Jenkins, D. J. A.; Leeds, A. R.; Newton, C.; Cummings, J. H. *Lancet* **1975**, *1*, 116.
Jenkins, D. J. A.; Leeds, A. R.; Slavin, B.; Mann, J.; Jepson, E. M. *Am. J. Clin. Nutr.* **1979**, *32*, 16.
Kay, R. M.; Truswell, A. S. *Am. J. Clin. Nutr.* **1977**, *30*, 171.
Kelly, J. J.; Tsai, A. C. *J. Nutr.* **1978**, *108*, 630.
Keys, A.; Grande, F.; Anderson, J. T. *Proc. Soc. Exp. Biol. Med.* **1961**, *106*, 555.
Kiriyama, S.; Enishi, A.; Yura, K. *J. Nutr.* **1974**, *104*, 49.
Lack, L.; Weiner, I. M. In "Bile Acids—Chemistry, Physiology, and Metabolism"; Nair, P. P.; Kritchevsky, D., Eds.; Plenum Press: New York, 1971; Vol. 1—Chemistry, Chapter 2, p 33.
Leveille, G. A.; Sauberlich, H. E. *J. Nutr.* **1966**, *88*, 209.
Miettinen, T. A.; Tarpila, S. *Clin. Chim. Acta* **1977**, *79*, 471.
Mosbach, E. H.; Kalinsky, H. J.; Halpern, H.; Kendall, F. E. *Arch. Biochem. Biophys.* **1954**, *51*, 402.
Poole, C. P., Jr.; Farach, H. A. "Relaxation in Magnetic Resonance"; Academic Press; New York, 1971; pp 74–75.
Riccardi, B. A.; Fahrenbach, M. J. *Proc. Soc. Exp. Biol. Med.* **1967**, *124*, 749.
Selvendran, R. R. *Chem. Ind. N.Z.* **1978**, *12*, 428.
Small, D. E. In "Bile Acids—Chemistry, Physiology, and Metabolism"; Nair, P. P.; Kritchevsky, D., Eds.; Plenum Press: New York, 1971; Vol. 1—Chemistry, Chapter 8, p 249.
Spiller, G. A.; Shipley, E. A.; Blake, J. A. *CRC Crit. Rev. Food Sci. Nutr.* **1978**, *10* (1), 31.
Story, J. A.; Kritchevsky, D. *J. Nutr.* **1976**, *106*, 2.
Wood, P. J.; Siddiqui, I. R. *Anal. Biochem.* **1971**, *39*, 418.

Received for review June 23, 1980. Accepted November 6, 1980. Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned. Meeting of the American Chemical Society, Houston, TX, March 23–28, 1980, Division of Agricultural and Food Chemistry.

Nutrient Utilization by Human Subjects Consuming Fruits and Vegetables as Sources of Fiber

June L. Kelsay,* Willa M. Clark, Barbara J. Herbst, and Elizabeth S. Prather

Apparent digestibilities of energy, nitrogen, and fat and balances of calcium, magnesium, zinc, and copper were determined for 12 men consuming 4 diets containing different amounts of fruits and vegetables. Mean intakes of neutral detergent fiber (NDF) from the four diets were 1.9, 10.1, 19.4, and 25.6 g/day. The diets were consumed for 3 weeks each in a 4 × 4 Latin square design. Urine and feces were collected during the last 7 days of each dietary period. Mean bowel transit time was not affected by the level of fiber intake. Number of defecations and fecal weight increased with fiber. Energy, nitrogen, and fat fecal excretions increased and apparent digestibilities decreased as fiber increased. Increased levels of fiber intake did not affect balances of calcium, magnesium, and copper. Zinc balance decreased, but remained positive, as fiber increased. Mean balances for these minerals were positive on all four diets.

