu>psyllium tohumu>kereviz şeklinde olduğu bulunmuştur. Bu maddeler ile beslenen gruplarda hepatik lipid damlacıklarının birikimi yüksek yağlı diyet ile beslenen gruba nazaran azalmıştır. Elma kabuğunun bu etkilerinin yüksek lif içeriğine bağlı olduğu düşünülmektedir.

Anahtar Kelimeler: Hipolipidemik, elma kabuğu, psyllium, kereviz, sıçanlar

Introduction

Dietary fat is one of the most important environmental factors associated with the cardiovascular diseases incidence [1]. Plant polyphenols exert cardiovascular benefits by altering concentrations of blood lipid components and a high intake can significantly reduce the risk of mortality from cardiovascular diseases [2].Consumption of fruits, vegetables, and tea has been strongly linked to reduced risk of those diseases [3]. A high-fat intake itself can contribute to the development of obesity and hyperlipidemia in human and rodents by altering cholesterol and triacylglycerol levels in plasma and tissues.

Epidemiological data suggested that, foods containing fibers have strong protective effect against major disease risks including cancer, diabetes, cardiovascular diseases and Alzheimer's disease [4]. Psyllium's effects on plasma and lipoprotein cholesterol concentrations, cholesterol metabolism, and diet-induced atherosclerosis were studied in adult male African green monkeys (Cercopithecus aethiops). Animals were fed for 3.5 y one of three experimental diets: low-cholesterol cellulose (LCC), high-cholesterol cellulose (HCC), or high-cholesterol psyllium (HCP). The LCC and HCP groups had significantly (P less than 0.05) lower plasma cholesterol concentrations (39 % lower) at 1 mo than did the HCC group. These responses persisted throughout the study. Plasma cholesterol changes were due to a reduction in intermediate-density and low-density lipoproteins; very-low and high-density-lipoprotein concentrations were similar among groups. Aortic atherosclerosis, evaluated as percent sudanophilia at 3.5 y, was lowest in the LCC group, intermediate in the HCP group, and highest in the HCC group. Cholesterol absorption, neutral steroid and fat excretion, HMGCoA reductase activity (in intestine and liver) and body weight were unrelated to psyllium's hypocholesterolemic effects [5].

Much attention has been paid in recent years to celery due to their potential implication in cardiovascular health. Animal and human intervention studies have shown that celery inhibit platelet activation [6], favorably alter eicosanoid synthesis [7], suppress production of proinflammatory cytokines and lipoxygenase activity [8], stimulate nitric oxide production [9], and improve endothelial function [7]. The present study was therefore designed to investigate the effect of long term consumption of fiber (apple peels or psylium seeds or celery) on the concentrations of serum lipid profile and atherogenic factor in rats.

Materials and methods

Animals

This study was conducted on 100 male Albino rats weighing ranged (50 $\pm$ 5 g) obtained from Animal House Unit, King Fahd Center for Medical Research, KAU, Jeddah, Saudi Arabia. They were adapted for one week before the experiment, water and food were given ad libitum. with light dark cycle 12 hrs. divided into 10 equal groups

Gp I (control-1): Rats fed on standard laboratory diet for 3 months.

Gp II (control-2): Rats fed on standard laboratory diet for 6 months.

Gp III (HFD): Rats fed standard diet supplemented with 20 % coconut oil for 3 months.

Gp IV: Rats fed HFD for 3 months, followed by standard laboratory diet for another 3 months.

Gp V (protect): Rats fed HFD supplemented with 5 % apple peels for 3 months.

Gp VI (protect): Rats fed HFD supplemented with 5 % psyllium seeds for 3 months.

Gp VII (Protect): Rats fed HFD supplemented with 5 % celery for 3 months.

Gp VIII (Treat): Rats fed HFD for 3 months followed by standard diet supplemented with 5 % apple peels for 3 months.

Gp IX (Treat): Rats fed HFD for 3 months followed by standard diet supplemented with 5 % psyllium seeds for 3 months.

Gp X (Treat): Rats fed HFD for 3 months, followed by standard diet supplemented with 5 % celery for 3 months.

