Influence of dietary fiber on trace element balance\textsuperscript{1, 2}

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ABSTRACT Five adult male volunteers were fed a diet containing (as percent of calories) 16\% protein, 40\% fat, and 44\% carbohydrate, a diet similar to that consumed by many American males. Twenty-six grams of soft white wheat bran or corn bran were added to the daily bread, and the effects on zinc, iron, and copper balance were assessed during the last 12 days of each 30-day study period. The soft white wheat bran appeared to decrease retention of zinc in four subjects but not significantly so. Iron retention was similar in all three treatments. Copper balance was improved by addition of soft white wheat bran and to a lesser degree by corn bran. An apparent copper requirement of 1.28 mg/day for the volunteers was calculated by regression analysis. \textit{Am. J. Clin. Nutr.} 31: S180--S184, 1978.

The influence of dietary fiber on the availability of zinc, copper, and iron for intestinal absorption by humans is incompletely defined. Based on limited observations, it appears that people fed diets rich in vegetables and cereals but containing less than 30 g of animal protein per day may have impaired absorption of minerals when their intakes of dietary fiber are increased by consuming bread prepared from high extraction wheat flour (1, 2). Because the cited studies tested people fed a Middle Eastern diet, the results may have limited application to Americans.

On the other hand, low dietary intakes of zinc (3), copper (4), and iron (5) have been reported in some Americans, with and without associated clinical evidence of deficiency. For these reasons, and because it has been suggested that increased intakes of dietary fiber might have beneficial effects on the incidence of diverticulosis (6) and might also have a preventive effect on coronary vascular disease (7) and colon cancer (8), we have studied the effects of increased dietary fiber on balances of zinc, copper, and iron.

Materials and methods

Five male volunteers who gave informed consent were housed in a controlled metabolic ward environment for 4 to 8 months. They were normal by clinical, nutritional, and psychological evaluations. Study periods were 28 to 30 days. After an initial 16- to 18-day equilibration, excreta and duplicate diets were collected for 12 days for chemical assessment of the balance. Throughout the studies, caloric intake, energy expenditure and, hence, body weight were maintained as uniformly as possible. As an index of body composition, triceps, biceps, and subscapular and suprailiac skinfolds and upper arm circumference were measured weekly for estimation of fitness and muscle mass. The psychological status of the volunteers was assessed periodically, and a psychologist met with the volunteers both in a group and individually, as needed. At the end of each study period, the nutritional and clinical status of the volunteers was reassessed. The reliability of the findings was improved by replication of the studies in some individuals.

The basal diet (Table I) was prepared from conventional foods to satisfy the nutrient needs of the volunteers. The protein, fat, carbohydrate, and cholesterol contents of the basal diet were similar to the levels in diets of many middle-class American men. Fiber intake was increased by adding about 26 g of American Asso-

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FIG. 1. Zinc, iron, and copper intake and excretion patterns of five adult male volunteers fed the basal diet. Fecal losses are indicated by the vertical hatching, and urinary losses are indicated by the horizontal hatching of the vertical bars which represent the average 24 excretions for one 12-day balance period. The dietary intake/24 hr is indicated by the height of the bar above the zero line. Positive balance is indicated by space between the zero line and the bottom of the vertical bar, if the bar does not touch the line. Negative balance is indicated by the length of the vertical bar below the zero line. Units for zinc and iron are in mg/24 hr; units for copper are in 0.1 mg/24 hr.

Daily displayed a negative balance. Zinc retentions of three individuals ingesting 14 to 15.5 mg/day were less than those of four individuals ingesting 10 to 15 mg of zinc while on the basal diet. Thus, wheat bran might have decreased the zinc absorption of four individuals. This apparent effect, however, was not statistically significant.

When the subjects were fed the wheat bran, iron balance was negative in three of five observations, a finding similar to that observed when the basal diet was fed. In contrast to the observations on zinc, the negative iron balances did not occur at a level of iron intake that was higher than that supplied by the basal diet alone.

Copper balance was improved when the wheat bran was fed, possibly because the copper intake was increased. The mean dietary intake of copper when wheat bran was fed was 1.32 ± 0.13 mg compared with 1.11 ± 0.19 mg when the basal diet was fed ($P < 0.066$).

When corn bran was fed, zinc balance was positive in all six observations (Fig. 3). Two observations, when the intake was 12.5 mg and another when the intake was 15 mg, revealed retentions similar to those when subjects consumed the wheat bran and 14 to 15.5 mg of zinc. When 12.5 to 16.0 mg of zinc were ingested. retentions for three observations were similar to those when 11 to 16.5 mg of zinc were fed for five observations on the basal diet. Thus it does not appear that 26 g of dry milled corn bran added to daily bread had an adverse effect on zinc retention.

Iron balance of the volunteers fed corn bran was similar to that observed on the basal diet or when wheat bran was fed.