In most studies of the effects of fiber on humans, cereal fibers were fed. In two studies carried out in this laboratory, the effects of diets containing fruits and vegetables as sources of fiber were studied. In an earlier study (I) (Kelsay et al., 1978), 2 diets were fed to 12 men in a crossover design for 26 days each. A low fiber diet containing fruit and vegetable juices was compared with a higher fiber diet containing fruits and vegetables. Mean intakes of neutral detergent fiber (NDF), as determined by the Goering and Van Soest (1970) method were 4.9 and 24.9 g/day on the low and higher fiber diets, respectively.

In study I, the inclusion of fruits and vegetables in the diet decreased bowel transit time and increased number of defecations and fecal weight. The higher fiber diet also increased fecal excretions and decreased apparent digestibilities of energy, nitrogen, and fat (Kelsay et al., 1978). Fecal excretions of calcium and zinc were greater on the higher fiber diet, resulting in negative balances that were significantly lower than those on the low fiber diet. Although magnesium and copper fecal excretions were not significantly different on the two diets, probably due to small differences in intakes of these two minerals, magnesium and copper balances were negative on the higher fiber diet and were significantly lower than those on the low fiber diet. Iron and phosphorus balances were not affected by the inclusion of fruits and vegetables in the diet (Kelsay et al., 1979a,b).

In the second study (II), reported here, the low fiber diet was compared to three diets containing increasing levels of fiber in fruits and vegetables. Since mineral balances were negative on the higher fiber diet fed in study I, we wished to determine the effects of increasing levels of fiber on mineral balances and to define the maximum level of fiber intake at which subjects would be in mineral balance.

EXPERIMENTAL SECTION

Twelve men 35–49 years of age participated in the study. Body weights ranged from 65.5 to 111.0 kg and heights from 162.0 to 187.5 cm. The subjects consumed four diets for 3 weeks each in a 4 × 4 Latin square design. Diet 1 was a low fiber diet and diets 2, 3, and 4 contained increasing amounts of fruits and vegetables. Diet 2 had half the amounts of fruits and vegetables in diet 3, and diet 4 had 1.5 times the amounts of fruits and vegetables in diet 3. Mean NDF intakes on the four diets, as analyzed by the American Association of Cereal Chemists' (AACC) modification of the NDF method (AACC, 1978), were 1.9, 10.1, 19.4, and 25.6 g/day for diets 1, 2, 3, and 4, respectively. In this method, residual starch is removed by the use of amylase, and the resulting NDF values are lower than those obtained by the original method. Caloric in-

Carbohydrate Nutrition Laboratory, Beltsville Human Nutrition Research Center, Human Nutrition, Science and Education Administration, U.S. Department of Agriculture, Beltsville, Maryland 20705 (J.L.K. and W.M.C.), and Department of Food, Nutrition, and Institution Administration, University of Maryland, College Park, Maryland 20742 (B.J.H. and E.S.P.).

