Short-Term Lipidemic Responses in Otherwise Healthy Hypercholesterolemic Men Consuming Foods High in Soluble Fiber[1]

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ABSTRACT

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This study examined the effect of foods high in water-soluble fiber on serum total cholesterol (CH), high-density lipoprotein CH, triglycerides, and glucose in otherwise healthy hypercholesterolemic (CH, 224 ± 24 mg/dl) men. Seventeen adults participated in this study and each served as his own control. Each consumed his usual diet for six weeks, and then for the next six weeks nearly doubled his daily soluble fiber intake from 5.0 to 9.4 g and total fiber intake from 15.0 to 28.3 g. Fiber in the diet originated from several refined cereal-based products, fruits, vegetables, and a supplement consisting of rice and oat bran. Results showed that serum total CH dropped between 1 and 17%, high-density lipoprotein-CH increased between 3 and 17%, triglycerides dropped between 3 and 46%, and glucose dropped between 1 and 9% in participants who responded favorably. Several participants did not respond favorably to one or more of the measurements, and where the response was favorable, it was consistent throughout the six-week test period only in a few participants.

To reduce the risk of heart disease, Americans are advised to lower their blood cholesterol (CH) levels (Anonymous 1984, 1985). Besides CH, elevated blood triglyceride levels are considered an independent risk factor in heart disease (Anderson 1980). For individuals with moderately elevated CH levels, diet modification and weight control are the first choices in therapeutic management of hyperlipidemia (Schucker et al 1987).

Diet modification invariably requires restricting the amount and type of dietary fat as well as CH. However, studies in recent years (Jenkins et al 1980, Behall et al 1984, Anderson et al 1984a, Anderson and Tietyen-Clark 1986) have shown that soluble fiber (SF) originating from various gums, beans, and oat bran may also be an effective hypocholesterolemic (and hypoglycemic) agent.

Fruits and vegetables are also a good source of SF. Although grain products other than oats are low in SF, in many refined grain products, a good portion of the total dietary fiber may be SF. This was recently documented for white bread (Ranhotra and Gelroth 1988a) and soda crackers (Ranhotra and Gelroth 1988b). Thus, several foods can be included in the diet when an increase in SF is desired. The purpose of this study was to examine the effect of SF originating from a wide variety of foods, including refined cereal-based products, on blood total CH, high-density lipoprotein (HDL)-CH, and triglyceride levels in men with moderately elevated blood CH levels; effect on blood glucose levels was also examined.

MATERIALS AND METHODS

Subjects

Seventeen men from the local community participated in the study. Based on the questionnaire they filled out, 15 listed no known abnormality of lipid or glucose metabolism or heart function. One had suffered a previous heart attack and one was mildly diabetic (type II). The participants ranged in age from 37 to 60 years and in weight from 155 to 236 pounds. None were considered obese. Fasting serum total CH of the participants averaged 224 ± 24 mg/dl (± SD); fasting triglyceride levels averaged 179 ± 289 mg/dl. The study was approved by the Committee on Research Involving Human Subjects of Kansas State University, and informed consent was obtained from each participant.

Experimental Design

The study consisted of a six-week control period followed by a six-week test period. All participants consumed their usual diet during the control period but maintained daily records for the first four weeks. Daily records were also maintained during the test period when additional fiber was included in the diet. Three blood samples—two weeks apart each—were collected during each of the two periods for lipid and glucose determinations. All participants were supplied with a listing of cereal-based and other foods identified as good sources of SF and were encouraged to include these foods in their daily menu. Additional SF was also provided as a diet supplement containing 30 g each of processed rice bran and oat bran.

Blood Sampling, Measurements and Statistics

Blood samples were collected by venipuncture at the local clinical laboratory. Sampling followed an overnight fast of 12 hr. Total CH, triglycerides, and glucose were measured in the resultant serum enzymatically using a Technicon SMA system (Technicon Instruments Corp., Tarrytown, NY). HDL-CH in the serum was determined following precipitation (used magnesium and dextran sulfate) of all fractions of serum lipoproteins except the HDL; the same method used for total CH determination was then used to determine CH in the supernatant.

Rice and oat brans were analyzed for total dietary fiber by the method of Prosky et al (1985). Modifications in the method (additional filtration and precipitation steps) allowed separate determination of SF. Nutrient intakes, based on records maintained by the participants, were calculated using the microcomputer program Nutritionist III, from N-Squared Computing, Silverton, OR (Table I). Total dietary fiber and SF values were calculated based on data generated in our laboratory and from other sources but primarily that published by the HCF Diabetes Research Foundation (Anderson 1986). Each subject served as his own control.

