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ABSTRACT

The effects of hard white and hard red winter wheats (whole flour, bran, straight-grade flour) and oatmeal on rat weight gains, serum and liver cholesterol levels, fecal fat, neutral sterols, and bile acids were compared. No differences in weight gains or feed efficiencies were noted for animals fed red versus white whole flours, brans or straight-grade flours. Only animals fed the white wheat bran diet gained less weight than the control animals. The bran diets were the least efficient feeds. By the end of week 8, animals fed red wheat diets tended to have lower serum cholesterol levels than those fed respective white wheat diets, but the difference was significant only in animals fed whole wheat flour. The wheat brans, whole red flour, red straight-grade flour, and oatmeal diets were hypocholesterolemic compared to the control diet. No significant differences occurred in liver cholesterol levels between groups fed respective hard white versus hard red wheat diets. Animals fed bran diets had significantly lower liver cholesterol concentrations than did those fed whole flour or straight-grade flour, but concentrations were similar to those of animals fed the oatmeal diet. Correlation analysis showed significant inverse relationships between total serum cholesterol and dietary fiber (especially soluble fiber), amount of fecal fat and neutral sterols excreted daily, dietary phenolics and phytic acid, and diet viscosity. The relationships were stronger for liver cholesterol. All of these factors may contribute to the hypocholesterolemic properties of grain diets.

The effects of various sources of dietary fiber on serum lipids have been studied extensively and have been subjects of several comprehensive reviews (Judd and Truswell 1985, Kritchevsky et al 1990). It is well established that some water-soluble plant polysaccharides (Kritchevsky and Story 1986, Reiser 1987, Anderson et al 1990) and cereal 1-3,1-4-β-D-glucans (Klopfenstein and Hoseney 1987, Kashtan et al 1992) can lower serum and tissue cholesterol levels.

Most studies indicate that wheat bran, which contains about 5% soluble fiber, has little hypocholesterolemic effect. However, conflicting data continue to appear (Kies 1985, Pilch 1987, Anderson et al 1990, Kashtan et al 1992). For example, in 14 studies in which wheat bran was fed to humans at levels ranging from 9 to 38 g/day for 21–365 days, there was no change in serum cholesterol in nine of the studies; there was an increase of 7% in one study, and reductions of 7–22% in four studies (Pilch 1987). The wheat varieties fed are often not reported. Studies in which hypocholesterolemic effects were detected suggested that the variety of wheat and the coarseness of the bran might have modulated its effects (Munoz et al 1979).

A number of mechanisms have been suggested to explain the hypocholesterolemic effect of certain dietary fibers. Much atten-

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tion has been paid to the ability of dietary fiber to bind or trap bile acids, leading to their decreased absorption and increased excretion. That would increase the amount of cholesterol required for bile acid synthesis and lower the body cholesterol pool. Also, excretion. That would increase the amount of cholesterol required for bile acids, leading to their decreased absorption and increased excretion. 

The objective of the experiment described here was to compare the effects of oatmeal and flours and brans of hard white and hard red winter wheats on rat weight gains; serum and liver cholesterol concentrations; and fecal fat, neutral sterols, and bile acids and to determine statistical relationships among the variables.

**MATERIALS AND METHODS**

Hard red winter wheat [Norkan (88-854)] and hard white winter wheat [KS84HW196 (88-850)] cultivars grown in 1988 at Fort Hays Agricultural Experiment Station, Hays, KS, were obtained. Each wheat cultivar was milled to whole wheat flour (100% of the grain) or straight-grade flour of 74% extraction and bran (26% of the grain). Whole wheat flour was milling using the Miag Multomat S/100 (Braunschweig, Germany). After milling, fractions were stored in a cold room (2°C) until needed. Bran particle size was reduced using a Fitzpatrick Co., Muncie, IN) before use. Diets were mixed in a Wenger ribbon mixer (Wenger Manufacturing Co., Sabetha, KS).

Eight groups of 10 male Wistar rats (SASCO Inc., Omaha, NE) were fed the following for eight weeks: 1) casein-based diet containing alphacel cellulose (control); 2) hard white wheat whole flour; 3) hard red wheat whole flour; 4) hard white wheat bran; 5) hard red wheat bran; 6) hard white straight-grade wheat flour; 7) hard red straight-grade wheat flour; or 8) oatmeal (Table I). Oatmeal was included as a comparison because it has been consistently shown to have a cholesterol-lowering effect when fed to animals or humans.