Table I. Diets Containing Four Levels of Fiber, Day 3 Menu, 2800 Calories

diet 1	diet 2	diet 3	diet 4
	Breakfast		
orange juice, 249 g	orange juice, 124.5 g		
	oranges, 100 g	oranges, 200 g	oranges, 300 g
	dried figs, 37.5 g	dried figs, 75 g	dried figs, 112.5 g
egg, 50 g	egg, 50 g	egg, 50 g	egg, 50 g
bread, white, 50 g	bread, white, 25 g	bread, white, 25 g	bread, white, 25 g
maple syrup, 39.4 g	maple syrup, 39.4 g	maple syrup, 39.4 g	
milk, 244 g	milk, 122 g	milk, 122 g	
sugar, 84 g[b]	sugar, 78 g[b]		
butter, 51.7 g[b]	butter, 51.7 g[b]	butter, 51.7 g[b]	butter, 51.7 g[b]
half and half, 90 g[b]	half and half, 90 g[b]	half and half, 90 g[b]	half and half, 90 g[b]
	Lunch		
pork chop, 85 g	pork chop, 85 g	pork chop, 85 g	pork chop, 85 g
bread, white, 25 g	bread, white, 25 g	bread, white, 25 g	bread, white, 25 g
mayonnaise, 14 g	mayonnaise, 14 g	mayonnaise, 14 g	mayonnaise, 14 g
apple juice, 124 g	apple juice, 62 g		
	pear, 77.5 g	pear, 155 g	pear, 232.5 g
	brussels sprouts, 38.8 g	brussels sprouts, 77.5 g	brussels sprouts, 116.2 g
ice cream, 66 g	ice cream, 66 g	ice cream, 66 g	ice cream, 66 g
	Dinner		
turkey, 75 g	turkey, 75 g	turkey, 75 g	turkey, 75 g
vegetable juice, 121 g	asparagus, 47.5 g	asparagus, 95 g	asparagus, 142.5 g
rice, 124 g[a]			
cranberry juice, 100 g	cranberries, 23.8 g	cranberries, 47.5 g	cranberries, 71.2 g
	sugar, 18 g	sugar, 36.0 g	
	apple, 25 g	apple, 50 g	apple, 75 g
	raisins, 25 g	raisins, 50 g	raisins, 75 g
roll, 28 g	roll, 28 g	roll, 28 g	
butterscotch pudding, 130 g	65 g of butterscotch and 90.5 g of pumpkin pudding	pumpkin pudding, 181 g	pumpkin pudding, 271.5 g
cookies, 25 g	cookies, 25 g	cookies, 35 g	cookies, 25 g
milk, 122 g	milk, 183 g		

[a] Cooked weight. [b] Amount for whole day.

takes were adjusted by increasing or decreasing all foods the appropriate percentage so that the subjects maintained their body weights throughout the study. Carbohydrate, fat, and protein made up 50, 37, and 13% of the total calories, respectively. Intakes of calories, fat, protein, calcium, and zinc were similar on all four diets. Intakes of magnesium and copper increased as the amounts of fruits and vegetables in the diet increased.

Diets 1 and 3 were similar to the diets fed in study I (Kelsay et al., 1978), except that a third menu was planned and rotated with the other two. The menu for day 3 gives examples of the four diets (Table I). Nutrient and fiber contents of the menu for day 3 were essentially the same as those for the other 2 days. In study II, minerals and carotene were not added to the low fiber diet, and spinach in the menu for day 1 was replaced with cauliflower.

During the last 7 days of each dietary period, food samples were collected and composited for each of the four diets. During the last 7 days of each dietary period, the subjects also collected all urine and feces. Feces were marked by ingestion of 50 mg of Brilliant Blue in a gelatin capsule. Composites of each subject's feces between markers were blended separately in a Teflon-coated Waring Blendor. Aliquots of urine for each of the 7 days were mixed separately for each subject. All samples were collected in plastic containers that had been washed with a decontaminating detergent and then with demineralized water.

Procedures for the determination of bowel transit time, energy, fat, and nitrogen were the same as in study I (Kelsay et al., 1978). Although the modified NDF method of the AACC (1978) was used in analysis of food samples, the fecal samples were analyzed without the enzyme treatment, as starch would not be expected to be present in the fecal samples. Calcium, magnesium, zinc, and copper were determined by atomic absorption spectrophotometry by Raltech Scientific Services, Inc., Madison, WI 53707. Intakes of coffee, tea, and water were recorded and representative samples of each were assayed for mineral content. Data were analyzed statistically by analysis of variance and treatment means were compared according to Duncan's multiple range test.

RESULTS AND DISCUSSION

Systolic and diastolic blood pressures of the subjects were 111 ± 3 and 74 ± 3 mm, respectively, on the low fiber diet and were not affected by the level of fiber in the diet. In study I, diastolic blood pressure in some of the subjects was lower on the low fiber diet than on the higher fiber diet (Kelsay et al., 1978). The lack of effect of fiber on blood pressure in study II may have been due to subject differences or to a slightly shorter study period.