Composition of standard diet:

Casein (15.3 g), sucrose (10 g), cornstarch (45.26 g), cellulose (5 g), dextrinated starch (15.5 g), mineral mix (3.5 g) vitamin mixture (1gm).

All rats were overnight fasted and blood samples were collected , sera were separated and kept at -20 °C till analysis. Liver was removed and kept in 10 % formaldehyde buffer for preparation of slides for histological examination.

Methods

Analysis of apple peel, psylium seeds and celery was carried out according to AOAC [10]. The biochemical parameters were assayed by using kits purchesd from Biosystem. Total serum cholesterol was determined according to Trinder [11] triacylglycerol [12], HDL-cholesterol [13], LDL cholesterol [14], VLDL-C [15] and atherognic index was calculated [16].

Liver morphology

Liver slices were dehydrated with ethanol, cleared with xylene and embedded in paraffin wax. After inclusion, material was cut on a microtome (CUT model 445, Olympus) at 4 μm. Liver sections were stained with hematoxylin and eosin (Merck) [17].

Pictures were taken with a photomicroscope (Model AX-70, Olympus) using Kodac color Gold 100 as a film at 40 X magnification. Histological analysis was qualitative.

Statistical analysis

Collected data were subjected to the Kolmogorov-Smirnov test to check for symmetry for variables with normal distribution. Student's *t* test was used to compare two independent samples (normal and HFD groups). Analysis of variance was used to compare three or more independent samples (HFD alone or supplemented with apple peel or psylium seeds or celery), followed by Tukey's test ($P<0.05$) when the F value was significant [18].

For asymmetric variables, the Mann-Whitney test was used to compare two independent samples, and the Kruskal-Wallis test was used to compare three or more independent samples, followed by Dunn's test ($P<0.05$), when the comparison was statistically significant. Analyses were carried out using Sigma Stat 0.02 (Software for Windows; Jandel Corp., San Rafael, CA, USA).

Results

The chemical analysis of the investigated fibers were shown in Table 1. It was found that apple peels showed higher fiber content compared with psylium seeds and celery. While psylium seeds have higher protein contents compared with apple peels and celery. However celery have higher content of fat and carbohydrate than apple and psylium seeds.

Table 1. Chemical analysis of celery, Pyslium seeds and apple peels.

Apple peels	Pyslium seeds	Celery	Parameters (%)
1.53	3.71	3.19	Water
1.75	2.80	1.35	Ash
2..29	4.12	3.10	Total protein
0.56	0.34	1.36	Total fat
2.11	3.67	4.57	Total carbohydrates
91.76	85.36	86.43	Fibers

Table 2 showed that, in the protective group, it was found that body weight was statistically significant elevated in rats fed on HFD for 3 months compared with control animals. Rats fed on HFD supplemented with 5 % of apple peel or psylium seeds or celery showed a significant reduction of body weight compared with HFD alone. The reduction of body weight in rats supplemented with in apple peel is more than celery than pyslium seeds. Also there was a significant elevation in the levels of total cholesterol, triacylglycerol, LDL-c and atherogenic factor in rats fed on HFD for 3 months compared with normal control while HDL-c and VLDL-c were non significantly changed in HFD rats compared with control group. Supplementation of diet with apple peel or psylim seeds or celery exerts improvement in the studied parameters by lowering triacylglycerol, total cholesterol, LDL-c and atherogenic factor till reach near to the value of control as compared with HFD fed rats.

