Effects of some cereal brans and textured vegetable protein on plasma lipids

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ABSTRACT The hypothesis that dietary fiber lowers serum cholesterol was tested in 10 healthy men, 19 to 54 years old, who ate a mixed diet similar to the diets of many American adult males, that contained 15% of calories as protein (70% from animal), 40% as fat (P/S = 0.3), 44% as carbohydrate (9% of calories as sucrose) and 3 g of crude fiber. The energy intake ranged from 2700 to 3500 kcal adjusted to their height and weight. Weight and fitness were held constant. After 30 days of equilibration on the basal diet, they ate 26 g of either 50% white wheat bran, corn bran (CB), soybean hulls (SH), textured vegetable protein, or hard red spring wheat bran (HRS) for periods of 28 to 30 days each in no particular sequence. Each fiber was fed to four to six subjects. The dietary fiber contents of soft white wheat bran, CB, SH, and HRS were: 44, 82, 87, and 51%, respectively. Mean daily fecal weight increased (P ≤ 0.01) from 72.4 to 144.68 to 128, and 151 g when CB, SH, and HRS were fed respectively. No effects were noted with soft white wheat bran or textured vegetable protein. Total plasma cholesterol decreased 12% with HRS (P ≤ 0.05) and 14.0% with SH (P ≤ 0.05). Low density lipoprotein cholesterol decreased 21% with HRS (P ≤ 0.05). High density lipoprotein cholesterol did not change with any of the dietary fiber sources nor did the ratio of high density lipoprotein cholesterol to total cholesterol. Some triglyceride lowering effect was seen with all sources of dietary fiber (P ≤ 0.01). There was a significant direct correlation between the area under the oral glucose tolerance curves and the levels of total cholesterol (r = 0.57, P ≤ 0.0001) and low density lipoprotein cholesterol (r = 0.49, P ≤ 0.0007), and between fasting plasma glucose and triglycerides (r = 0.32, P ≤ 0.03). Results were replicated when subjects were fed the same fiber source on two occasions at 2 to 4 month intervals. Am. J. Clin. Nutr. 32: 580-592, 1979.

The increased incidence of degenerative and malignant diseases observed in Western countries in recent years has been attributed, in part, to changes in dietary habits (1-4). During the past century, the production and consumption of refined carbohydrates have apparently increased more than 100% (5). Today, more animal and less vegetable protein are consumed. Less bread and other cereal foods are eaten (6), and these foods are prepared from low-extraction flour (7). Whereas some investigators (8, 9) have postulated that the increased consumption of refined carbohydrates is the principle factor for the high prevalence of degenerative diseases in Western countries, Burkitt et al. (1) and others (2-4) attach the principle blame to the widespread consumption of foods low in dietary fiber. Burkitt and Trowell (10) have __________

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5 From the United States Department of Agriculture, Science and Education Administration, Northern Re
reviewed the epidemiological and experimental evidence that supports their hypothesis. However, other investigators have disputed the hypothesis that “fiber deficiency” is the cause for the recent increased incidence of degenerative diseases in the Western countries (11, 12).

How dietary fiber might prevent atherosclerosis and ischemic heart disease is not clear. Because the level of serum cholesterol is lower in people who have higher intakes of dietary fiber than in Western people who consume less dietary fiber (4), and because hyperlipidemia is a well known risk factor in the development of atherosclerosis and ischemic heart disease, several investigators have evaluated the effects of a variety of sources of dietary fiber or fractions of dietary fiber on serum lipids and atherosclerosis. Experiments in animals have shown that the feeding of certain plant fibers not only lowers serum cholesterol, but also ameliorates atherosclerosis and decreases the concentration of cholesterol in the liver (13–22). In other studies, certain plant fibers had no hypocholesterolemic effects (13, 23) and some have shown to elevate serum levels and hepatic synthesis of cholesterol (24, 25).