RESULTS AND DISCUSSION

Test Subjects

Based on serum total CH measurements made during the control period (average 224 ± 24 mg/dl), participants can be classified as moderately hypercholesterolemic, a condition appropriately treated by dietary modification. To minimize diurnal and daily variations, baseline (control) values for serum total CH, HDL-CH, triglycerides, and glucose represent the average of three measurements (which differed minimally for most participants) during the control period (Table II).

Body Weight

Individual weight loss or gain during the test period ranged between one and seven pounds. Average weight, however,

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remained identical from the beginning (187 ± 25 lb) to the end (187 ± 24 lb) of the test period. Consequently, body weight change may be excluded as a factor influencing blood lipid and glucose responses.

Nutrient Intakes

The participants consumed about twice as much fiber—total and soluble—in the test period as in the control period (Table I). The intake of other diet components was not significantly different between the two study periods. When diet is modified, a complete absence of differences in nutrient intakes between the two regimens is difficult to achieve in individuals who are not in institutions. However, the differences noted in this study were small indeed and, thus, likely had a minimal effect on blood responses measured. Polysaturated and saturated fat ratios were, in fact, identical in the two periods, and the CH intake was only slightly lower in the test period.

In both periods, SF represented one-third of the content of total dietary fiber consumed. A higher SF intake was intended, but very few foods contain SF in high enough amounts to permit this. The rice and oat bran supplement provided 15.3 g of total dietary fiber that included 4.6 g of SF. Many participants failed to consume the entire amount each day.

Serum Total CH

Serum total CH values for each subject are shown in Table II. Although the mean total CH values during the test period were not significantly different from that of the control period, individual responses varied greatly. Two subjects (WD and LS) showed a CH-lowering effect that persisted throughout the six-week test period. Many others showed a lowering effect at one or two of the three sampling periods. Three participants, however, showed a consistent increase. This increase was most profound for the subject ML. Other lipid measurements on this subject were also highly unfavorable (Table III).

The magnitude of the CH-lowering effect, where observed, ranged between 1 and 17% compared with the control values. This is graphically illustrated in Figure 1. In studies reported by Anderson et al (1984a,b), an average drop of 23% in serum CH was observed in participants who lived in the hospital; their SF intake (from oat bran or beans) was about twofold higher than achieved here. With guar and arabic gum, others (Behall et al 1984) have also reported a decrease in serum CH but of a lesser magnitude. A drop in serum CH exceeding 20% is rarely observed in uninstitutionalized individuals unless the diet is drastically modified. The increase in bile acid excretion due to colonic fermentation of SF is postulated as a probable mechanism for the CH-lowering effect (Vahouny and Cassidy 1985); attenuation of hepatic CH synthesis due to short-

TABLE I
Average Daily Nutrient Intake of Subjects During the Control and Test Periods

	Intake	
Nutrient	Control Period	Test Period
Energy (kcal)	2,378 ± 431	2,331 ± 419
Protein (% kcal)	15.6 ± 2.1	16.6 ± 1.3
Carbohydrates (% kcal)	48.5 ± 6.5	51.6 ± 5.8
Fat (% kcal)	35.3 ± 4.7	33.9 ± 4.9
Saturated fat (g)	25.5 ± 4.6	23.0 ± 5.0
Monounsaturated fat (g)	20.6 ± 6.2	19.7 ± 7.0
Polyunsaturated fat (g)	11.6 ± 4.6	10.3 ± 4.6
P:S (ratio)	0.45	0.45
Cholesterol (mg)	260 ± 87	242 ± 64
Fiber (g)		
Total	15.0 ± 5.8	28.3 ± 4.7
Soluble	5.0 ± 1.6	9.4 ± 1.5

TABLE II
Serum Total Cholesterol Levels of Individual Subjects During the Control and Test Period[a]

	Total Cholesterol (mg/dl)			
		Test Period		
Subject	Control Period	2 Week	4 Week	6 Week
DB	246	265	285	269
GB	207	226	191	203
EB	214	211	208	216
JC	231	255	230	245
DC	194	200	193	210
WD	241	221	227	237
DH	186	168	174	188
CH	224	219	230	200
HH	267	256	262	264
DK	229	199	237	242
ML	198	237	265	270
TM	223	232	217	235
LS	272	226	260	259
RS	195	184	···	212
JS	219	212	239	239
RW	232	201	242	218
RZ	224	214	220	224

[a] Average (± SD) body weight of subjects: Initial, 187 ± 25 g; final, 187 ± 24 g. Age ranged between 37 and 60 years.