Table 3 showed the protective trail of fibers as hypolipidemic agents. It was found that the tested fibers (apple peels, psylium seeds and celery) used posses hypolipidemic action compared with non treated group, but the protection effect is better than treated trail

Liver Histology:

Figure 1 shows lipid deposition in liver slices. The intensity of liver steatosis was classified as more than 30 % of hepatocytes affected (+), more than 50 % of hepatocytes affected (++), and more than 75 % of hepatocytes affected (+++). Lipid vesicles appeared in livers of animals fed HFD. Hepatocytes of the HFD group presented a flattened nucleus due to high lipid content. The amount of lipids deposited is reduced in fiber supplementation

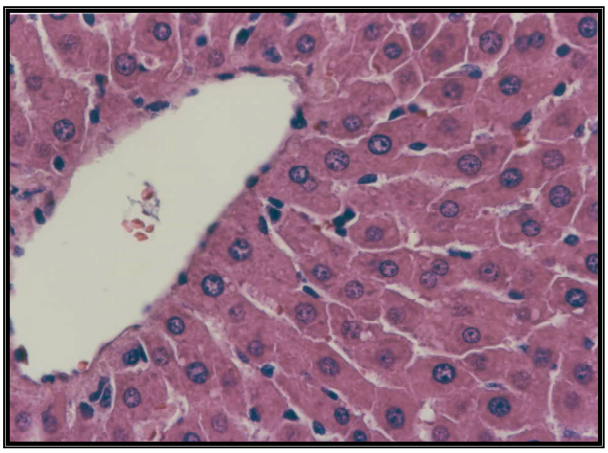

Figure 1. Section of normal rat liver fed on standard diet for 3 months

Discussion

A high level of serum cholesterol is well established as a risk factor for coronary heart disease (CHD) [19]. In fact, it has been stated that for every 1 % decrease in serum cholesterol humans get a 2 % decrease in risk of CHD [20]. The present study have demonstrated the impact of dietary intake of the fibers on lowering serum cholesterol and reduction of atherogensis.

Epidemiological studies suggested that dietary fiber intake, especially of the soluble type is associated with a reduction in serum cholesterol concentration and with decreased risk for coronary heart disease [21]. Intake of insoluble dietary fiber, like cellulose or lignin, also reduce serum cholesterol concentration. With regard to the differences in fiber and saturated fat intake and their influence on the lipoprotein-lipid profiles, it appears that the ratio of each may be more critical than the absolute amounts of each as the individual variables did not predict any of the lipoprotein-lipid values. This study aimed to examine the protective and treated effects of dietary fibers in the form of apple peel or pyslium seeds or celery as hypolipidemic and hypocholeserolemic actions in rats

Table 2. Serum levels of total-cholesterol, triacylglycerol, HDL-c, LDL-c, VLDL-c and atherogenic factor in the protective trail for (Mean±SD)

Groups / Parameters	Control-1	HFD	HFD+standartd diet	HFD +5% apple peel	HFD+ 5% psyllium	HFD+5% celery
Body weght Mean±SD P value P*	295±11.7 ---	347±26 <0.01 ---	309±50 <0.001 <0.05	262±26 <0.001 <0.05	281±37 <0.01 <0.01	±15272 <0.001 <0.01
T-cholesterol (mmol/L) Mean±SD P value P*	1.85±0.16 ---	2.82±0.12 <0.001 ---	1.83±0.21 N.S <0.001	1.81±0.21 N.S <0.001	1.85±0.21 N.S <0.001	1..9±0.17 <0.05 <0.001
Triacyglycerol (mmol/L) Mean±SD P value P*	0.59±0.14 ---	0.82±0.52 <0.001 --	0.62±0.52 N.S. <0.05	0.53±0.08 N.S. <0.01	0..58±0.22 N.S <0.01	0..5±0.\05 N.S. <0.01
HDL-c (mmol/L) Mean±SD P value P*	0.49±0.03 ---	0.46±0.42 N.S --	0.44±0.48 <0.05 N.S	0.59±0.07 <0.05 <0.05	0.58±0.05 <0.05 <0.05	0.58±0.06 <0.01 N.S.
LDL-c (mmol/L) Mean±SD P value P*	1.48±0.11	2.46±0.11 <0.001 ---	1.3±0.19 <0.05 <0.01	1.3±0.15 <0.05 <0.001	1.38.±0.14 <0.05 <0.001	1.4±0.13 <0.05 <0.01
VLDL-c (mmol/L) Mean±SD P value P*	0.11±0.02	0.1±0.009 N.S. --	0.12±0.01 N.S. N.S	0.1±0.01 N.S. N.S.	0.11±0.04 N.S N.S	0.1±0.01 N.S. N.S.
Atherogenic factor Mean±SD P value P*	3.22±0.16 ---	5.54±0.48 <0.001 --	3.4±0.42 N.S <0.001	2.4±0.28 <0.01 <0.001	2.43±0.41 <0.05 <0.001	2.6±0.27 <0.001 <0.001