In humans, a hypocholesterolemic effect of dietary fiber has not always been found. Some studies have shown that dietary fiber lowers blood lipids (26–35), whereas others have shown no effects on serum cholesterol or triglycerides (36–46). These differences in findings might be due to several factors. First, dietary fiber is a heterogenous material and the composition of plant fiber varies among plants (47). Perhaps as a consequence, lipid lowering effects of dietary fiber have been reported for oat fractions (31), Bengal gram (Cicer arietinum) (33), pectin (26–29, 35) and guar gum (35), but not for wheat bran (36–42) or cellulose (26). Second, cooking may be a factor because cooked bran apparently has less effect on intestinal transit than does a comparable amount of raw bran (48). Third, the amount of fiber consumed is probably a factor (28, 48, 49). Fourth, in some studies, the control diet was a “formula” (34), in others, it was “a basic low fiber diet” and in others, the diet was modified when fiber was introduced (30).

The above observations prompted us to assess the effects of the American Association of Cereal Chemists soft white wheat bran (SWW), dry milled corn bran (CB), soybean hulls (SH), textured vegetable protein (TVP), and waldron strain hard red spring wheat bran (HRS) on total serum cholesterol and its fractions, serum triglycerides, stool frequency, stool weight, and stool fat of healthy volunteers studied under carefully controlled conditions. Although TVP contains only 14 to 17% acid and neutral polysaccharides (50), we decided to study its effects on serum lipids because others have reported that it lowered the levels of serum lipids (51, 52).

Materials and methods

Study design

Twelve male volunteers, 19 to 54 years old were admitted to the metabolic unit of the USDA, SEA Human Nutrition Laboratory after they gave informed consent according to the Declaration of Helsinki, and after medical, psychological, and nutritional evaluations established their normality. They lived in the metabolic unit for periods of 4 to 6 months under close supervision. They were fed a constant diet, similar to diets consumed by many American males, prepared from conventional foods, and designed to meet their individual nutrient needs according to guidelines of the United States National Research Council (53). The basal diet contained about 16% of calories as protein (70% from animal), 40% as fat (linoleic:saturated fat ratio = 0.3) and 44% as carbohydrate with 9 ± 2% of calories as sucrose. The calculated dietary cholesterol ranged from 360 to 780 mg/day. Dietary cholesterol was increased over the control level in some individuals in association with an increase in calories, or a modification in the diet to improve acceptance. The calculated crude fiber content was 1 g/1000 kcal. The menus were repeated in a 6-day cycle. Examples of three menus are given in Table 1. To maintain a constant level of fitness, the previous level of physical activity of the volunteers was estimated by history, and they were given an exercise prescription on a treadmill according to the guidelines of Cooper (54). Their aerobic points ranged from 0 to 35/week. Their previous calorie intakes were also estimated by history.
The loaves of bread were prepared and frozen at the USDA, SEA, Spring and Durum Wheat Quality Research Laboratory, Fargo, North Dakota, and baked at the Human Nutrition Laboratory (see Appendix).

Of the 12 volunteers, six had a second basal period halfway through their time on the Unit, i.e., either their 3rd or 4th month after having had two or three periods of dietary fiber. Each subject had at least two different sources of dietary fiber and four of them ate the same dietary fiber during two different balance periods, 1 to 3 months apart.

Body composition was assessed by measuring four skin folds (biceps, triceps, subscapular, and suprailiac) with the Holtain/Tanner-Whitehouse Skinfold Caliper which delivers a constant pressure of 10 g/mm² over a range of openings from 0 to 48 mm; and by measuring mid upper arm circumference. The percentage of fat was estimated by the Siri's equation:

\[
\text{\% fat} = \left( \frac{4.95}{\text{density}} - 4.50 \right) \times 100
\]

where density was estimated from the log of the sum of four skinfold thicknesses, using the linear regression equation of Durnin and Womersly (55). The muscle circumference was estimated with Jelliffe's formula:

\[
\text{Mc} = C_1 - \pi S \text{ cm} \quad (56)
\]

where \(\text{Mc} = \text{muscle circumference}, C_1 = \text{mid upper arm circumference in cm, and } S = \text{triceps skin fold in cm.}\)

### Measurements of plasma lipids and glucose

Plasma triglycerides were measured, after 12 hr of fasting, by the manual procedure of Giege et al. (57). Total plasma cholesterol was measured by the method of Leffler and McDougal (58). High density lipoprotein (HDL) cholesterol in plasma was determined by the heparin-manganese precipitation method (59) and low density (LDL) cholesterol was determined indirectly, according to Friedewald et al. (60), by subtracting HDL cholesterol and very low density lipoprotein cholesterol (estimated as \(1/5\) of plasma triglycerides) from total cholesterol. The mean batch-to-batch percent coefficient of variation of plasma cholesterol was 2.7%. Plasma glucose was determined by a glucose oxidase-peroxidase method (61).

