Effects of Dietary Cellulose Supplements on the Body Composition and Cholesterol Metabolism of Albino Rats

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The effect of inclusion of microcrystalline cellulose (>300 mesh) in a 26% casein diet on the body composition and cholesterol metabolism of albino rats was studied. Inclusion of cellulose to the extent of 5 to 20% resulted in a gradual decrease of productive energy of the diet. Energy consumption rates progressively declined as dietary energy level was reduced, and were reflected in corresponding changes in the fat content of the carcass. Increased plasma and liver cholesterol induced by cholesterol feeding in the rat could be largely counteracted by the concurrent feeding of cellulose at 20% level in the diet. Sulfaguanidine fed at the 1% level failed to modify the effect of cellulose administration. The increased excretion of bile acids in the feces of rats on the 20% cellulose diet could be responsible for the cholesterol lowering effect of cellulose.

Incorporation of fiber or cellulose in the diet could hasten passage of the food through the gut, with consequent lowered absorption of different nutrients. Macrae *et al.* (1942) found that the time required to pass carmine markers was approximately 24 hr on brown bread diets as compared to 40 hr on white bread diets. Radiological studies have also shown that brown bread is evacuated from the stomach and passed through the small intestines more rapidly than white bread (McCance *et al.*, 1953) An increased fiber content in the diet may also result in lowered absorption and utilization of nutrients, especially protein (Macrae *et al.*, 1942). Thus the principal controlling factor in the digestibility of high extraction flours is the crude fiber which it contains.

Hill and Dansky (1954) reported that changes in energy concentration of the diet brought about by incorporation of cellulose in the diet showed a striking effect on the carcass composition of chicks. Also, there have been speculations that dietary characteristics other than fat content may contribute to the striking differences in serum cholesterol levels observed in comparisons between populations (Portman and Stare, 1959). Walker and Arvidsson (1954) suggested that high fiber content or bulk of the diet of some Bantu natives may be partly responsible for the characteristically low serum cholesterol levels in those people in South Africa.

Recent work carried out in our laboratories revealed that inclusion of 5 to 20% of extraneous cellulose in a finely divided form (>300 mesh) in a casein diet did not significantly influence gastric emptying time in adult albino rats and utilization of nitrogen in young weanling rats, as revealed by nitrogen balance studies and net protein utilization determinations (Narayana Rao and Sundaravalli, 1970; Shurpalekar *et al.*, 1969). The present investigation was carried out to determine the effect of inclusion of finely divided cellulose (>300 mesh) in the diet on the body composition and cholesterol metabolism of albino rats.

EXPERIMENTAL AND RESULTS

Experiment 1. Effect of Cellulose on the Body Composition. The aim of this experiment was to determine the effect of inclusion of extraneous cellulose in a finely divided form (>300 mesh) in a casein diet on the growth and body composition of albino rats.

Materials and Methods. A microcrystalline cellulose (AVICEL-PH obtained from FMC Corporation, Marcus Hook, Pa.) was used in the present studies. The material had a particle size of about 40 μ (>300 mesh, Tyler standard).

Animal Trials. Male rats of Wistar strain from CFTRI colony weaned at 21 days of age were allotted to four groups in a random block design. The animals were fed *ad libitum* for 28 days, and feed intake and weight gain data were recorded. Group 1 received the basal casein diet, while groups 2, 3, and 4 received the basal casein diet in which 5, 10, and 20% of microcrystalline cellulose was incorporated at the expense of corn starch. The protein (N $\times$ 6.25) content of all the diets was 20%. The composition of the diets is given in Table I. At the end of the feeding period, all the rats were sacrificed and the carcasses analyzed for moisture, fat, and protein, according to Tasker *et al.* (1961).

Table II presents the results obtained in this experiment. The feed intake of the animals on the basal diet and experimental diets containing cellulose was nearly the same. Energy consumption rates progressively declined as dietary energy level was reduced and were reflected in corresponding changes in the fat content of the carcass. The fat content of the carcass of rats receiving the diet containing 20% extraneous cellulose (10.51%) was significantly ($P < 0.001$) less than that (12.59–12.86%) of rats receiving the basal diet or diet containing 5% cellulose.

Experiment 2. Effect of Cellulose on Cholesterol Metabolism. The aim of this experiment was to determine the effect of inclusion of extraneous cellulose on the cholesterol metabolism of rats receiving a hypercholesterolemic diet.