HFD: High fat diet *p*: compared with control group. *p**: compared with HFD group N.S.: non significant $p<0.05$ was considered as significant

fed on HFD. Chemical analysis of apple peel, pyslium seeds and celery showed that, apple peel contain high percent of fibers as compared with the pyslium seeds and celery (Table 1).

Results obtained showed that, serum levels of triacylglycerol, total cholesterol, LDL-c and atherogenic factor were significantly elevated in rats fed on HFD. Celery was found to positively affect serum lipid and lipoprotein profiles and to decrease levels of markers of lipid peroxidation such as malondialdehyde (MDA), or low-density lipoprotein (LDL) oxidizability [25]. All these data are indicative of a putative cardioprotective action of celery. Most of these effects are attributed to the fibers fraction of celery.

The use of individual fiber types as the sole source of fiber in the diet for an extended time (24 wk) has allowed determination of the relative effects of each fiber type on the serum cholesterol profile and on serum triacylglycerol and glucose concentration. Use of single dietary fiber types also allows easier identification of mechanisms of action of the various fiber types. In regard to the mechanisms of action of dietary fibers, in vitro studies have demonstrated that some but not all types of dietary fiber bind bile acids [26], leading to the hypothesis that bile acid binding, interference with absorption of bile acids or nutrients in the intestine and excretion of bile acids are mechanisms whereby certain types of dietary fiber lower plasma cholesterol.

Lignin has been reported to reduce serum cholesterol levels in humans [27] and animals [22] however other authors have reported that lignin was ineffective in lowering serum cholesterol in patients with hypercholesterolemia [28] or in rats fed high amounts of lignin [20]. Results of the present study conclusively demonstrate that long-term consumption of 5 % apple peel or psylium seeds or celery lignin, as source of dietary fiber,

Table 3. Serum levels of total-cholesterol, triacylglycerol, HDL-c, LDL-c, VLDL-c and atherogenic factor in the treated trail (Mean±SD)

Groups / Parameters	Control-2	HFD+standartd diet	HFD +5% apple peel	HFD+ 5% psyllium	HFD+5% celery
Body weght					
Mean±SD	356±35	309±50	311±34	303±32	±28329
P value	---	<0.001	<0.01	<0.01	<0.01
P*		---	N.S	N.S	<0.001
T-cholesterol (mmol/L)					
Mean±SD	1.98±0.2	1.75±0.21	1.8±0.16	1.7±0.21	1.73±0.2
P value	---	<0.001	<0.001	<0.01	<0.001
P*		---	<0.001	N.S	N.S
Triacyglycerol (mmol/L)					
Mean±SD	0.51±0.14	0.62±0.52	0.54±0.54	0..48±0.07	0..48±0.06
P value	---	<0.05.	N.S.	<0.05	N.S.
P*		--	N.S.	<0.01	N.S.
HDL-c (mmol/L)					
Mean±SD	0.46±0.03	0.44±0.48	0.43±0.03	0.4±0.04	0.38±0.04
P value	---	N.S	N.S.	<0.05	<0.01
P*		--	<0.05	<0.05	N.S.
LDL-c (mmol/L)					
Mean±SD	1.67±0.18	1.4±0.19	1.5±0.14	1.4.±0.16	1.42±0.17
P value		<0.01	<0.01	<0.001	<0.001
P*		---	<0.05	<0.001	<0.01
VLDL-c (mmol/L)					
Mean±SD	0.1±0.007	0.12±0.01	0.2±0.26	0.08±0.01	0.09±0.02
P value		N.S.	N.S.	N.S	N.S.
P*		--	N.S.	<0.01	N.S.
Atherogenic factor					
Mean±SD	3.6±0.24	3.4±0.42	3.7±0.33	3.4±0.26	4.9±0.33
P value	---	N.S	N.S	N.S.	<0.001
P*		--	<0.001	<0.01	<0.01