### Percent composition of fiber sources

Cellulose and lignin contents of the bran were determined by the Holst modification of the Van Soest acid detergent method (62). Starch content of the bran was estimated by taking a portion of 18 to 30 mesh sample, grinding it to pass a 16-mesh screen, and then incubating the material with amyloglucosidase (63). Starch was estimated by measuring glucose generated by amyloglucosidase action upon the ground bran. Glucose was determined using a glucostat procedure (64). Protein was measured by amino acid analysis (65) of a separate portion of the finely ground bran.

Phytic acid, as ferric phytate, was extracted and precipitated by the procedure of Wheeler and Ferrel (66). Phytate phosphorus was measured by wet ashing the

### TABLE 1

Typical daily diet

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<tr>
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<td>Noon meal</td>
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<td>Cheese</td>
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ferric phytate precipitate with concentrated nitric acid and determining phosphorus by 1) a colorimetric method in which phosphomolybdic acid was reduced to a blue complex (67) and 2) by gravimetric determination as ammonium phosphomolybdate (68). The particle size distribution of the wheat and corn brans were controlled by passage through a 18-mesh and collection on a 30-mesh U.S.A. Standard Sieve (1.00 and 0.59 mm openings, respectively). The soybean hulls were passed through a 25-mesh. Of the particles 85% were collected on a 40-mesh and the remaining 15% on a 60-mesh U.S.A. Standard Sieve.

Statistical analysis

Data were analyzed by computer with paired t test using Dunnett's correction for multiple comparisons to a control (69), and by simple regression analysis (70). Dunnett's tables do not include t test critical points for groups smaller than 5, so one-way analysis of variance with Scheffe (71) contrasts was substituted for such groups. The area under the glucose tolerance curve was determined by numerical integration via the trapezoid rule (72).

Results

The volunteers accepted the diet well and experienced no untoward effects.

Effects of diet on body weight and skin folds

During their stay in the metabolic unit, the mean coefficient of variation for body weight of the 17 volunteers averaged 0.76% with a range from 0.46 to 1.18%; the coefficient of variation for their skin fold measurements averaged 0.098% with a range from 0.069 to 0.122%. Percentage fat increased slightly in all the volunteers; the increases averaged 0.85% with a range from 0.3 to 1.8%.

Effect of diet on fecal weight

The average daily stool wet weights and the number of stools per week significantly increased in volunteers fed CB, SH, and HRS. SWW significantly increased the daily stool weights, but not the number of stools per week. No significant changes were seen when they were fed TVP, nor during the second basal period (Tables 2 and 3). The amount of fecal fat, expressed either as grams per 24 hr or as percentage of intake did not change significantly as a function of diet, F ≤ 0.94 and ≤ 0.09, respectively (by analysis of variance and Scheffe contrasts (71)).

Effect of diet on plasma lipids

There was no relationship between dietary cholesterol, time in the study, and total plasma cholesterol.

The total plasma cholesterol (Table 4) fell from a mean of 172.4 (SEM ± 8.8) to 147.8 (SEM ± 10.2) P < 0.05 and from a mean of

| Table 2
| Average daily stool weights (g)* |
|------------------|-----|-----|-----|-----|-----|-----|
| Volunteer no.    | Basal I | Basal II | SWW | CB | SH | TVP | HRS |
| 1                | 27.1 | 42.3 | 65.6 | 95.4 | 59.3 |
| 2                | 56.5 | 62.5 | 97.4 | 142.5 | 118.5 |
| 3                | 78.1 | 76.1 | 117.3 | 149.1 | 114.5 |
| 4                | 103.9 | 201.9 | 193.0 | 129.2 | 198.6 |
| 5                | 86.2 | 106.9 | 139.0 | 128.2 | 135.6 |
| 6                | 60.0 |       | 142.6 |     |     |
| 7                | 91.76 |       | 155.2 |     |     |
| 8                | 72.2 | 69.0 |       | 60.5 | 128.4 |
| 9                | 99.6 | 99.1 |       | 115.5 | 155.2 |
| 10               | 63.43 | 84.6 | 137.7 | 132.6 |     |
| 11               | 49.81 |       | 101.7 |     |     |
| 12               | 87.96 |       | 103.2 |     |     |