Animal Trials. Male weanling albino rats of Wistar strain were allotted to four groups of 12 each, and were fed the following diets: group 1, 26% casein diet, cholesterol free

Table I. Percentage Composition of Basal and Test Diets

Constituents	Basal Diet 1	Test Diet 2	Test Diet 3	Test Diet 4
Casein	26	26	26	26
Cornstarch	61	56	51	41
Microcrystalline cellulose	. . .	5	10	20
Salt mixture[a]	2	2	2	2
Vitamin mixture[b]	1	1	1	1
Peanut oil[c]	10	10	10	10

[a] Hubbell *et al.* (1937) salt mixture supplemented with zinc carbonate (0.115 g per 1000 g). [b] According to Chapman *et al.* (1959). [c] Contained per 100 g, 2000 I.U. of vitamin A, 100 I.U. of calciferol and 100 mg of vitamin E.

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Table III. Percentage Composition of Basal and Test Diets

Constituents[a]	Basal Diet 1	Test Diet 2	Test Diet 3	Test Diet 4
Casein	26	26	26	26
Cornstarch	61	59.5	39.5	38.5
Microcrystalline cellulose	...	...	20	20
Salt mixture	2	2	2	2
Vitamin mixture	1	1	1	1
Peanut oil	10	10	10	10
Cholesterol	...	1.5	1.5	1.5
Sulfaguanidine	...	...	...	1.0

[a] Same as in Table I.

(control), group 2, control diet plus 1.5% cholesterol; group 3, control diet plus 1.5% cholesterol and 20% microcrystalline cellulose; and group 4, control diet plus 1.5% cholesterol, 20% microcrystalline cellulose and 1% sulfaguanidine.

The complete diets are listed in Table III. The rats were fed the diets *ad libitum* for 5 weeks. During the last week of feeding, the animals were kept in metabolism cages with wide mesh screen bottoms and the feces were collected daily and dried at 60° C. At the end of the feeding period, the rats were anesthetized with diethyl ether. Blood was drawn by heart puncture and serum separated. The liver was quickly removed, washed with normal saline to remove adhering blood, wiped between filter papers, and homogenized in a Potter Elvehjem homogenizer with ice cold distilled water. Free and total cholesterol in the serum and liver homogenates were estimated according to Abell *et al.* (1952). The total bile acids in the feces were estimated according to Mosbach *et al.* (1954). The ion exchange procedures of Kuron and Tennent (1961) were followed for the separation of the bile acids. Observations are summarized in Table IV. The addition of 1.5% cholesterol to the basal semipurified ration resulted in a highly significant ($P < 0.001$) increase in total plasma and liver cholesterol over that obtained when the basal ration alone was fed. Incorporation of 20% microcrystalline cellulose in the diet resulted in a significant reduction ($P < 0.01$) in liver and serum cholesterol levels. Plasma and liver cholesterol of rats fed sulfaguanidine supplements were not significantly different from that of rats fed on a similar diet without the sulfa drug. Sulfaguanidine did not modify the effects of cellulose administration. The rats receiving diets containing 20% microcrystalline cellulose excreted significantly ($P < 0.001$) higher amounts of bile acids (18.53 mg/per day) than those receiving basal ration containing cholesterol (8.24 mg per day).

DISCUSSION

Shurpalekar *et al.* (1969) and Narayana Rao and Sundaravalli (1970) have shown that incorporation of finely divided cellulose (>300 mesh) does not affect the gastric emptying time in adult rats or nitrogen utilization in young albino rats. Present studies have shown that incorporation of such a cellulose in the diet to even an extent of 20% does not seriously affect growth, but reduces the serum and liver cholesterol of rats receiving a hypercholesterolemic diet.

Inclusion of cellulose in the basal diet results in a decrease of productive energy. Rats have a remarkable ability to adjust their level of feed consumption within wide limits to compensate in large part for differences in productive energy content of otherwise adequate diets. However, the consumption of the diet is also influenced by the bulk density of the diet,

Table II. Effects of Inclusion of Microcrystalline Cellulose on the Body Composition of Rats[a]

Diet	Body weight Initial G	Body weight Final G	Gain in weight G	Diet intake G	Calories in diet kcal/100 g diet	Calorie intake kcal	Calories per g gain in wt, kcal	Body Composition Moisture %	Body Composition Fat %	Body Composition Protein %
Basal	40.2	144.2	104.0 ± 4.1[b]	223.4	442	987.7	9.50 ± 0.31[b]	64.4 ± 2.8[b]	12.59 ± 0.28[b]	17.79 ± 0.36[b]
5% Cellulose	39.9	147.0	107.1 ± 3.2	222.9	422	939.9	8.79 ± 0.28	64.4 ± 3.0	12.86 ± 0.26	17.29 ± 0.48
10% Cellulose	40.1	141.0	99.9 ± 3.3	220.0	402	916.0	8.83 ± 0.26	65.2 ± 2.6	11.44 ± 0.17	17.60 ± 0.31
20% Cellulose	39.9	135.8	95.9 ± 3.5	229.6	362	831.2	8.67 ± 0.27	66.2 ± 2.9	10.51 ± 0.21	17.67 ± 0.42

[a] 12 rats in each group; duration of experiment 4 weeks. [b] Standard deviation.