HFD: High fat diet *p*: compared with control group. *p**: compared with HFD+ standard diet group N.S.: non significant. $p<0.05$ was considered as significant

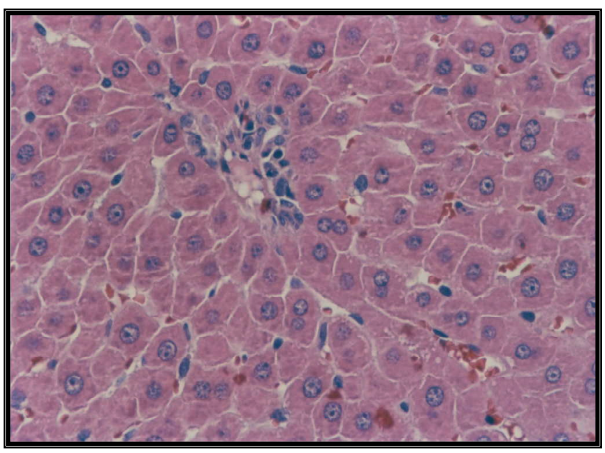

Figure 2. Section of rat liver fed high fat diet for 3 months

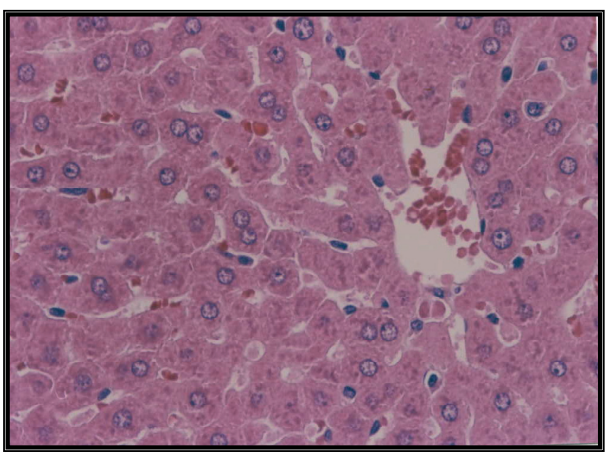

Figure 3. Section of liver rats fed on HFD + peel apple for 3 months (protect).

was effective at lowering total serum cholesterol in rats fed HFD.

It has been suggested that soluble dietary fibers decrease serum cholesterol by binding or entrapping bile acid resulting in decreased absorption and increased excretion of the bile acid in feces. If increased excretion of bile acids were a significant factor in reduction of serum cholesterol in this study, it would be expected that serum cholesterol would inversely correlate with fecal bile acid excretion.

One explanation for the decrease in serum cholesterol associated with consumption of dietry fibers relates to

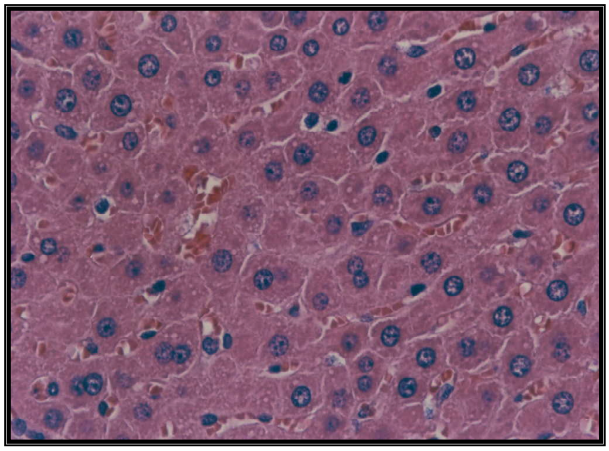

Figure 4. Section of liver rats fed on HFD + psylium seeds for 3 months (protect).