Mean bowel transit time, number of defecations, and fecal weights of the 12 men consuming the 4 levels of fiber appear in Table II. Mean transit time on the low fiber diet was 30 h and was not significantly altered when the fiber in the diet increased. In study I, transit time of some subjects was relatively long on the low fiber diet and decreased on the higher fiber diet. Other investigators reported that increasing the fiber in the diet did not further decrease transit times that were already short (Eastwood et al., 1973; Harvey et al., 1973; Brodribb and Humphreys, 1976). Number of defecations and fecal weight increased with the fiber content of the diet. Some subjects complained of large amounts of watery feces when they consumed diet 4. Apparently intakes of fiber higher than we fed in study II might cause diarrhea in some subjects. Heller and Hackler (1978) calculated that the U.S. intake of crude fiber per capita was about 4.8 g/day in the early 1970s. Dorfman et al. (1976) reported a daily intake of

Table II. Transit Times, Number of Defecations, and Fecal Weights of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
transit time, h	30 ± 3[a]	27 ± 2[a]	27 ± 2[a]	31 ± 4[a]
no. of defecations, 7 days	7 ± 1[c]	9 ± 1[b]	10 ± 1[b]	11 ± 1[a]
wet fecal wt, g/7 days	611 ± 37[d]	890 ± 57[c]	1197 ± 83[b]	1566 ± 181[a]
dry fecal wt, g/7 days	160 ± 8[d]	227 ± 13[c]	293 ± 15[b]	353 ± 23[a]

[a] Row means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range comparisons.

1.6–11.0 g of crude fiber by 21 subjects in Connecticut. From the few published values available for fiber content of foods, it appears that the total fiber content of foods may be from 2 to 5 times higher than crude fiber values (Kelsay, 1978). Some of our subjects probably ate low fiber diets before their participation in the study and were not accustomed to the levels of fiber which we fed.

Energy, nitrogen, and fat fecal excretions increased and apparent digestibilities decreased as the fiber content of the diet increased (Table III). The mean difference between fecal energy excretion on the highest fiber diet (diet 4) and the lowest fiber diet (diet 1) was 142 cal/day. This might cause a small weight loss over a long period of time; however, the feeling of satiety associated with a high fiber diet and the concurrent decrease in food intake would probably be a greater factor in weight loss. When the subjects ate diet 4, they complained of too much food, even though caloric intake was constant among diets.

Mean NDF intakes, fecal excretions, and apparent digestibilities appear in Table IV. Mean fecal NDF was greater than mean intake of diet 1, probably due to the difficulty of assaying for such small quantities of fiber. Apparent digestibilities did not differ significantly among the other three diets.

Mean calcium intake ranged from 1045 to 1094 mg/day (Table V) and was slightly but significantly higher on diet 2 than on diets 1 and 4. Fecal excretions of calcium, as a percent of intake, and calcium balances were not significantly different on the four diets.

Magnesium intakes increased as the amounts of fruits and vegetables in the diet increased (Table VI) and ranged from 238 mg/day on diet 1 to 351 mg/day on diet 4. Only diet 4 met the recommended dietary allowances of the National Research Council ("Recommended Dietary Allowances", 1974) of 350 mg/day, yet the subjects were in positive magnesium balance on all diets. The percent of magnesium intake excreted in the feces did not differ among the diets. Magnesium balance was significantly more positive on diet 4 than on the other three diets.

Mean zinc intakes ranged from 11.8 to 12.4 mg/day and did not differ significantly among the four diets (Table VII). Fecal zinc as a percent of intake was greater on diet 4 than on diets 1 and 2. Zinc balance was less positive on diet 4 than on diets 1 and 2. Mean zinc balances were positive on all diets even though mean zinc intakes were below the recommended dietary allowance of 15 mg/day ("Recommended Dietary Allowances", 1974).

Mean copper intakes were greater on diet 4 than on diet 1 (Table VIII) and ranged from 2.3 to 3.0 mg/day. Fecal copper, as percent of copper intake, and copper balances did not differ significantly among the four diets. Copper intakes were higher in study II than in study I due to a higher copper content of the water used for cooking and for drinking. In both studies, the water came from the tap in the diet facility. Both water samples were analyzed in two different laboratories.

