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HIGH CELLULOSE DIET LOWERS SERUM, LIVER AND LDL CHOLESTEROL CONTENTS BUT ENHANCES HDL AND FECES CHOLESTEROL IN RATS

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ABSTRACT

Objective: To investigate the effects of different levels of dietary cellulose on lipid profile in growing rats.

Research Methods & Procedures: 4-wk-old rats were fed 0%, 5%, 7.5% and 10% cellulose. After 28 d on the diet, serum and hepatic lipid and HDL, LDL and feces cholesterol contents were determined.

Results: The 10% cellulose diet exhibited lower body, liver and adipose tissue weights but higher food, and energy intakes than the control diet, the 10% cellulose diet raised lipid intake and in feces, which is accompanied with lower fat digestibility. Rats fed the 10% cellulose diet had low serum and liver lipid than those fed the 0%, 5% and 7.5% cellulose diets. Increasing cellulose level (from 5% to 10%) in the diet lower serum, LDL and hepatic cholesterol but higher HDL and fecal cholesterol. The consumption of 10% cellulose diet elevated the CT/LDL-C ratio and reduced the CT/HDL-C ratio as compared to the 5% cellulose diet. Liver phospholipids were significantly lower in the 10% cellulose group than in 5% group. Serum triacylglycerols were enhanced in the 0%, 7.5% and 10% cellulose groups than in the 5% cellulose group. Liver triacylglycerols were lower in the 10% cellulose than in the control diet.

Conclusion: The 10% cellulose diet has a beneficial effect since it lowers serum, liver and LDL cholesterol and increases HDL cholesterol. These findings have important implications for the prevention and management of hypercholesterolemia, particularly in populations in which high plasma cholesterol is prevalent in association with diets low in fiber.

Key words: • Rats • Cellulose • Liver • Serum • Feces • Lipids • Cholesterol

INTRODUCTION

Several epidemiologic studies found weak protective relations between dietary fiber intake and the risk of cardiovascular disease events [1]. Numerous risk factors, including dietary pattern, physical inactivity, serum lipids, diabetes, smoking, obesity, and psychological stress, have been proposed as contributing to the initiation and development of atherosclerosis and its clinical manifestations [2].

Dietary fiber intake has been inversely related to the risk of developing coronary heart disease [3, 4, 5]. They may contribute to the prevention and treatment of adverse dietary and physiological situations in humans [6]. Consumption of dietary fibers is encouraged because their benefits have been reported to include maintenance of the large intestine, reduction of the formation of gallastones, and control of major risk factors of diverticular disease, ischemic heart disease, diabetes and obesity [7].

Animal studies are required to assess the physiological characteristics of dietary fibers, with the notions that a pure fiber exerts metabolic consequences that might differ from those observed when the fiber is an integrated part of a complex system [8].

Increased blood lipids and serum cholesterol concentrations contribute to the etiology of cardiovascular diseases [9]. The effects of dietary fibers on serum and liver lipids metabolism in humans and animals have been extensively studied. Numerous investigations have suggested that including certain sources of dietary fiber in the diet of humans and animals can lead to reduction of plasma cholesterol and triglyceride levels [10, 11].

The hypocholesterolemic effect of plant fibers may be due to fiber-induced alterations of intestinal absorption, intestinal or pancreatic hormone secretion, lipoprotein metabolism, bile acid metabolism, or fermentation by-products and their effects on hepatic cholesterol synthesis [12].

The exact mechanisms by witch soluble and insoluble fiber exert their hypocholesterolemic effects have not been elucidated. One of the major primary mechanisms suggested to explain the fiber-mediated lowering of plasma LDL-C is the interruption of the enterohepatic circulation of bile acids [13, 14].The body eliminates excess cholesterol by a major regulation pathway involving the conversion of hepatic cholesterol to bile acids [15]. Hepatic cholesterol enzyme in the bile acids boisynthesis pathway [16]. Hara et al [17] reported that products of fermentation of sugar beet fiber by cecal bacteria lower the plasma cholesterol concentration in rats and that SCFA, as a fermentation product, suppresss cholesterol synthesis in the liver and intestine [18].

In addition, dietary fiber level has also been reported to influence lipid metabolism. In rat, the consumption of 10% of psyllium lowered serum and liver cholesterol concentrations, increased steroids and bile acids excretion and cholesterol 7α-hydroxylase activity as compared to those fed the 0%, 3.33%, and 6.67% [19]. Naveh et al [6] has indicated that serum cholesterol contents were not modified with 3%, 6% and 10% cellulose diets.