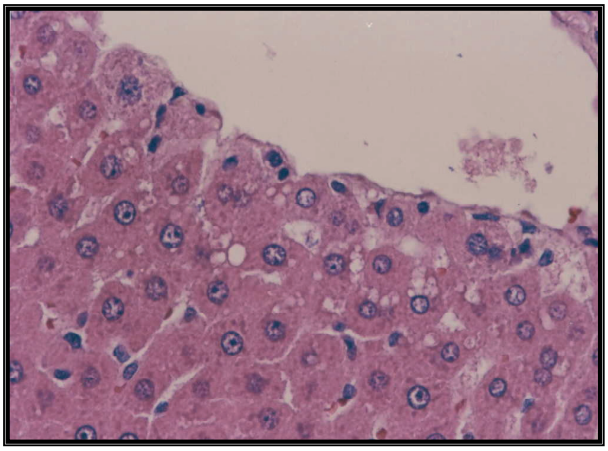

Figure 5. Section of liver rats fed on HFD + celery for 3 months (Protect).

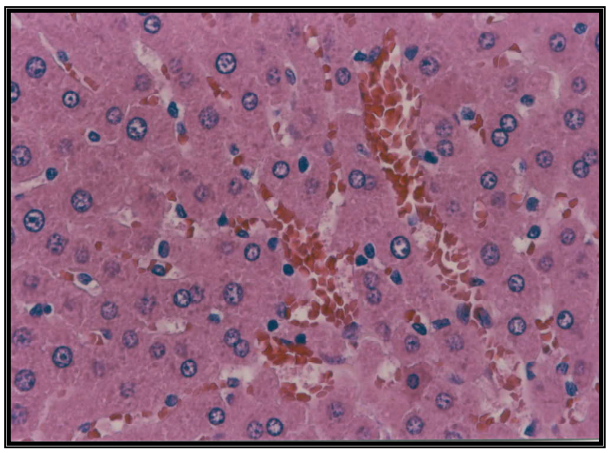

Figure 6. Section of liver rats fed on HFD for 3 months followed by standard diet+ peel apple for 3 months (treat).

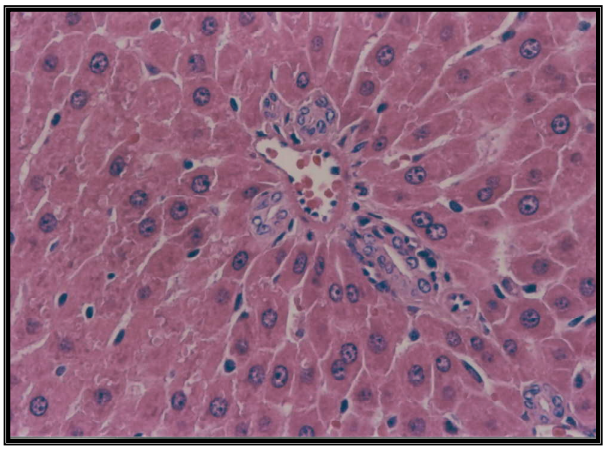

Figure 7. Section of liver rats fed on HFD for 3 months followed by standard diet+ psylium seeds for 3 months (treat).

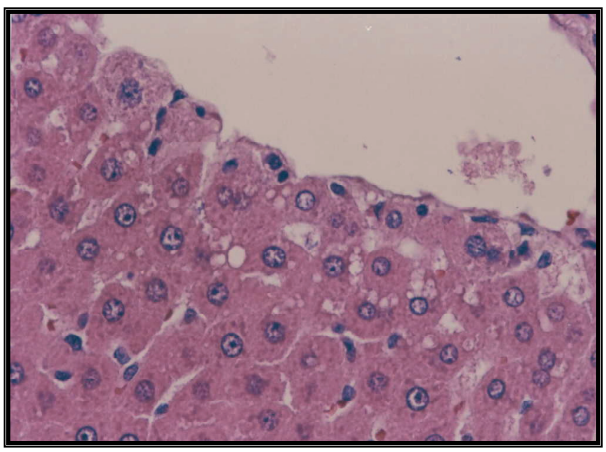

Figure 8. Section of liver rats fed on HFD for 3 months followed by standard diet+ celery for 3 months (treat).

decreased food consumption. The results of the present study clearly show that consumption of increasing levels of fibers resulted in a significant decrease in atherogenic factor.