Diets were formulated to contain 20% protein and 6% fat and 45 or 50% by weight of the test product. Protein (%N × 6.25), fat, ash, calculated caloric value, insoluble dietary fiber (IDF), soluble dietary fiber (SDF), and total dietary fiber (TDF) contents are presented in Table II. Standard AACC (1983) methods were used in analyzing diets: method 46-16 for protein; method 30-25 for fat; method 08-01 for ash; and method 32-07 for IDF, SDF, and TDF. Wheat bran diets (Diet 4 and 5) were high in IDF. The oatmeal diet (Diet 8) had about equal amounts of SDF and IDF. TDF was lowest for the straight-grade flour diets (Diets 6 and 7). Whole wheat flour diets had intermediate levels of TDF.

Animals, initially weighing 150 ± 5 g, were individually housed in stainless steel cages in an environmentally controlled room with a 12-hr light-dark cycle. Diets and water were provided ad libitum. Animals were weighed weekly, feed consumption records were kept, and feed efficiencies were calculated.

**Total Serum Cholesterol**

Blood samples were drawn by cardiac puncture from ether-anesthetized animals after weeks 4 and 8. Blood was allowed to clot at room temperature, then centrifuged at 12,000 × g for 15 min. Serum samples were analyzed in duplicate for total cholesterol using reagents from Sigma Chemical Co., St. Louis, Mo. (Procedure 352 and 352-3).

**Liver Cholesterol**

After eight weeks of feeding, the animals were sacrificed by placing them in an ether atmosphere. Their livers were removed, rinsed under cold tap water, blotted dry, weighed and frozen. Lipids were extracted with chloroform-methanol (Klopfenstein and Clegg 1980). In that method, lipids are extracted from tissue samples by homogenizing with 7.5 ml of 2:1 chloroform-methanol.

### TABLE I

<table>
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<th>Diet</th>
<th>Content</th>
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<tr>
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<tr>
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<td>...</td>
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<td>1.4</td>
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### TABLE II

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<th>Diet</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Ash (%)</th>
<th>IF (%)</th>
<th>SF (%)</th>
<th>TDF (%)</th>
<th>Total Phenolics (µg/g)</th>
<th>Diet Viscosity (cP)</th>
<th>Energy (kcal/100 g)</th>
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<td>7.10</td>
<td>0.59</td>
<td>60.4</td>
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*aAll diets contained 4% salt mixture XVII, 1% vitamin mix 2 (both obtained from ICN Nutritional Biochemicals, Cleveland, OH); 1% cholesterol, 0.30% dl-methionine, 0.2% choline bitartrate (all from Sigma Chemical Co., St. Louis, MO); and 12% sucrose.

*bVitamin-free casein and corn starch from Sigma Chemical Co., St. Louis, MO.

*Vegetable oil (soybean) from a local supermarket.

*Alphacel from ICN Nutritional Biochemicals, Cleveland, OH.

*bIf = insoluble dietary fiber, SF = soluble dietary fiber, TDF = total dietary fiber.
neutral sterols. The straight-grade flour diets had the lowest concentrations. No significant difference was found for SDF and weight gain.

**Total Serum Cholesterol**

At the end of four weeks, no significant differences were observed in total serum cholesterol levels in animals fed respective...
hard white versus hard red wheat diets (Table IV). Animals fed the bran diets had lower total serum cholesterol than those fed any other diet. None of the other diets had any cholesterol lowering effect when compared to the control diet. Because the amount of cholesterol ingested by animals fed bran diets was not statistically lower than that ingested by animals fed any other diet, the data indicate that both white and red wheat bran fractions lowered serum cholesterol by the end of four weeks.