The aim of the present study was conducted to explore the hypocholesterolemic effects of cellulose fed at different levels and to verify whether changes in cellulose levels in the diet improve or alter serum and liver lipids and fecal lipids and cholesterol excretion in the growing rats fed cholesterol-free diet.

MATERIALS AND METHODS

Animals and diets

Male Wistar rats (Iffa-Credo, l'Arbresle, France), weighing 50 ± 5g at the beginning of the experiment, were housed in stainless-steel cages in a room maintained at constant temperature (24°C) and humidity (60%) with a 12-h light:dark cycle. Rats were allowed free access to an adequate semipurified diet (20% casein and 5% cellulose) for 10 d. After this adaptation period, when their weight was 80 ± 5g, they were randomly assigned to four groups. For 28 d, rats were fed diets containing 0%, 5%, 7.5%, or 10% cellulose with 20% casein, 5% tournesol oil, 4% minerals, and 2% vitamins. Diets were completed to 100% with starch. Compositions of the diets are shown in Table I. Food and water were freely available and animals were weighed weekly. We followed the general guidelines for the care and use of laboratory animals as recommended by Council of European communites [20].

Blood and tissue samples

After an overnight fast following the 28-d dietary period, nine rats of each group were anaesthetized with sodium pentobarbital (60 mg/kg of body weight) before blood collection. Blood was then collected by abdominal puncture in the aorta. Serum was prepared by low-speed centrifigation (1000×g for 20min at 10°C), preserved on 0.26 mmol/L of disodium EDTA + 3 mmol/L of sodium azide.

Liver, adipose tissue, gastrocnemius muscle, kidneys, heart were isolated, washed in cold saline solution, dried, and weighed. Approximately 1 g of the greatest lobe was removed for lipid extraction, and 1 g of the same lobe was used for protein determination.

Chemical analyses

Liver and serum total lipid concentrations were extracted according to the methode of Folch et al [21]. Liver and serum were assayed for cholesterol, triacylglycerols and phospholipids with Boehringer enzyme Kits (Boehringer, Mannheim, Meylan, France) by using cholesterol and glycerol, respectively, as standard. Protein concentrations were measured according to the method of Lowry et al [22] using bovine serum albumin as the standard. Cholesterol in the feces and in the LDL and HDL fractions were determined by enzymatic method using Boehringer enzyme Kits (Boehringer, Mannheim, Meylan, France).

Statistical analysis

Data are presented as means ± SEM for nine rats per group. Statistical analysis of the data was performed with Statistica (version 4.1, Statsoft, Inc., 1994, Paris, France). The significance of differences among treatment groups was determined by analysis of variance with Fisher's test. Results were considered significant at $P < 0.05$.

RESULTS

Food and energy intakes, weight gain and body and tissue weights

Rats fed the 10% cellulose diet grew at a slower rate than those fed the control diet (Table II). Higher food intakes were observed in the rats fed the 7.5% and 10% cellulose diets as compared to those fed the control diet. Moreover, energy intake per 100 g BW was 1.12-fold higher in rats fed the 10% cellulose as compared to fed the control diet. Therefore, final body weight was also significantly lower in the 10% cellulose group as compared to the 5% cellulose group at the end of the experimental period (Table II). In addition, the 10% cellulose diet induced a decrease in absolute liver and adipose weights in the rats as compared to control diet. The relative liver weight for the rats on the 10% cellulose diet was also significantly lower than that of the animals received the control diet. The values represented 3.35 ± 0.30, 3.40 ± 0.16, 3.30 ± 0.20, and 2.97 ± 0.27 g/100 g BW in rats fed with 0%, 5%, 7.5 % and 10% cellulose diets, respectively. The relative adipose (perirenal + epididymal fat) weight in rats fed the diet containing 10%

cellulose was significantly decreased as compared to that of the rats on the control diet (the values are 7.90 ± 0.60 , 6.77 ± 1.0 , 5.68 ± 0.50, versus 7.63± 0.52). However, absolute heart, kidneys, muscle weights remained unchanged between the 4 groups after 28 d of experiment.