Likewise, the overall reduction in energy consumed correlated significantly with lower serum concentration of triacylglycerol. Consumption of soluble dietary fiber resulted in a lower energy and nutrient intake. One possibility is that the soluble dietary fibers are fermented in the large bowel resulting in the production of short chain fatty acids (SCFAs). These SCFAs account for the acidification of the fecal contents.

Short chain fatty acids serve as a source of metabolizable nutrients for the rat and it has been proposed that the sustained production and delivery of short chain fatty acids to the rat liver and systemic circulation in someway modulates blood levels of cholesterol, triacylglycerol and glucose [29]. The production of SCFAs from fermentation of soluble dietary fiber over time might also explain the observed lower energy intake of the rats fed high levels of soluble dietary fiber perhaps by suppression of a hunger sensation.

The findings of the present study revealed that long-term consumption of food with soluble dietary fiber significantly reduces serum cholesterol this support the idea that increased intake of the soluble dietary fibers, like pectin and guar gum, is an effective non-pharmacologic means of reducing risk factors associated with CHD .

Histological examination support the biochemical analysis. It was found that, rats fed high fat died showed a highly fatty liver (Figure 1) as compared with control group (Figure 2). Rats fed peel apple for (Figure 3) or psylium seeds (Figure 4) or celery (Figure 5) ameliorate the deleterious effects more than treated effects (Figures 6,7,8). Based on the results of our rat studies and on the results of past human research it is projected that a diet containing 5 g/100 g dry wt of fibers can cause a 20 to 30 % reduction in serum cholesterol and the other serum lipid risk factors.

References

[1] Anderson JW, Zettwoch N, Feldman T, Tietyen-Clark J, Oeltgen P and Bishop CW. (1988) Cholesterol-lowering effects of psyllium hydrophilicmucilloid for hypercholesterolemic men. Arch Intern Med. 148: 292-296.

[2] Anderson JW, Spencer D, Hamilton C, Smith S, Tietyen J, Bryant C and Oeltgen P. (1990) Oat bran cereal lowers serum total and LDL cholesterol hypercholesterolemic men. Am J Clin Nutr. 52: 661-666.

[3] Aprikian O, Levrat-Vemy M, Besson C, Busserolles J, Remesy J, and Demigne C. (2001) Apple favorably affects parameters of cholesterol metabolism and of antioxidative protection in cholesterol- fed rats. Food Chem. 75: 445-452.

[4] Aprikian O, Busserolles J, Manach C, Mazur A, Morand C, Davicco M, Besson C, Rayssiguie Y, Remesy C and Demigne C. (2002) Lyophilized apple counteract the development hypercholesterolemia, oxidative stress and renal dysfunction in obese zucker rats . Nutr. 132(7): 1969-1976.

[5] Beth H, Sallee M, Andrson J, Mark P. (1997) Psyllium-Enriched Cereals Lower Blood Total Cholesterol and LDL Cholesterol, but Not Cholesterol, in Hypercholesterolemic Adults: Results of a Meta-Analysis. J Nutr. 127: 1973-1980.

[6] Bijkerk CJ, Muris JW, Knottnerus JA, Hoes AW, and De Wit N J. (2004) Systematic review: the role of different types of fiber in the treatment of irritable bowel syndrome. Aliment Pharmacol Ther. 19(3): 245-51.

[7] Castro IA, Barroso LP and Sinnecker B. (2005) Functional foods for coronary heart disease risk reduction: a meta-analysis using a multivariate approach. Am J Clin Nutr. 82(1): 32-40.

[8] Erkkila AT, Herrington DM, Mozaffarian D and Lichtenstein AH. (2005).Cereal fiber and whole-grain intake are associated with reduced progress of coronary-artery atherosclerosis in postmenopausal women with coronary artery disease. Am Heart J. 150(1): 94-101.

[9] Erkkila AT and Lichtenstein AH. (2006) Fiber and cardiovascular disease risk: how strong is the evidence. J Cardiovasc Nurs. 21(1): 3-8.