Mean ± SEM 72.2 ± 7.9 98.8 ± 7.2 144.3 ± 10.8 128.2 ± 15.9 101.7 ± 21.0 150.7 ± 8.0
Basal I mean ± SEM 66.1 ± 9.9 64.3 ± 9.8 72.4 ± 9.7 67.9 ± 9.3 91.9 ± 9.9 81.1 ± 6.01
P = NS ≤0.01 ≤0.01 ≤0.01 NS ≤0.01

* SWW, soft white wheat bran; TVP, textured vegetable protein. * Fed 3 to 4 mo after admission and after having had two cycles of high fiber diet.
TABLE 3
Average number of stools per week*

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<th>Volunteer no.</th>
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<th>Basal II</th>
<th>SWW</th>
<th>CB</th>
<th>SH</th>
<th>TVP</th>
<th>HRS</th>
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Mean ± SEM 3.7 ± 0.28 5.2 ± 0.70 5.8 ± 0.39 5.5 ± 0.28 4.1 ± 0.60 6.1 ± 0.38
Basal I mean ± SEM 3.9 ± 0.35 4.2 ± 0.67 4.7 ± 0.51 4.3 ± 0.38 4.5 ± 0.52 4.7 ± 0.48
P = NS NS ≤0.05 ≤0.05 NS ≤0.01

* SWW, soft white wheat bran; TVP: textured vegetable protein. Fed 3 to 4 mo after admission and after having had two cycles of high fiber diet.  

TABLE 4
Total plasma cholesterol (mg/dl)*

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Mean ± SEM 163.6 ± 6.9 163.2 ± 12.8 156.6 ± 9.3 147.8 ± 10.2 155.0 ± 3.5 148.7 ± 10.1
Basal I mean ± SEM 170.2 ± 9.2 165.7 ± 9.6 176.0 ± 8.9 172.4 ± 8.8 161.0 ± 8.5 168.1 ± 7.6
P = NS NS NS ≤0.05 NS ≤0.05

* SWW, soft white wheat bran; TVP: textured vegetable protein. Fed 3 to 4 mo after admission and after having had two cycles of high fiber diet.  

168.1 (SEM ± 7.6) to 148.7 (SEM ± 10.1) P < 0.05 when SH and HRS were fed, respectively. No significant changes were observed when SWW, CB, or TVP were fed, nor during the second basal period.

The LDL cholesterol (Table 5) fell from a mean of 106.0 (SEM ± 8.1) to 83.4 (SEM ± 9.7) P < 0.05 when HRS was fed. No significant changes were observed with the other sources of dietary fiber. Neither the HDL cholesterol nor the HDL cholesterol/total cholesterol changed.
Plasma triglycerides decreased some with the administration of all dietary fiber sources, except TVP. The difference was significant ($P \leq 0.01$) when the data obtained with SWW, CB, SH, and HRS were grouped and compared with the findings during the control period (Fig. 1).

There was a significant direct correlation between the area under the oral glucose tolerance curves and the plasma levels of total cholesterol ($r = 0.57$, $P \leq 0.0001$) (Fig. 2) and LDL cholesterol ($r = 0.49$, $P \leq 0.0007$) and between fasting plasma glucose and triglycerides ($r = 0.32$, $P \leq 0.03$) (Fig. 3). There was an inverse correlation between fecal weight and plasma cholesterol ($r = -0.30$, $P \leq 0.05$).