Balances of these four minerals were decidedly positive on all diets, even though the intakes of magnesium and zinc were below the recommended dietary allowances ("Recommended Dietary Allowances", 1974). However, the Recommended Dietary Allowances are estimated to exceed the requirements of most individuals and allow a margin of safety for individual variation. The decidedly positive mineral balances could be due to previous low intakes of these minerals. Extended studies of mineral balances are needed to determine the time required for subjects on experimental diets to reach mineral balance. Present information on mineral balances is inadequate for establishment of acceptable limits of variation from the true balance.

Results of our first study indicated that diets high in fiber may result in negative balances of minerals. Some investigators reported that mineral balances decreased or became negative when fiber in the diet was increased (Ismail-Beigi et al., 1977; Reinhold et al., 1976; Drews et al., 1979; Kies et al., 1979). On the other hand, other investigators found that the addition of fiber to the diet did not affect mineral balances (Guthrie and Robinson, 1978; Sandstead et al., 1978). Possibly these differences in results reported by different investigators were due to the kind or amount of fiber fed or to the length of the adaptation period.

In our study II, increasing the level of fiber in the diet did not significantly affect balances of calcium, magnesium, or copper. Zinc balances decreased as the fiber in the diet increased, but the subjects were in positive balance even

Table III. Intake, Fecal Excretion, and Apparent Digestibility of Energy, Nitrogen, and Fat of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
energy				
intake, kcal/day	2925 ± 111[b]	3040 ± 123[a]	3008 ± 115[ab]	2927 ± 116[b]
fecal, kcal/day	113 ± 6[d]	162 ± 10[c]	209 ± 11[b]	255 ± 16[a]
apparent digestibility, %	96.1 ± 0.2[a]	94.7 ± 0.2[b]	93.0 ± 0.2[c]	91.2 ± 0.5[d]
nitrogen				
intake, g/day	13.64 ± 0.54[a]	14.11 ± 0.58[a]	13.77 ± 0.52[a]	13.86 ± 0.58[a]
fecal, g/day	1.38 ± 0.08[d]	1.84 ± 0.12[c]	2.28 ± 0.14[b]	2.60 ± 0.18[a]
apparent digestibility, %	89.9 ± 0.5[a]	86.9 ± 0.7[b]	83.5 ± 0.8[c]	81.2 ± 1.1[d]
fat				
intake, g/day	116.8 ± 5.9[a]	119.8 ± 4.8[a]	119.2 ± 4.1[a]	119.5 ± 4.6[a]
fecal, g/day	4.8 ± 0.4[b]	5.4 ± 0.4[ab]	6.0 ± 0.4[a]	6.2 ± 0.4[a]
apparent digestibility, %	95.9 ± 0.3[a]	95.5 ± 0.3[ab]	95.0 ± 0.3[bc]	94.8 ± 0.3[c]

[a] Row means followed by the same letter or letters are not significantly different at the 5% level according to Duncan's multiple range comparisons.

Table IV. Intake, Fecal Excretion, and Apparent Digestibility of Neutral Detergent Fiber (NDF) of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
intake, g/day	1.9 ± 0.2[d]	10.1 ± 0.5[c]	19.4 ± 0.9[b]	25.6 ± 1.1[a]
fecal, g/day	2.3 ± 0.3[d]	6.8 ± 0.5[c]	11.5 ± 0.8[b]	15.5 ± 1.5[a]
apparent digestibility, %		31.9 ± 4.9[a]	40.4 ± 4.1[a]	38.4 ± 6.4[a]

[a] Row means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range comparisons.

on the highest level of fiber intake. These results indicate that large amounts of fruits and vegetables can be consumed without fear of adverse effects of the fiber content on mineral balances.