Lipid intake, fecal dry weights, fecal fat excretion and fat digestibility

Feeding cellulose at 10 g/100 g and 7.5 g/100 g diet led to fecal fat excretion 1.29– and 1.14-fold greater than that the control-fed group, respectively. Lipid intake was enhanced with increasing cellulose proportion in the diet. Both the 10% and 7.5% cellulose groups compared to the 5% cellulose group, showed lower lipid digestibility (Table III).

Liver and serum protein and lipid concentrations

The serum and liver protein and lipid contents are shown in Table 3. Serum protein contents were respectively, 8% and 57% enhanced in rats fed the 7.5% and the 10% cellulose diets as compared to the control diet (Table IV). However, liver protein concentrations were 1.23-fold lower in the 10% cellulose-fed rats as compared to the control diet. The cellulose-free diet showed the highest liver protein values. Serum total lipids were decreased when the cellulose level increased from 5% to 7.5% and 10%. Rats fed free-cellulose diet presented the greatest serum lipid concentrations as compared to other experimental diets. Hepatic lipid concentrations were significantly lower in rats treated with the 10% cellulose diet, followed by the 7.5% compared to control diet. Free-cellulose diet resulted in the greatest values.

Serum, liver, lipoprotein and feces cholesterol concentrations

After 28 d of feeding, serum total cholesterol concentrations were respectively, 5% and 12% reduced in rats fed the 7.5 % and 10% cellulose diets as compared to the control diet, whereas, free-cellulose diet enhanced by about 35% serum cholesterol contents as compared to the control diet (Table V). Therefore, liver cholesterol concentrations were lowered by about 7% and 19% in rats treated with 7.5% and 10% cellulose diets, respectively than in those treated with control diet. Rats fed free-cellulose diet showed the greatest (38%) hepatic cholesterol values as compared to control rats.

The distribution of serum total cholesterol between LDL and HDL indicated that the diets containing 7.5% and 10% cellulose increased by about 21% and 29% the HDL cholesterol concentrations as compared to control diet, respectively. Where as, a reduction of 24% of HDL-C was noted with free-cellulose diet. Therefore, 58% of serum cholesterol was exported by HDL in 10% cellulose-fed rats, while only 22%, 39% and 51% were exported by HDL in rats fed the 0%, 5%, and 7.5% cellulose diets.

LDL cholesterol contents were respectively, 2- and 4-fold lower the 7.5% and 10% cellulose diets as compared to the control diet. LDL cholesterol was elevated by about 56% in rats fed free-cellulose diet as compared to the control diet. In animals treated with 10% cellulose diet 13% of serum cholesterol was transported by LDL, while 52%, 42%, and 18% of cholesterol were exported by LDL in 0%, 5% and 7.5% groups, respectively. Rats consumed the 7.5% and 10% cellulose diets had higher TC/LDL-C ratio as compared to the control diet. The TC/HDL-C ratio was 1.30- and 1.46-fold lower when rats were given the 7.5% and 10% cellulose diets than those fed the control diet. The free-cellulose diet increased the TC/HDL-C ratio. The LDL/HDL cholesterol ratio was significantly reduced by about 80.37%, 66.35% in rats submitted to 10% and 7.5% cellule proportions, respectively, whereas, an increase by about 120.56% was observed in cellulose free group as compared to the control group

The 10% cellulose group exhibited the highest fecal cholesterol concentrations as compared to control group, followed by the 7.5% cellulose group. Rats fed the free-cellulose diet presented the lowest values.

Liver and serum triacylgycerol and phospholipid contents

After 4 wk of feeding, serum triacylglycerol concentrations were significantly higher in rats fed the 10% cellulose diet, followed by those fed the 7.5% cellulose diet (Table VI). The 0% cellulose diet induced the highest values. Phospholipid concentrations in serum were not modified by the dietary cellulose level. In liver, triacylglycerol and phospholipid contents were significantly lower with 10% cellulose diet as compared to control diet.

Table I. Composition of the experimental diets[1].