At the end of eight weeks, all animals except those fed white whole flour and white straight-grade flour had lower total serum cholesterol than those fed the control diet, which contained no cereal product. Animals fed red wheat diets tended to have lower serum cholesterol levels than those fed respective white wheat diets, but the difference was only significant in animals fed whole flour diets. Among animals fed the different wheat fractions, those fed bran had the lowest serum cholesterol concentration and those fed straight-grade flour had the highest serum cholesterol concentration (Table IV). Animals fed red whole flour, white or red bran, or red straight-grade flour had serum cholesterol levels not significantly different than those of animals fed oatmeal. Ranhotra et al (1977) has reported that diets containing 50% wheat bran of different particle size lowered serum cholesterol when fed to rats for four weeks, with the fine bran having the greatest cholesterol-lowering effect. Munoz and colleagues (1979) demonstrated that soft white wheat bran had no effect on serum cholesterol, whereas hard red spring wheat bran significantly lowered plasma total cholesterol levels. In the present study, both hard red and hard white brans (ground to pass through a 1.5-mm screen) reduced serum cholesterol.

Liver Cholesterol

No significant differences in liver cholesterol levels occurred between groups fed respective hard white versus hard red wheat diets (Table IV). Among the different wheat fractions, bran gave significantly lower liver cholesterol concentrations than did whole flours or straight-grade flours. Liver cholesterol values were similar for animals fed the bran diets and the oatmeal diet. Animals fed all diets containing cereal fractions had lower liver cholesterol concentrations than did those fed the control diet containing no cereal.

Numerous studies have been conducted concerning liver cholesterol concentrations in relation to diet. One study by Chang et al (1979) showed liver cholesterol levels to be higher in rats fed whole wheat or low-grade flours than in those fed patent flour. Another study by Van Beresteyn et al (1979) showed that animals fed wheat bran diets had lower liver cholesterol concentrations than those fed cellulose-containing or fiber-free diets. In contrast, Klopfenstein (1990) reported no significant difference in liver cholesterol concentrations in animals fed diets containing 5% cellulose or 5% wheat bran. Oatmeal, which is rich in the water-soluble (1,3)(1,4)-β-glucan, has been shown to have significant hypcholesterolemic effects. However, in the present study, the bran diets had statistically the same cholesterol-lowering effect as the oatmeal diet.

Serum cholesterol concentrations after eight weeks were negatively correlated with TDF (r = -0.3701, P = 0.0002), IDF (r = -0.3275, P = 0.0044) and SDF (r = -0.5186, P = 0.0001). Correlations with liver cholesterol followed a similar pattern but were stronger (TDF: r = -0.6994, P = 0.0001; IDF: r = -0.6483, P = 0.0001; and SDF: r = -0.8114, P = 0.0001). Phytic acid and phenoic compounds in the diets were highly correlated with IDF (r = 0.9579, P = 0.0001 and r = 0.8691, P = 0.0001, respectively). That suggests that all dietary fiber fractions, as well as phytic acid and phenoic compounds, might play roles in lowering body cholesterol.

Diet Slurry Viscosity

The viscosity and gelling properties of soluble dietary fibers may have important effects on the hydrolysis and absorption of lipids (Anderson et al 1990). Also, SDF can increase the viscosity of the luminal contents in the small intestines. This process has been indicated as a possible means by which SDF lowers serum cholesterol (Gordon 1989). In this experiment, the oatmeal diet had the highest viscosity, whereas the straight-grade flour and control diets had the lowest (Table II). Correlation analyses showed a weak but significant inverse relationship between diet viscosity and total serum (r = -0.3580, P = 0.0007) and liver cholesterol (r = -0.5321, P = 0.0001).

Fecal Lipids (Ether Extract) and Total Neutral Sterols

Animals fed red wheat diets had significantly higher fat concentration in the feces than did animals fed white whole wheat diets (Table V), except for those fed the bran fractions (Diets 4 and 5). However, daily fecal fat loss was not significantly different for animals fed red versus white wheats. The oatmeal group (Diet 8) had the highest daily fecal fat loss. The control animals, whose diet contained no cereal product, had the lowest daily fecal fat loss. Animals fed brans (Diets 4 and 5) had lower fecal lipid and total neutral sterol concentrations than did those fed straight-grade flours (Diet 6 and 7). Feces of animals fed whole wheat flours (Diets 2 and 3) had intermediate lipid and neutral sterol concentrations, and those of animals fed the straight-grade flours (Diet 6 and 7) had the highest concentrations. Feeding animals diets containing cereal products resulted in higher daily amounts of neutral sterols excreted than did feeding the no-cereal diet. Significant inverse relationships were present between fecal neutral sterol concentrations and dietary fiber, with the strongest correlations being with TDF (r = -0.7868, P = 0.0001) and IDF (r = -0.8072, P = 0.0001). Regression analyses showed a weak but significant relationship between amount of neutral sterols excreted and total serum (r = -0.3580, P = 0.0007) and liver cholesterol (r = -0.5321, P = 0.0001).