### TABLE 5
Plasma LDL cholesterol (mg/dl)$^a$

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<th>Volunteer no.</th>
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<td>77.2</td>
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<td>135.4</td>
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<td>90.0</td>
<td>67.5</td>
<td>81.8</td>
<td>64.8</td>
<td>60.2</td>
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<td>63.6</td>
<td>95.2</td>
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<td>88.2</td>
<td>102.0</td>
<td>90.0</td>
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<td>70.6</td>
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</tbody>
</table>

Mean ± SEM
- Basal I mean ± SEM 107.7 ± 11.0 113.1 ± 13.7 102.5 ± 9.7 115.2 ± 8.1 110.5 ± 8.9 93.6 ± 11.9 104.5 ± 8.1
- Basal I mean ± SEM 101.1 ± 10.8 102.5 ± 9.7 115.2 ± 8.1 89.4 ± 9.6 93.0 ± 5.9 82.9 ± 9.6

**Discussion**

Unlike many other studies, the diet in this study was similar in composition to diets

### TABLE 6
Fiber analysis (62-68)

<table>
<thead>
<tr>
<th></th>
<th>AACC soft white wheat bran</th>
<th>Corn bran</th>
<th>Soy hull</th>
<th>Hard red spring wheat bran</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemicellulose</td>
<td>32.0</td>
<td>70.0</td>
<td>33.0</td>
<td>38.0</td>
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<td>Cellulose</td>
<td>9.1</td>
<td>22.0</td>
<td>53.0</td>
<td>9.3</td>
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<td>Lignin</td>
<td>3.0</td>
<td>0.1</td>
<td>0.7</td>
<td>3.5</td>
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<tr>
<td>Phytate phosphorus</td>
<td>0.5</td>
<td>0.6</td>
<td>4.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Ash</td>
<td>5.7</td>
<td>&lt;1.0</td>
<td>&lt;1.0</td>
<td>7.8</td>
</tr>
<tr>
<td>Starch</td>
<td>31.0</td>
<td>&lt;1.0</td>
<td>&lt;1.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Protein</td>
<td>15.0</td>
<td>5.5</td>
<td>7.0</td>
<td>20.9</td>
</tr>
<tr>
<td>Oil</td>
<td>4.0</td>
<td>0.6</td>
<td>0.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Total fiber</td>
<td>44.1%</td>
<td>92.1%</td>
<td>86.7%</td>
<td>59.8%</td>
</tr>
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</table>
commonly consumed. The amounts of cholesterol, polyunsaturated and saturated fat, protein, total carbohydrate, sucrose, and total energy changed very little. Thus, the principle differences among experimental periods were the amounts and sources of dietary fiber. Because diet was adjusted to meet energy needs and exercise was prescribed to maintain fitness, the changes in body weight and composition occurred slowly. The minimal changes in body composition were due to slight increments in the percentage fat. These did not appear to contribute to the changes in cholesterol because serum cholesterol was not related to time in the metabolic unit. Besides, the physiological day-to-day variation (percent coefficient of variation) of plasma cholesterol in healthy individuals has
been reported to be 4.8 to 5.3% (73, 74) and the hour-to-hour within-day coefficient of variation has been reported to be 3.8% (74); both values are markedly lower than the changes observed in this study.

Although it is widely held that plasma cholesterol decreases during hospitalization or confinement, we observed that whereas some volunteers experienced a decrease in plasma cholesterol from the admission value when fed the basal diet, others showed an increase. The mean difference between admission and basal cholesterol levels for the 10 volunteers was: 21.4 mg/dl (SEM ± 9.72), \( P \leq 0.06 \).

Because the changes in plasma cholesterol were not related to the time the volunteers spent in the metabolic unit and because plasma cholesterol was not significantly affected by dietary cholesterol, it seems likely that the significant differences in cholesterol and its fractions were caused by the addition of the fiber sources to the diet.

A reduction in total plasma cholesterol of 14.0% (range: 6.33 to 26.25%) occurred when SH was fed to five volunteers (\( P \leq 0.05 \)). HRS caused a reduction of 12% (range 0 to 26%) in nine volunteers (\( P \leq 0.05 \)). One subject who was fed HRS did not experience a decrease in his cholesterol level. Plasma cholesterol also decreased in five of six volunteers fed CB (3 to 21.87% reduction), but the decrease was not significant for the group because one subject displayed an increase. SWW and TVP did not affect total plasma cholesterol. Sirnori et al. (51) reported that TVP significantly lowered plasma cholesterol in a group of patients with type II hyperlipoproteinemia. Their findings were undoubtedly due to the replacement in the diet of almost all the animal protein by vegetable protein, and to the very low levels of cholesterol (0 to 6 mg/day) in their diet.