Ingredient	0%C	5%C	7.5% C	10%C
	g/kg diet			
Casein (C)[2]	200	200	200	200
Corn starch	650	590	575	550
Sucrose	40	40	40	40
Sunflower oil	50	50	50	50
Cellulose	00	50	75	100
Vitamin[3]	20	20	20	20
Mineral[4]	40	40	40	40

[1]Diets were given in powdered form; [2]Prolabo, Paris, France ; [3]UAR 200 ; (Villemoisson), 91360 Epinay/Orge, France. Vitamin mixture provides the following amounts (mg/kg diet) : retinol, 12 ; cholecalciferol, 0.125 ; thiamine, 40 ; riboflavin, 30 ; pantothenic acid, 140 ; pyridoxine, 20 ; inositol, 300 ; cyanocobalamin, 0.1 ; ascorbic acid, 1.600 ; dl-α-tocopherol, 340 ; menadione, 80 ; nicotinic acid, 200 ; para-aminobenzoic acid, 100 ; folic acid, 10 ; biotin, 0.6. [4]UAR 205 B (Villemoisson), 91360 Epinay/Orge, France. The salt mixture provides the following amounts (mg/kg diet) : $CaHPO_4$, 17200 ; KCl, 4000 ; NaCl , 400 ; MgO, 420 ; $MgSO_4$, 2000 ; Fe_2O_3, 120 ; $Fe_2SO_4.7H_2O$, 200 ; trace elements, 400 ; $MnSO_4.H_2O$, 98 ; $CuSO_4.5H_2O$, 20 ; $ZnSO_4$, 80 ; $CoSO_4.7H_2O$, 0.16 ; Kl, 0.32.

Table 2. Body weight, food and energy intakes and tissues weights of rats fed different proportions of cellulose

	C	0%	7.5%	10%
Body weight (g)	270.71 ± 10.92	280.55 ± 14.32	268.37 ± 25.4	258.52 ± 14.32
Food intake (g/rat/d)	20,21± 1.17^{cy}	18,31±2.22^{by}	21,56±1.25^{aw}	22,15±2.3^{av}
Energy intake	338± 23.78^{dy}	348,78±34.76^{cx}	362.89±45.70^{bw}	380.24±65,31^{av}
Liver weight (g)	9.2 ± 0.55^{bw}	9.46 ± 1.02^{av}	8.86 ± 0.94^{bcx}	7.81 ± 0.63^{dy}
Relative liver weight	3.40 ± 0.16^{abw}	3.35 ± 0.30^{aw}	3.30 ± 0.20^{bcx}	2.97 ± 0.27^{cy}
Heart weight (g)	0.75 ± 0.26	0.75 ± 0.32	0.74 ± 0.04	0.75 ± 0.03
Relative heart weight	0.27 ± 0.45	0.27 ± 0.06	0.28 ± 0.08	0.27 ± 0.02
Kidney weight (g)	1.75 ± 0.09	1.74 ± 0.01	1.76 ± 0.07	1.76 ± 0.05
Relative kidney weight	0.64 ± 0.69	0.64 ± 0 .45	0.65 ± 0.68	0.68 ± 0.02
Muscle weight (g)	0.81 ± 0.01	0.79 ± 0.54	0.79 ± 0.01	0.78 ± 0.01
Relative muscle weight	0.29 ± 0.02	0.29 ± 0.02	0.29 ± 0.03	0.30 ± 0.03
White adipose tissue (g)	7.01 ± 0.84^{a}	7.52 ± 0.54^{a}	6.19 ± 0.58^{b}	5.09 ± 0.27^{c}
Relative white adipose tissue	2.58 ± 0.84^{a}	2.7 ± 0.45^{a}	2.3 ± 0.65^{b}	1.99 ± 0.87^{c}
Brown adipose tissue (g)	0.62 ± 0.04	0.62 ± 0.02	0.61 ± 0.07	0.60 ± 0.09
Relative brown adipose tissue	0.22 ± 0.05	0.22 ± 0.79	0.24 ± 0.03	0.24 ± 0.03
Coecum (g)	4.90 ± 0.12	4.90 ± 0.32	4.80 ± 0.01	4.80 ± 0.12

Values are means ± SEM for 9 rats per group. ^{a}P < 0.05, 0% cellulose diet *vs* C diet; ^{b}P < 0.05, 7.5% cellulose diet *vs* C diet; ^{c}P < 0.05, 10% cellulose diet *vs* C diet.
Relative tissue weight = Tissue weight/100 body weight.