### Table V: Effects of Wheat Diets on Rat Fecal Fat, Total Neutral Sterols, and Bile Acids\(^a\)\(^b\)

<table>
<thead>
<tr>
<th>Diet(^c)</th>
<th>Ether Extracted Lipid</th>
<th>Total Neutral Sterols</th>
<th>Total Bile Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/g</td>
<td>mg/day</td>
<td>mg/g</td>
</tr>
<tr>
<td>1</td>
<td>5.8 d</td>
<td>14.2 c</td>
<td>9.1 d</td>
</tr>
<tr>
<td>2</td>
<td>6.2 d</td>
<td>17.8 c</td>
<td>10.3 c</td>
</tr>
<tr>
<td>3</td>
<td>7.5 c</td>
<td>18.4 c</td>
<td>9.7 cd</td>
</tr>
<tr>
<td>4</td>
<td>4.5 e</td>
<td>25.3 b</td>
<td>6.8 e</td>
</tr>
<tr>
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<td>4.6 e</td>
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<td>6.9 e</td>
</tr>
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<td>26.9 ab</td>
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</tr>
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<td>31.2 a</td>
<td>13.4 b</td>
</tr>
<tr>
<td>LSD(^d)</td>
<td>1.05</td>
<td>4.96</td>
<td>0.94</td>
</tr>
</tbody>
</table>

\(^a\)Means in the same column not followed by the same letter are significantly different (P < 0.05).

\(^b\)Dry matter basis.

\(^c\)Diet 1 = control, 2 = white whole wheat flour, 3 = red whole wheat flour, 4 = white wheat bran, 5 = red wheat bran, 6 = white wheat straight-grade flour, 7 = red wheat straight-grade flour, 8 = oatmeal. All diets contained 1% cholesterol.

\(^d\)Least significant difference.
Total Bile Acid Concentration

Although no significant differences were observed in fecal bile acid concentrations in animals fed white versus red wheat, significant differences were observed for the various wheat fractions (Table V). In general, animals fed bran (Diets 4 and 5) had the lowest concentrations of fecal bile acids, whereas the straight-grade flour (Diets 6 and 7) produced the highest concentrations. The whole flour (Diets 2 and 3) and oatmeal (Diet 8) diets resulted in intermediate bile acid concentrations. Linear regression analysis showed significant negative relationships between total fecal bile acid concentration and IDF ($r = -0.8211$, $P = 0.0001$), SDF ($r = -0.6425$, $P = 0.0001$), TDF ($r = -0.8254$, $P = 0.0001$), and phytic acid ($r = -0.7986$, $P=0.0001$).

CONCLUSIONS

Weight gains in rats fed red versus white hard winter wheat diets were not significantly different. Both wheats were equally efficient feeds. Animals fed oatmeal gained the same amount of weight as those fed the whole wheat flours.

Both oatmeal and wheat diets were shown to be hypcholes-
terolemic, and the effect tended to be greater with the red wheat diets. Regression analysis of the data indicated that multiple factors are probably responsible. The data suggest that increased excretion of fat and neutral sterols, but not higher excretion of bile acids, may be one mechanism by which red and white wheat bran and oatmeal lowered serum and liver cholesterol. SDF was moderately correlated with serum cholesterol combination and more strongly correlated with liver cholesterol levels. Therefore, it cannot be ruled out as a contributing agent to the cholesterol-lowering effect of wheat, especially bran, diets. Dietary phytic acid and phenolic compounds and diet viscosity were also correlated consistently with serum and liver cholesterol. These and possibly other factors associated with the bran may affect cholesterol status in animals.

LITERATURE CITED


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