Table IV. Effect of Microcrystalline Cellulose on Plasma and Liver Cholesterol and Fecal Bile Acids in Cholesterol Fed Rats[a]

Supplements fed with basal ration	Body weight at sacrifice G	Plasma cholesterol Total Mg/100 ml	Liver cholesterol Total Mg/G	Fecal bile acids Mg/Day
None	134.7	63.8 ± 6.2[b]	1.87 ± 0.45[b]	4.29 ± 0.52[b]
1.5% cholesterol	135.2	146.6 ± 8.4	9.70 ± 0.81	8.24 ± 0.91
1.5% cholesterol + 20% cellulose	122.0	90.9 ± 7.3	7.97 ± 0.71	18.53 ± 1.56
1.5% cholesterol + 20% cellulose + 1% sulfaguanidine	114.6	92.7 ± 6.8	7.51 ± 0.74	18.53 ± 1.50

[a] 12 rats in each group; duration of experiment 5 weeks. [b] Standard deviation.

and the volume of feed significantly limited the amount of diet consumed. Finely divided cellulose, when suspended in water, occupies a larger volume than cornstarch and other components of the diet. The volumes occupied by 2 g each of cellulose or corn starch were 7.9 ml and 1.8 ml, respectively. The feed intake of the animals on the basal diet and experimental diet containing 5 to 20% microcrystalline cellulose was nearly the same. Significantly less ($P < 0.05$) calories were utilized per g of increase in weight, in the case of rats fed the 20% cellulose diet. This was reflected in the lowered body fat content of the rats.

Hill and Dansky (1954) also observed similar results in chicks. Incorporation of oat hulls to the extent of 40% in the basal diet did not significantly affect the normal growth of chicks. Differences in the energy consumption was reflected in the lowered fat content of the chicks.

The investigations of Wells and Ershoff (1961) have shown that the increased plasma and liver cholesterol induced by cholesterol feeding in the male rat could not be counteracted by the concurrent feeding of cellulose to the extent of 5%. Keys *et al.* (1961) reported similar results in humans. Present studies, however, have shown that cellulose at higher levels (20%) has a beneficial effect in lowering serum and liver cholesterol in rats receiving a hypercholesterolemic diet. The paucity of data on the fiber content of human diets makes it difficult to relate the present studies to diets as eaten normally. The amount of cellulose used in the present studies is certainly higher than commonly ingested in so-called civilized diets. A study of Hardinge *et al.* (1958) showed that the fiber intake could vary widely over a period of years without adverse effects on the digestive tract.

No data are available as to the mechanism whereby cellulose exerts its cholesterol lowering effect. A possibility is that cellulose which is not absorbed in the gut may induce changes in the intestinal microflora which results in greater degradation of bile acids, thereby leaving less of this material available for absorption. The failure of sulfaguanidine to modify the effects of cellulose administration, however, raises doubt as to the validity of this hypothesis. The increased excretion of bile acids in the feces by rats receiving the diet containing 20% cellulose could be responsible for the cholesterol lowering effect of cellulose. In rats injected radiocholate, Portman and Murphy (1958) reported that inclusion of 20% celluflour in a sucrose synthetic diet resulted in an increased excretion of cholate and degradation of products of cholate.

The microcrystalline cellulose used in the present study is of very fine particle size (>300 mesh) and could be easily incorporated in the diet without affecting the taste and acceptability. Earlier studies from our laboratory (Narayana Rao and Sundaravalli, 1970; Shurpalekar *et al.*, 1969) have shown that incorporation of this microcrystalline cellulose even to the extent of 20% does not affect the overall nutritional value of the diets or the utilization of protein. Probably incorporation of finely divided cellulose could be advocated for use in the low calorie diets for dietary treatment of obesity. This increases the bulk and may result in better satiety value of low calorie diets. The efficacy of cellulose in lowering serum and liver cholesterol confers an added advantage.

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