Table 3. Serum and liver lipids and proteins of rats fed different proportions of cellulose

	C	0%	7.5%	10%
Serum				
Proteins (g/l)	82 ± 6.48^{cx}	82.44 ± 3.04^{cdx}	113 ± 13.74^{bx}	129.11 ± 17.96^{av}
Total lipids (g/l)	4.38 ± 0.5^{C}	7.78 ± 0.86^{c}	3.96 ± 0.77^{cz}	3.94 ± 0.84^{dX}
Triglycerides (mmol/l)	1.34 ± 0.10^{cdy}	2.41 ± 0.22^{av}	1.84 ± 0.08^{bx}	1.67 ± 0.08^{bcx}
Phospholipids (mmol/l)	0.73 ± 0.25^{W}	1.19 ± 0.39^{v}	0.87 ± 0.12^{w}	1.09 ± 0.55^{W}
Liver				
Proteins (mg/g tissue)	120.92 ± 8.26^{bx}	141.97 ± 9.89^{av}	122.22 ± 11.72^{bcy}	97.66 ± 5 .34^{cdz}
Total lipids (mg/g tissue)	60.33 ± 3.90^{bcx}	69.10 ± 8.58^{av}	60.66 ± 5.61^{bw}	43.22 ± 4.79^{dy}
Triglycerides (mg/g)	29.61± 12.77^{bw}	36.27 ± 11.57^{av}	29.02 ±10.71^{bCX}	25.02 ± 11.71^{dx}
Phospholipids (mg/g)	21.80 ± 5.05^{bw}	24.97 ± 8.42^{av}	21.67 ± 9.47^{bw}	18.35 ± 9.98^{cw}

Values are means ± SEM for 9 rats per group. ^{a}P < 0.05, 0% cellulose diet *vs* C diet; ^{b}P < 0.05, 7.5% cellulose diet *vs* C diet; ^{c}P < 0.05, 10% cellulose diet *vs* C diet.

Table 4. Serum, liver and lipoproteins cholesterol of rats fed different proportions of cellulose

	C	5%	7.5%	10%
Serum-C (mmol/l)	3.18 ± 0.10^{bw}	4.28 ± 0.43^{av}	3.01 ± 0.08^{bcx}	2.79 ± 0.09^{dz}
Liver -C (mg/g)	6.22 ± 0.35^{vw}	8.58 ± 0.41^{av}	5.81± 0.54^{bcx}	5.02 ± 0.11^{dy}
LDL-C (mmol/l)	1.33 ± 0.12^{abx}	2.10 ± 0.36^{av}	0.57 ± 0.11^{cy}	0.36 ± 0.14^{dz}
HDL-C (mmol/l)	1.26 ± 0.13^{cx}	1.08 ± 0.01^{dy}	1.53 ± 0.03^{bw}	1.63 ± 0.06^{av}
Serum-C/LDL-C	2.41 ± 0.19^{cx}	1.97 ± 0.29^{dy}	5.56 ± 1.33^{bw}	10.22 ± 7.88^{av}
Serum- C/HDL-C	2.57 ± 0.25^{bx}	4.56 ± 0.07^{av}	1.97 ± 0.08^{cy}	1.72 ± 0.09^{dz}

Values are means ± SEM for 9 rats per group. ^{a}P < 0.05, 0% cellulose diet *vs* C diet; ^{b}P < 0.05, 7.5% cellulose diet *vs* C diet; ^{c}P < 0.05, 10% cellulose diet *vs* C diet.

Table 5. Lipid intake, lipid excretion and fat digestibility of rats fed different proportions of cellulose

	C	0%	7.5%	10%
Faeces weight (g)	1.50 ± 0.16^{cx}	1.10 ± 0.014^{dy}	2.19 ± 0.14^{bw}	2.56 ± 0.09^{av}
Lipid intake (mg/rat/d)	966.83 ± 29^{dy}	1030.11 ± 54.37^{cx}	1675 ± 33.28^{bw}	11098 ± 15.94^{av}
Fecal lipids (mg/rat/d)	26.27 ± 1.09^{dy}	21.72 ± 1.49^{dy}	30.08 ± 0.90^{bw}	34.01 ± 1.99^{av}
Fat digestibility %	97.26	98.51	97.16	96.62
Faecal-C (mg/faeces)	1.20±0.89^{dy}	2.21±0.56^{cx}	4.32±0.56^{bw}	5.45±1.34^{av}

Values are means ± SEM for 9 rats per group. ^{a}P < 0.05, 0% cellulose diet *vs* C diet; ^{b}P < 0.05, 7.5% cellulose diet *vs* C diet; ^{c}P < 0.05, 10% cellulose diet *vs* C diet.