[10] Billet MA, Bruce JS, White DA, Bennett AJ, Salter AM. (2000) Interactive effects of dietary cholesterol and different saturated fatty acids on lipoprotein metabolism in the hamster. Br J Nutr. 84: 439-4347.

[11] Truswell AS. (1995) Dietary fiber and blood lipids. Curr Opin Lipidol. 6(1): 14-19.

[12] Tsi D and Tan BK (1996) Effects of celery extract and 3-N-butylphthalide on lipid levels in genetically hypercholesterolaemic (RICO) rats. Clin Exp Pharmacol Physiol. 23 (3): 214-217.

[13] Van Horn L, Annemidy LK, Baio Y, Ballew C, King J and Stamler J. (1988). Serum lipid response to effect modified, oat meal-enhanced. Prev Med. 17: 377-386.

[14] Van Horn L. (1997) Fiber, lipids. and coronary heart disease. A statement for care professionals from the Nutrition Committee, Amer Heart Assoc. Circulation. 95: 2701-2704.

[15] Vega-Lopez S, Conde-Knope K, Vidal-Ouintanar R, Shachter N S and Fernandez ML. (2002) Sex and hormonal status influence the effects of psyllium on lipoprotein remodeling and composition. Metabolism. 51 (4): 500-506.

[16] Vega-Lopez S, Freake HC and Fernandez ML. (2003) Sex and hormonal status modulate the effects of psyllium lipids and monocyte gene expression in humans. J Nutr. 133 (1): 67-70.

[17] Vigne JL, Lairon D, Borel P, Portugal H, Pauli AM, Hauton JC and Lafont H. (1987) Effect of pectin, wheat bran and cellulose on serum lipids and lipoproteins in rats fed on a low or high fat diet. Br J Nutr. 58: 405-413.

[18] Morise A, Serougne C, Gripois D, Blouquit M, Lutton Chemie D. (2004) Effects of dietary alpha linolenic acid on cholesterol metabolism in male and female hamsters of the LPN strain. J Nutr Biochem: 15:51-61.

[19] Nestle PJ. (1990) Effect of n-3 fatty acids on lipid metabolism Annual Review of Nutrition. 10: 149-167.

[20] O'Keefe JH, Nguyen T, Nelson J. (1999). Potential beneficial effects of monounsaturated and polyunsaturated fats in elderly patients with or at risk of coronary artery disease. Cardiol Elderly. 3: 5-10.

[21] Ramesh G, Das UN. (1996) Effects of free fatty acids on two-stage skin carcinogenesis in mice. Cancer Letters. 100: 199-209.

[22] Storlien LH, Higgins JA. Thomas TC. (2000) Diet composition and insulin action in animal models. British Journal of Nutrition. 83: 85-90.

[23] Sheehan D and Deckelboum R (1980) Phory and Practical histotechnology. Second Ed ,Ohio.

[24] Snedecor G and Cochram W. (1980) Statistical methods 7^{the} Ed. Iowa State Univ. Press.Library of Congress 31-44.

[25] Zambon D, Sabate J, Munoz S, Campero B, Casals E, Merlos M. (2000) Substituting walnuts for monounsaturated fat improves the serum lipid profile of hypercholesterolemic men and women: a randomized crossover trial. Ann Intern Med. 132: 538-546.

[26] Abeywardena MY. (2003) Dietary fats, carbohydrates and vascular disease: Sri Lankan perspectives. Atherosclerosis. 171: 157-161

[27] Almario RU, Vonghavaravat V, Wong R, Kasim-Karakas SE. (2001) Effects of walnut consumption on plasma fatty acids and lipoproteins in combined hyperlipidemia. Am J Clin Nutr. 74: 71-79.

[28] Annuzzi G, Rivellese A, Capaldo B, Di Marino L, Lovine C, Marotta G, Riccardi G. (1991) A controlled study on the effect of n-3 fatty acids on lipid and glucose metabolism in non-insulin-dependent diabetic patients. Atherosclerosis. 87: 65-73.