TABLE III
Percent Change in Serum High-Density Lipoprotein Cholesterol, Triglyceride, and Glucose Levels in Individual Subjects Fed Additional Fiber

	High-Density Lipoprotein Cholesterol				Triglycerides				Glucose			
	Control Period[a]	Percent Change[b]			Control Period[a]	Percent Change[b]			Control Period[a]	Percent Change[b]		
Subject	(mg/dl)	2 Week	4 Week	6 Week	(mg/dl)	2 Week	4 Week	6 Week	(mg/dl)	2 Week	4 Week	6 Week
DB	39	0	0	+3	137	+8	+55	−21	97	+1	+4	−9
GB	30	0	−20	+3	135	+56	−3	−33	108	+10	−3	−3
EB	36	−17	−14	−11	240	−7	−5	+10	98	+5	+7	−1
JC	55	+11	+9	+9	43	−9	−7	+21	86	+5	0	+3
DC	38	−8	−18	+13	80	+6	+45	−2	110	+6	−11	+7
WD	48	+8	+15	0	92	−4	+16	+20	101	+9	+4	+6
DH	22	0	−27	+5	365	−19	+1	−15	102	0	−3	+8
CH	30	+17	0	−17	203	−6	−3	−26	143	+5	−2	−4
HH	39	+10	+8	0	161	−15	+9	−2	100	−4	−1	−7
DK	34	−21	−21	−12	344	−30	+29	+19	101	+3	+9	0
ML	35	−23	−11	−9	183	+68	+31	+99	93	0	0	−6
TM	48	0	−2	+10	93	−2	−29	−22	104	+8	+9	+22
LS	41	−7	−15	−12	162	−7	+7	+37	96	−1	+4	−4
RS	36	−6	···	−14	178	−12	···	+3	112	+23	···	+45
JS	31	−10	+10	+16	186	+8	+18	+12	91	+8	+8	+22
RW	34	−6	−9	−12	271	+1	−46	−15	97	−5	−2	−4
RZ	39	−8	+5	−21	113	+83	+172	+35	99	−4	−4	−5

[a] Average of three samplings during the control period.
[b] Compared with control values.