DISCUSSION

The purpose of this study was to evaluate the effect of dietary cellulose fed at different proportions on serum, liver and lipoprotein cholesterol in growing rats fed cholesterol-free diet. Although food and energy intakes were significantly higher, decreased body, liver and adipose tissue weights were observed in rats fed the 10% cellulose diet as compared to control diet. Thus, 10% cellulose-fed rats gained less body weight and required significantly more food to gain a gram of body weight than their counterpart cellulose-fed rats. In general, as dietary fiber levels increased, more food was needed to gain a gram of body weight. Our findings are consistent with those Naveh et al [6] who reported a reduction in body weight of rats fed 100 g/kg cellulose or avocado fiber diet compared to those fed 30 and 60g/kg diets. Kimberly et al [19] found that the liver weight was decreased in rats fed the 10% psyllium (soluble fiber) diet than in those fed the 0, 3.33, and 6.67% psyllium diets, whereas, body weight gain and food intake remained unchanged. It is therefore possible, that the reduced liver and adipose tissue weights of rats fed the high cellulose diet likely contributed to the lower body weight. Parrish [23] reported that the decreased adipose tissue was possibly related to an increase in lipolysis.

In this experiment, the increase of the fecal output in the 7.5% and 10% cellulose groups revealed that both amounts of cellulose are not easier to be degraded and to be utilized by intestinal enzymes than control diet and however, induced an inhibitory effect on fat digestion. Our data corroborate with those of Naveh et al [6].

It has been proposed that a protective effect of dietary fiber against cardiovascular disease (CVD) is mediated through direct or indirect effects on serum lipids [24]. Ingestion of insoluble dietary fiber generally was reported to have little or no effect on the serum lipid profile [25]. In the present investigation, high cellulose diet produced significantly lower serum total cholesterol concentrations in comparison to the control diet. The lowered serum cholesterol concentration obtained in 10% cellulose fed group could be related to the lowered cholesterol synthesis via diminished hydroxy-3-methylglutaryl CoA (HMGCoA) reductase activity, the rate-limiting enzyme in the biosynthesis of cholesterol. A similar finding was indicated in rats fed the 10% psyllium as compared to those fed the 0, 3.33, and 6.67% [19]. Numerous reports demonstrated that dietary fibers produced elevated hepatic cholesterol synthesis [26, 27, 28]. In our study, a significant decrease in the liver cholesterol concentration was observed in rats fed on a 10% cellulose diet. Moreover, the lowered serum cholesterol concentrations in the 10% cellulose group resulted from enhanced fecal cholesterol excretion. It seems probable that the 10% cellulose amount stimulated the activity of cholesterol 7α-hydroxylase, enzyme involved in the conversion of hepatic cholesterol to fecal bile acid and total steroid. Thus, the lowered serum cholesterol concentrations by increasing cellulose consumption by rats might be resulted from decreased liver cholesterol contents and enhanced fecal cholesterol excretion. Hepatic cholesterol content is related to the rate at which cholesterol is absorbed by the intestine and delivered to the liver. Cholesterol accumulation in the liver can result in increased esterification and storage, increased secretion of cholesterol in hepatic lipoproteins and decreased uptake of plasma cholesterol via the LDL receptor [29]. Our data are consistent with those of Kimberly et al [19] who showed a decrease in liver cholesterol in rats fed 10% psyllium as compared to those fed the 0%, 3.33% and 6.67%. On the other hand, the cholesterol-lowering of dietary fibers has been related to small chain fatty acids (SCFA) produced by fermentation of the fiber in the large intestine [30]. Propionate generated by bacterial fermentation of fibers reduced cholesterol accumulation in both serum and liver of cholesterol [31]. The hypocholesterolemic effect of propionate may be related to altered hepatic cholesterol synthesis. Thus, the reduced serum and liver cholesterol contents after administration of high cellulose diet might be explained by increased (SCFA). Nishina et al [32] showed that propionate can inhibit the activity of pyruvate deshydrogenase in liver and thus reduce the synthesis of fatty acids.