In study I, we attempted to equalize the mineral contents of the low fiber and higher fiber diets by the addition of some minerals to the low fiber diet. This was not done in study II. When the fiber content of the diet is increased by the consumption of natural foods containing fiber, the vitamin and mineral content of the diet is likely to be increased also. This is a positive aspect of increasing fiber intake from natural foods. Adverse effects of fiber on mineral balances may be evident at marginal or inadequate levels of intake, whereas higher levels of intake may compensate for any minerals made unavailable by binding to fiber.

One cause of the differences in results between studies I and II might have been the difference in oxalic acid content of the diets. It is well-known that spinach contains oxalic acid, which can complex calcium. In study I, however, we did not consider that oxalic acid might be a problem because the amount of spinach in the diet was small (102 g every other day on a 2800-cal diet). Results of most human studies indicated that spinach in the diet did not adversely affect calcium balance (McLaughlin, 1927; Bonner et al., 1938; Johnston et al., 1952; Basu and Ghosh, 1943; Schlutz et al., 1933). Sherman and Hawley (1922) reported that calcium balance became less favorable in three children for whom half the milk was replaced by vegetables, including 196–350 g of spinach per day.

Possibly oxalic acid, together with the fiber in the higher fiber diet, was responsible for the decreased mineral balances in study I. Oxalic acid contents of the feces from both studies were determined and are reported in Table

Table V. Calcium Intake, Excretion, and Balance of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
intake, mg/day	1050 ± 38[b]	1094 ± 52[a]	1079 ± 43[ab]	1045 ± 43[b]
fecal, mg/day	835 ± 40[b]	909 ± 58[ab]	927 ± 54[a]	844 ± 44[b]
fecal, % of intake	79.4 ± 2.3[a]	83.0 ± 3.2[a]	85.4 ± 1.7[a]	80.8 ± 2.3[a]
urinary, mg/day	129 ± 13[a]	127 ± 11[a]	117 ± 14[a]	96 ± 10[b]
balance, mg/day	86 ± 31[a]	58 ± 37[a]	35 ± 18[a]	104 ± 36[a]

[a] Row means followed by the same letter or letters are not significantly different at the 5% level according to Duncan's multiple range comparisons.

Table VI. Magnesium Intake, Excretion, and Balance of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
intake, mg/day	238 ± 10[d]	267 ± 14[c]	294 ± 13[b]	351 ± 15[a]
fecal, mg/day	140 ± 11[d]	163 ± 14[c]	180 ± 12[b]	204 ± 14[a]
fecal, % of intake	58.6 ± 3.4[a]	61.1 ± 4.0[a]	61.0 ± 2.8[a]	58.4 ± 3.7[a]
urinary, mg/day	75 ± 6[b]	87 ± 6[a]	88 ± 6[a]	90 ± 6[a]
balance, mg/day	22 ± 7[b]	16 ± 10[b]	26 ± 9[b]	57 ± 13[a]

[a] Row means followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range comparisons.

Table VII. Zinc Intake, Excretion, and Balance of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
intake, mg/day	11.8 ± 0.4[a]	12.4 ± 0.5[a]	12.2 ± 0.7[a]	11.9 ± 0.5[a]
fecal, mg/day	8.6 ± 0.4[c]	9.1 ± 0.7[bc]	9.7 ± 0.5[ab]	10.0 ± 0.6[a]
fecal, % of intake	73.1 ± 2.7[b]	73.8 ± 4.2[b]	80.6 ± 2.5[ab]	83.7 ± 2.8[a]
urinary, mg/day	0.35 ± 0.04[b]	0.40 ± 0.04[ab]	0.38 ± 0.03[ab]	0.42 ± 0.07[a]
balance, mg/day	2.8 ± 0.3[a]	2.9 ± 0.6[a]	2.1 ± 0.4[ab]	1.5 ± 0.3[b]

[a] Row means followed by the same letter or letters are not significantly different at the 5% level according to Duncan's multiple range comparisons.