The copper balance of the volunteers fed corn bran was negative in four volunteers. The negative balance seemed related to low dietary intake of copper. Copper intake with the corn bran diet was 1.12 ± 0.10 mg, a level significantly less ($P < 0.05$) than the 1.32 ± 0.13 mg intake with the wheat bran diet.
FIBER INFLUENCE ON TRACE ELEMENT BALANCE

TABLE 1
Diet characteristics

<table>
<thead>
<tr>
<th>Diet</th>
<th>Constant, 6 day</th>
<th>Conventional foodsa</th>
<th>Rotating 6 day menus</th>
<th>Low fiber (3.0 g/d crude fiber)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>70% animal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat, linoleate/saturated</td>
<td>40% of energy</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total carbohydrate</td>
<td>44% of energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sucrose</td>
<td>9% of energy</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Cholesterol</td>
<td>750 mg/day</td>
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a Eggs, margarine, potatoes, bread, butter, peaches, sucrose, white flour, noodles, tomatoes, round steak, chicken, rice, orange juice, grape juice, cherries, pineapple, cheese, tea, coffee, powdered milk, bouillon, paprika, silt, pepper, jelly, pears, grapefruit juice.

TABLE 2
Percentage composition of fiber sourcesa

<table>
<thead>
<tr>
<th>AAC</th>
<th>Wheat bran</th>
<th>Corn bran</th>
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</thead>
<tbody>
<tr>
<td>Hemicellulose</td>
<td>32.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>9.1</td>
<td>22.0</td>
</tr>
<tr>
<td>Lignin</td>
<td>3.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Ash</td>
<td>5.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Phytate phosphorus</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>31.0</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Protein</td>
<td>15.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Oil</td>
<td>4.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Total fiber</td>
<td>44.1</td>
<td>92.1</td>
</tr>
</tbody>
</table>

a See References 9 to 15.

The wheat bran contained substantially more starch and protein, and less than half as much hemicellulose and cellulose as the corn bran. Wheat bran also contained 0.5% phytate phosphorus and less than half the dietary fiber present in corn bran (Table 2). Zinc balance was negative in one of nine basal observations (Fig. 1). Urinary zinc losses were small and apparently were little affected by dietary intake. The subject who displayed a negative balance had an intake of 13 mg/day. Spencer et al. (19) have reported negative zinc balances in men fed mixed hospital diets, containing about 12.5 mg of zinc daily.

Iron balance was negative in three of seven basal observations when the subjects were fed the basal diet. Intake of iron did not appear to influence the balance. Very small amounts of iron were lost in urine.

In seven of nine basal observations, copper balance was negative when the subjects were fed the basal diet. It appears that copper balances were more negative when copper intakes were smallest. Small amounts of copper were excreted in the urine.

The balances when the volunteers were fed soft white wheat bran are shown in Figure 2. One individual who consumed 13 mg of zinc...
The improvement of the copper balance with increased copper ingestion made it possible to estimate the copper requirement for adult males by regression (20). Excluding losses in sweat, the requirement was 1.28 mg/day \( (r = 0.8, P < 0.001) \). We are refining our estimate of copper requirement and will report our findings in more detail elsewhere.

Evaluation of the other parameters listed in the methods did not reveal highly significant differences among the means. The lack of significant differences may be attributable to the small number of observations.

The limited observations of this study neither support nor refute the reports of Reinhold et al. (1, 2) that bread prepared from high-extraction wheat flour can impair intestinal absorption of zinc. His observations were made on subjects fed a Middle Eastern diet, the composition of which was substantially different from the basal diet in the present experiments.

Summary

The addition of about 26 g of AACC standard soft white wheat bran to a constant diet similar to an American "middle-class diet" appeared to decrease the retention of zinc by some male volunteers. In contrast to its effects on zinc, the soft white wheat bran appeared to improve copper balance. Corn bran, on the other hand, had little effect on zinc balance and less effect on copper balance. Iron balance did not appear to be affected by either bran.

By regression analysis, a provisional copper requirement, excluding losses in sweat, for adult males was calculated as 1.28 mg/day.

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The authors also thank the Lathoff Grain Co. (Dannville, Ill.) for donation of the corn bran. ( Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the United States Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.)

References


FIBER INFLUENCE ON TRACE ELEMENT BALANCE

SOFT WHITE WHEAT BRAN

ZINC (MG/24 HOURS)  IRON (MG/24 HOURS)  COPPER (.1MG/24 HOURS)

FIG. 2. Zinc, iron, and copper intake and excretion patterns of five adult male volunteers fed the basal diet with 26 g of soft white wheat bran added to the daily bread.

CORN BRAN

ZINC (MG/24 HOURS)  IRON (MG/24 HOURS)  COPPER (.1MG/24 HOURS)

FIG. 3. Zinc, iron, and copper intake and excretion patterns of five adult male volunteers fed the basal diet with 26 g of corn bran added to the daily bread.