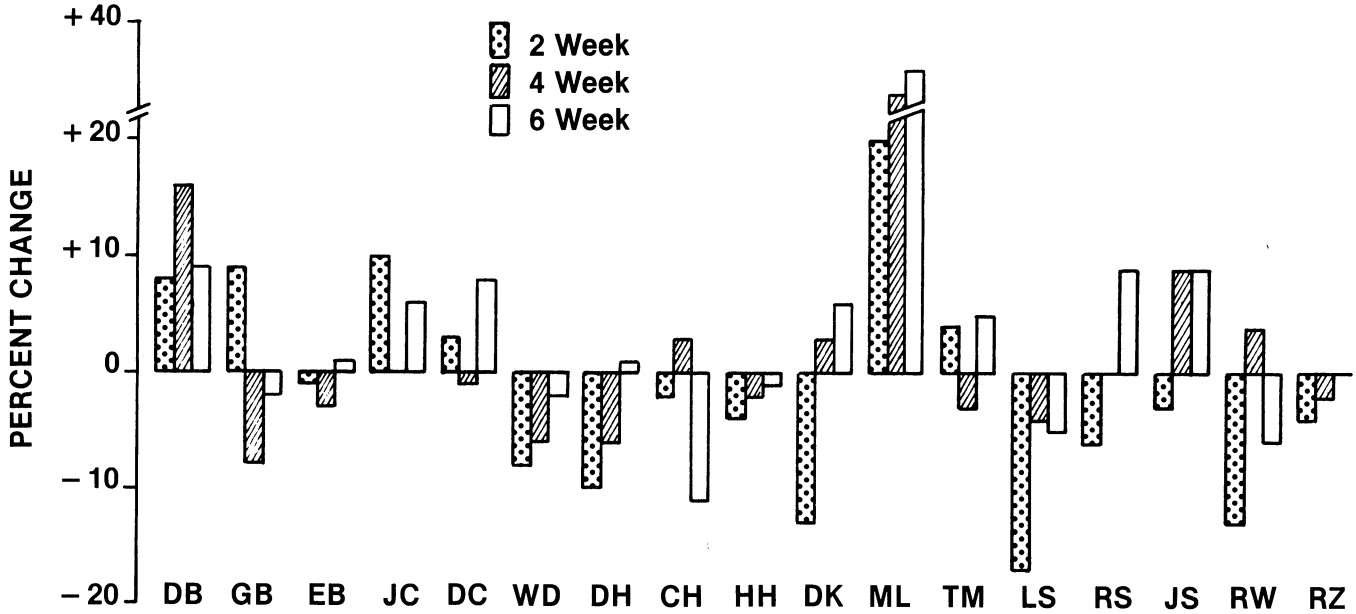

Fig. 1. Percent change (increase or decrease) in serum total cholesterol at two, four, and six weeks during the test period. Participants are identified by initials corresponding to those in Tables II and III.

chain fatty acids absorbed from the colon may be another CH-lowering mechanism (Chen et al 1984).

Serum HDL-CH

Serum HDL-CH levels appear to be inversely related to the incidence of heart disease (Anonymous 1984, 1985). The effect of fiber—total or soluble—on HDL-CH is little known. The responses obtained in this study are shown in Table III. Only one participant (JC) showed a persistent increase in HDL-CH. Several other participants also showed an increase but only at one or two of the three sampling periods. The magnitude of this increase varied between 3 and 17%. In contrast, several individuals also showed a decrease in HDL-CH; subject ML showed a decrease of up to 23% compared to his baseline value. In human subjects fed oat bran or beans, Anderson et al (1984a,b) reported an average drop of 20% in HDL-CH. These subjects also experienced weight loss, whereas subjects in this study maintained body weight. In some individuals (WD and HH, for example), a drop in serum CH paralleled an increase in HDL-CH.

Serum Triglycerides

Serum triglyceride levels above 250 mg/dl can be a marker for secondary disorders for a subset of patients with genetic forms of hypertriglyceridemia. Dietary intervention is the primary preventive treatment for these individuals. In this study, the baseline serum triglyceride values in five individuals exceeded 200 mg/dl (Table III). They all showed a triglyceride-lowering effect during the test period, although this effect was persistent throughout only in one subject (subject CH). Several others also showed a lowering effect, but it varied, ranging between 3 and 46%. Anderson et al (1984a) reported an average lowering effect of 21% in subjects fed oat bran and beans for three weeks. On other SF sources, no triglyceride-lowering effect was observed, however (Behall et al 1984). For several participants (CH, TM, and RW, for example), the triglyceride-lowering effect was positively correlated with lower CH.

Increase in carbohydrate intake, unless accompanied by an increase in fiber, often leads to hypertriglyceridemia. In this study, the increase in carbohydrate intake (during the test period) was modest (Table I) while fiber intake of the participants increased substantially.

Serum Glucose

SF is reported (Anderson and Bryant 1986) to lower insulin dose in diabetics. It is also reported to attenuate postprandial serum glucose responses. In this study, fasting glucose levels in the one subject (CH) who was mildly diabetic, dropped 4% at the end of the test period (Table III). All other participants showed either a drop or an increase. Where glucose levels dropped, the effect was persistent throughout in only three subjects (HH, RW, and RZ). In others, a drop occurred at one or two of the three sampling periods with a magnitude that ranged between 1 and 9%. Three individuals (TM, JS, and RS) showed a sizable increase in fasting glucose levels.

CONCLUSIONS

In otherwise healthy hypocholesterolemic individuals, the effect of modifying diet to induce desirable lipidemic responses is difficult to study because other dietary factors influencing these responses are difficult to factor out. Such was the case in this study. To maximize the number of participants and to sort our responders and nonresponders, each individual in this study served as his own control. Although the intake of total dietary fiber and SF varied greatly among the participants, the overall increase in fiber intake was nearly double the baseline intake values, with a minimal change occurring in other diet components. Restricting cholesterol and saturated fat in the diet may augment desirable lipidemic responses, but this study was limited to examining the effect of additional SF.

For about half of the participants, increasing SF lowered circulating CH and triglyceride levels with some increase also occurring in HDL-CH. Desirable correlations were seen in these responses but only in a few participants. Several participants failed to respond favorably to SF in the diet. This suggests that the level of SF tested may have been inadequate or that SF may not be the sole answer to managing elevated serum CH and triglyceride levels even when the levels are not excessively elevated.

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