From this study it is not clear if the effect of some sources of dietary fiber on plasma cholesterol are related to the amount or the type of dietary fiber fed. While HRS caused a 12% reduction in plasma cholesterol, SWW caused no significant effects. Because the composition and the amount of dietary fiber in both brans are similar (Table 6), the failure of SWW to lower plasma cholesterol is difficult to explain. An obvious possibility is the presence of something in the bran other than dietary fiber that lowers plasma cholesterol. The fact that CB which has the highest content of dietary fiber was less effective in lowering plasma cholesterol than HRS tends to support this suggestion. The report of a glycoprotein isolated from black gram \( (Phaseolus mungo) \) which has hypocholesterolemic effects in rats (75) also supports this interpretation. Another possibility is that some persons are not susceptible to the hypocholesterolemic...
olemic effect of dietary fiber. Two of the six
volunteers fed SWW displayed a cholesterol-
lowering effect that was similar to that seen
with CB, SH, and HRS and four of the nine
subjects fed HRS did not show marked cho-
lesterol-lowering. These findings might sup-
port the above suggestion of individual sus-
ceptibility to dietary fiber. HDL cholesterol
and the ratio of HDL cholesterol to total
cholesterol did not change significantly with
the feeding of any of the dietary fiber sources.
LDL cholesterol decreased 21% ($P \leq 0.05$)
when volunteers were fed HRS. Recent stud-
ies suggest that the plasma levels of HDL and
LDL cholesterol are more important than the
level of total cholesterol as predictors of cor-
onary artery disease (76–79). Therefore, the
effects of dietary fiber on cholesterol fractions
may be more important than its effects on
total cholesterol. Similar effects have been
reported for vegetarian diets (80).
SWW was less effective in increasing daily
stool weights and the number of stools per
week. In contrast, HRS was associated with
an average fecal weight of 151 g/day, signifi-
cantly higher than the basal fecal weight of
81 g/day (Table 2). Recently, Spiller et al.
(81) have shown that the minimum fecal
weight necessary to modify intestinal transit
time was 140 to 150 g/day. HRS had the
most significant hypocholesterolemic effect
and was associated with the highest fecal
weight; linear regression analysis showed a
significant correlation between fecal weight
and plasma cholesterol ($r = -0.30, P \leq 0.05$).

Several mechanisms have been postulated
to explain the hypocholesterolemic effect of
Certain sources of dietary fiber. Impaired in-
testinal absorption of cholesterol and bile
acids (82–85) and in vitro binding of bile
acids by various types of dietary fiber (86, 87)
have been reported. However, the significant
binding of fat and bile acids by bagasse was
not associated with significant changes in
serum cholesterol (40). We did not measure
bile acids, but the amount of fecal fat did not
increase when dietary fiber was fed ($P \leq 0.9$).
Apparently the binding of bile acids by fiber
and the hypocholesterolemic effects of fiber
are not necessarily related. It has also been
suggested that changes in the composition of
intestinal microflora may affect serum cho-
lesterol. Although intestinal microflora may
change after dietary fiber is increased, the
significance and consistency of the changes
are not well documented (40, 88). Further-
more, other studies have shown that the hy-
pocholesterolemic effect of dietary fiber per-
sists after antibiotic administration (82), sug-
gesting that the hypocholesterolemia is not
related to changes in intestinal flora. It, there-
fore, seems reasonable to conclude that the
mechanism by which some sources of dietary
fiber lower serum cholesterol is unknown.