Table VIII. Copper Intake, Excretion, and Balance of Twelve Men Consuming Four Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	diet 1	diet 2	diet 3	diet 4
intake, mg/day	2.3 ± 0.2[b]	2.6 ± 0.2[ab]	2.7 ± 0.1[ab]	3.0 ± 0.2[a]
fecal, mg/day	1.6 ± 0.1[c]	1.7 ± 0.2[bc]	1.9 ± 0.1[ab]	2.2 ± 0.1[a]
fecal, % of intake	72.1 ± 4.9[a]	66.8 ± 3.7[a]	71.3 ± 3.5[a]	73.8 ± 3.2[a]
urinary, mg/day	0.09 ± 0.01[a]	0.16 ± 0.05[a]	0.09 ± 0.01[a]	0.11 ± 0.02[a]
balance, mg/day	0.6 ± 0.2[a]	0.7 ± 0.1[a]	0.7 ± 0.1[a]	0.7 ± 0.1[a]

[a] Row means followed by the same letter or letters are not significantly different at the 5% level according to Duncan's multiple range comparisons.

Table IX. Fecal Oxalic Acid Excretion of Twelve Men Consuming Different Levels of Fiber from Fruits and Vegetables (Mean ± SEM)[a]

	Study I low fiber	higher fiber
mg/day	41 ± 6[b]	423 ± 53[a]

	Study II diet 1	diet 2	diet 3	diet 4
mg/day	21 ± 3[d]	81 ± 8[c]	157 ± 14[b]	210 ± 16[a]

[a] Row means followed by the same letter are not significantly differnet at the 5% level according to Duncan's multiple range comparisons.

IX. In study I, fecal oxalic acid was 10 times as high on the higher fiber diet as on the low fiber diet. In study II, fecal oxalic acid increased with the fiber in the diet. The diets in study II did not include spinach but included other foods that contained oxalic acid in smaller amounts. Oxalic acid excretion on diet 3 in study II was only about one-third of that on the similar diet in study I. The 423 mg of oxalic acid excreted on the higher fiber diet in study I could conceivably tie up 188 mg of calcium, which might have been just enough to result in negative calcium balance.

Further studies are needed to determine whether greater levels of intake, different sources, or different forms of fiber would affect mineral balances. The effects of phytic acid and oxalic acid with and without fiber in the diet should be defined. The time required for adaptation of the mineral balances of subjects to interfering factors should be determined in long-term controlled studies.

ACKNOWLEDGMENT

The authors express their appreciation to Priscilla Steele and Sheryl Cottrell of the Diet Facility for their assistance in conducting this study.