More originally, our data showed that high the cellulose diet decreases serum and also the LDL-cholesterol concentration and consequently the LDL: HDL-cholesterol ratio (2.36 ± 0.44, 0.36 ± 0.08, 0.21 ± 0.08 in 0%, 7.5%, and 10% cellulose groups, respectively versus 1.07 ± 0.16 in control group). Since VLDL is the precursor of LDL, it is possible that the decrease in LDL cholesterol may be the result of decreased VLDL cholesterol in rats fed the high cellulose diet. The process by which high cellulose diet lowers the LDL-cholesterol has not been examined. However, it is probable that molecules which promote an increase in bile-acid secretion induce a decrease in serum LDL levels. In addition, our results, however, showed that 10% cellulose in the diet has an HDL cholesterol-elevating effect even though a reduction in the total cholesterol concentrations was noted in serum. Elevated of HDL cholesterol has been linked to weight loss [33, 34]. In our report, no correlation between body weight and HDL cholesterol was found in rats fed the 10% cellulose diet. It is interesting to observe that the redistribution of the cholesterol among the different fractions of lipoproteins shows that the proportion of cholesterol in the HDL was highest in the 10% cellulose group, and LDL-cholesterol was lower ($P < 0.05$) in comparison to the control diet. Higher HDL cholesterol concentration upon feeding 10% cellulose diet may reflect an enhanced secretion of HDL from the liver or intestine, or a reduced catabolism of HDL particles. In humans, a negative correlation was observed between the amount of HDL-cholesterol and the occurence of cardiovascular diseases [35]. In the present experiment, we used diets free of cholesterol to eliminate the influence of exogenous cholesterol.

Our findings, however found that rats fed a 10% cellulose diet had higher HDL cholesterol levels. HDL cholesterol content is, in part dependent on the activity of lecithin-cholesterol acyltransferase (LCAT), and the HDL is reshaped due to the action of LCAT [36]. Furthermore, HDL_2 acted as a carrier of cholesterol from peripheral tissue to the liver [37]. Thus, it is possible that rats fed a 10%C diet might have higher LCAT activity because the action of LCAT is thought to prevent the accumulation of unesterified cholesterol derived from the surface of VLDL in the plasma [38]. The lower LDL cholesterol associated with the higher HDL cholesterol observed with the 10% cellulose diet may reflect acceleration in the lipoprotein metabolism. This may suggest that the lipoprotein metabolism is promoted by 10% cellulose amount. The ratio of total cholesterol to HDL cholesterol was proposed as the best metabolic predictor for the effectiveness of intervention for CVD [39]. Thus, the association of total cholesterol to HDL cholesterol with dietary fiber in the present study suggests a significant influence of dietary fiber levels on lipid metabolism relevant to the pathogenesis of atherosclerosis and thrombotic events. Taken together, these findings suggest that increasing the amount of cellulose in the diet plays an important role in cholesterol metabolism.

There is increasing interest in serum triacylglycerol as a possible risk factor for cardiovascular disease in susceptible individuals, including those with diabetes, low HDL-cholesterol concentrations, or elevated apolipoprotein B concentrations [40, 41]. In the present study, serum and liver triacylglycerol concentrations were significantly affected by dietary cellulose level. A significant increase in serum triacylglycerol concentrations occurred in rats fed the high cellulose diet as compared to control diet. It is therefore, suggested that hypertriglyceridemia induced by the highest amount of cellulose might be explained by an enhanced secretion of VLDL from the liver or to decreased catabolism of VLDL by the low lipoprotein lipase and hepatic lipase, enzyme implicated in hydrolysis of triacylglycerol carried by VLDL and hepatic lipase catalyses the hydrolysis of HDL_2-TG and HDL_2-PL. Many reports describe that propionic acid affects fatty acid synthesis. In rat liver [42] or in isolated rat hepatocytes [32, 43] triacylglycerol synthesis was lowered by perfusion with propionic acid. In our experiment, lower hepatic triacylglycerol contents were reported in rats submitted to 10%C diet than in those fed control diet. It seems probable that administration of high proportion of cellulose in the diet might enhance the concentration of short-chain fatty acids in the cecal contents and thus, decreased the liver triacylglycerol concentrations. Serum phospholipid concentrations remained unaffected by the changes in the cellulose level, whereas those of liver were decreased with increasing cellulose proportion in the diet.

In conclusion, the 10% cellulose diet decreased liver and serum triacylglycerol and cholesterol and increased fecal cholesterol excretion. This suggests that increased dietary fiber intake has cardiovascular benefit and that the regulation of serum lipids by dietary fiber may be involved in the process of slowing the progression of atherosclerosis.

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