Perhaps the effects of some sources of die-
tary fiber on plasma cholesterol and its frac-
tions are mediated through changes in the
number and/or size of the lipoprotein mole-
cules. That diets of different composition in-
fluence lipoprotein metabolism has been
demonstrated by Durrington et al. (89) who
found that pectin significantly decreased apop-
rotein-B in 12 healthy subjects and by
Shonfeld et al. (90, 91) and Ruderman et al.
(92) who showed that the size and number of
very low density lipoproteins increased and the levels of apoproteins changed
in humans who ate high carbohydrate diets.
These findings and the recently reported
strong negative correlation between HDL
cholesterol levels and obesity and carbohy-
drate intolerance (76, 93, 94), might indi-
cate that changes in carbohydrate metabolism,
and possibly in insulin levels, modify chole-
sterol metabolism. Though we did not find a
relation between glucose tolerance and HDL
cholesterol but did find a direct correlation
between total (Fig. 2) and LDL cholesterol,
with the area under the glucose tolerance
curve, $P \leq 0.0001$ and $\leq 0.0007$, respectively.
We also observed a direct correlation between
fasting plasma glucose and triglyceride levels
(Fig. 3). These findings support the sugges-
tion that the effects of dietary fiber on lipid
and glucose metabolism are related.
Addendum

After this manuscript was submitted for publication, Dr. David Knittlevsky and Ms. Shirley Tepper kindly measured the in vitro binding of bile acids to samples of the AAAC, white wheat bran, hard red spring wheat bran, corn bran, and soy bean hulls fed in this study. No apparent relationship was found between the mean binding of the bile acids in vitro, and the in vivo effect of the fiber sources on serum cholesterol. When components of the fiber sources were compared to the binding of the bile acids by step-wise regression analysis, it became evident that certain components were correlated with the binding of certain bile acids. About 60% of the variance was explained when the oil content of the fiber sources was compared to cholic acid binding, when the cellulose content was compared with binding of chenodeoxycholic acid, and when the cellulose content was compared with binding of taurodeoxycholic acid. The relationships were significant at $P < 0.001$. Also of interest was the finding that about 50% of the variance was explained when the binding of taurocholic or glycocholic acids were compared with the two independent variables, lignin and ash. The level of significance in both cases, was $P < 0.05$. About 36% of the variance was explained when chenodeoxycholic acid was compared to the starch content of the fiber sources. The level of significance was $P < 0.05$. When the binding of individual bile acids and the individual components of dietary fiber were compared with serum cholesterol, it was found that the binding of taurocholic and glycocholic was positively correlated with the levels of serum cholesterol. In both instances, about 30% of the variance was explained. In contrast, the level of serum cholesterol was inversely correlated with the level of ash and 36% of the variance was explained. By step-wise regression, it was found that the serum cholesterol level was predicted by the two independent variables, lignin and ash. The slope of the lignin line was 0.30, while the slope of the ash line was $-14.4$. Of the variance 95% was explained with a level of significance of $P < 0.0001$. These intriguing associations have been mentioned because they may warrant further research.

References

25. Morgan, B., M. Heald, S. D. Atkinson, J. Green and E. B. Chain. Dietary fiber and sterol metabolism in...
CEREAL BRANS AND TEXTURED VEGETABLE PROTEIN ON PLASMA LIPIDS


Appendix

Frozen bread dough

The sponge and sponge-dough are mixed in an appropriate sized Hobart mixer equipped with a dough hook to accommodate the dough mass. The procedure is as follows:

Sponge formula: 60% of total fiber; 2% yeast; 0.5% yeast food; 57.8% water (based on 60% total four weight), Mix at low speed 1½ min, then ½ min on intermediate

*Percentage expressed as total flour weight.
speed. Ferment for 2 hr at 90 C and 100% relative humidity.

Sponge-dough formula: 40% of total flour, 3% shortening; 2% salt; 3% sugar; 3% milk; 5% yeast; 0.025% calcium propionate; 25 ppm potassium bromate; 12.5% crushed ice (based on total flour weight). Add sufficient water to give proper dough consistency. Mix on slow speed until ingredients are incorporated into the dough mass, then mix on intermediate speed until dough is developed. Divide dough and round into 1 pound mass. Ferment for 15 min at 90 C and 100% relative humidity. Sheet and pan dough and enclose in plastic sack, then place panned loaf in -20 F freezer overnight.

9 Replace 25% of the total flour weight with fiber ingredient (as is basis) as needed.