LITERATURE CITED

American Association of Cereal Chemists "Approved Methods of the AACC"; 1978 Revisions; AACC: St. Paul, MN, 1978; Method 32-40.
Basu, K. P.; Ghosh, D. *Indian J. Med. Res.* **1943**, *31*, 37.
Bonner, P.; Hummel, F. C.; Bates, M. F.; Horton, J.; Hunscher, H. A.; Macy, I. G. *J. Pediatr. (St. Louis)* **1938**, *12*, 188.
Brodribb, A. J. M.; Humphreys, D. M. *Br. Med. J.* **1976**, *1*, 424.
Dorfman, S. H.; Ali, M.; Flock, M. H. *Am. J. Clin. Nutr.* **1976**, *29*, 87.
Drews, L. M.; Kies, C.; Fox, H. M. *Am. J. Clin. Nutr.* **1979**, *32*, 1893.
Eastwood, M. A.; Kirkpatrick, J. R.; Mitchell, W. D.; Bone, A.; Hamilton, D. *Br. Med. J.* **1973**, *4*, 392.
Goering, H. K.; Van Soest, P. J. *U.S., Dep. Agric., Agric. Handb.* **1970**, *No. 379*.
Guthrie, B. E.; Robinson, M. F. *Fed. Proc., Fed. Am. Soc. Exp. Biol.* **1978**, *37*, 254.
Harvey, R. F.; Pomare, E. W.; Heaton, K. W. *Lancet* **1973**, *1*, 1278.
Heller, S. N.; Hackler, L. R. *Am. J. Clin. Nutr.* **1978**, *31*, 1510.
Ismail-Beigi, F.; Reinhold, J. G.; Faradji, B.; Abadi, P. *J. Nutr.* **1977**, *107*, 510.
Johnston, F. A.; McMillan, T. J.; Falconer, G. D. *J. Am. Diet. Assoc.* **1952**, *28*, 933.
Kelsay, J. L. *Am. J. Clin. Nutr.* **1978**, *31*, 142.
Kelsay, J. L.; Behall, K. M.; Prather, E. S. *Am. J. Clin. Nutr.* **1978**, *31*, 1149.
Kelsay, J. L.; Behall, K. M.; Prather, E. S. *Am. J. Clin. Nutr.* **1979a**, *32*, 1876.
Kelsay, J. L.; Jacob, R. A.; Prather, E. S. *Am. J. Clin. Nutr.* **1979b**, *32*, 2307.
Kies, C.; Fox, H. M.; Beshgetoor, D. *Cereal Chem.* **1979**, *56*, 133.
McLaughlin, L. *J. Biol. Chem.* **1927**, *74*, 455.
"Recommended Dietary Allowances", 8th ed.; National Academy Sciences, National Research Council: Washington, DC, 1974.
Reinhold, J. G.; Faradji, B.; Abadi, P.; Ismail-Beigi, F. *J. Nutr.* **1976**, *106*, 493.
Sandstead, H. H.; Munoz, J. M.; Jacob, R. A.; Klevay, L. M.; Reck, S. J.; Logan, G. M., Jr.; Dintzis, F. R.; Inglett, G. E.; Shuey, W. C. *Am. J. Clin. Nutr.* **1978**, *31*, S180.
Schlutz, F. W.; Morse, M.; Oldham, H. *Am. J. Dis. Child.* **1933**, *46*, 758.
Sherman, H. C.; Hawley, E. *J. Biol. Chem.* **1922**, *53*, 375.

Received for review June 23, 1980. Accepted November 26, 1980. Presented at the 179th National Meeting of the American Chemical Society, Houston, TX, March 23–28, 1980, Division of Agricultural and Food Chemistry.

Nutritional Significance of Dietary Fiber: Effect on Nutrient Bioavailability and Selected Gastrointestinal Functions

R. Ali,* H. Staub, G. Coccodrilli, Jr., and L. Schanbacher

Fiber in foods varies considerably in composition and physicochemical properties. Water-active and gel-forming polysaccharides modify viscosity of the gut content and may influence bioavailability of nutrients. All undigestible structured fibers reach the large bowel relatively unchanged to exert a direct effect on gut microflora and motility. Conflicting results in the literature do not allow definitive conclusions to be drawn regarding the effect of dietary fiber on requirements of macro- and micronutrients in experimental animals and man. The role of fiber, however, in relieving symptoms associated with chronic constipation and diverticular diseases is well documented. The favorable changes in rate of gastric emptying and intestinal transit time and motility seem to be related mainly to the bulking properties of dietary fiber which decrease the forcefulness of contractile pressure in the lumen. Furthermore, metabolites of bacterial fermentation of dietary polysaccharides which modify the environment in the colon may positively contribute to promotion of regularity.

The significance of dietary fiber in nutrition is the subject of wide scientific review (Heaton, 1979; Kelsay, 1978; Kimura, 1977; Roth and Mehlman, 1978; Spiller and Amen, 1975, 1976, 1978; Staub and Ali, 1981). Little is known about quantitative intake of dietary fiber in relation to health, and qualitative differences in composition and lack of agreement on a single definition makes even current estimates of dietary fiber intake suspect. Although the

Department of Nutrition and Health Sciences, General Foods Technical Center, Tarrytown, New York 10591.

