Proximate Composition, Phytic Acid, and Total Phosphorus of Selected Breakfast Cereals[1]

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ABSTRACT

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Twelve cereals that are promoted as natural foods or high-fiber cereals were assayed for proximate compostion and for phosphorus and phytic acid contents. Proximate composition was found to be close to published values and to product label claims. Phosphorus content ranged from 0.206% in Nature Valley Granola Bar to 0.592% in Roman Meal (moisture free basis). Phytic acid content ranged from 0.13% in Quaker 100% Natural Cereal to 1.42% in Roman Meal. Five of the products had 1% or more phytic acid. None of the cereals had a phytate-zinc molar ratio less than the 6:1 that has been reported to prevent zinc depletion. Recommendations are made to consumers, dietitians, and manufacturers of cereals to be aware of potential problems so that dietary or other compensations can be made.

The demand for "natural" foods with high fiber content has resulted in the development of a wide variety of high-fiber cereals and granola products. High-fiber cereals commanded 16% of the ready-to-eat cereal market in 1979 (Warren 1979). High-fiber cereals may be ready-to-eat cereals or old-fashioned, quick-cooking, or instant products. In addition to whole grains, the products may contain bran, sunflower seeds, nuts, dried fruits, and other minimally processed ingredients. Harland and Prosky (1979) reported that as intake of dietary fiber from fruits, nuts, vegetables, and whole grains is increased, intake of phytic acid is also increased.

Erdman and Forbes (1977) reported that, at dietary levels of 1% or greater, phytic acid can interfere with mineral availability. A dietary phytate-zinc molar ratio of 6:1 supplies adequate zinc to maintain serum levels in human subjects (Harland and Prosky 1979). However, if phytate is increased, interference with zinc nutrition may result if zinc is not proportionately increased. In a 15-week study with human volunteers, the addition of high-fiber foods to a self-selected diet resulted in a decrease of plasma cholesterol and triglycerides and a 12.5% reduction of plasma zinc. These products had phytate-zinc molar ratios of 18:1–19:1 (Harland and Prosky 1979).

The phytic acid content of foods can be reduced by some processing and preparation steps. Harland and Prosky (1979) demonstrated that the phytic acid in yeast breads can be reduced by increasing the amount of yeast and the rising time. Yeast produces phytase, which hydrolyzes the phytate. Reduction of phytate in yeast breads was shown earlier by Pringle and Moran (1942) and by Ranhotra et al (1974). Toma and Tabekhia (1979) reported that phytate was reduced in rice by cooking with domestic tap water. Chang et al (1977) observed a reduction of phytate in beans following a hot water blanch or overnight soak. Lolas and Markakis (1975) and Tabekhia and Luh (1980) reported that germination reduced the phytate content in beans. Tabekhia and Luh (1980) also reported that cooking slightly decreased and canning markedly decreased the phytate content of beans.

Toma and Tabekhia (1979) have suggested that phytic acid in cereals and grains should be listed in the revised Food Composition Handbook published by the U.S. Department of Agriculture, and Davies (1979) emphasized the need for compositional information with respect to antinutritional factors. Tabekhia and Luh (1980) suggested that alterations in phytic acid content of foods following processing and preparation should be determined with direct measurement of phytic acid, not by measurement of inorganic phosphate. The objective of the present study was to determine the phytic acid content of selected high-fiber cereals available in local supermarkets and to evaluate each cereal's potential for interference with the availability of dietary zinc.

MATERIALS AND METHODS

The cereals were purchased during the spring of 1979 from local supermarkets in Moscow, ID. The products, selected on the basis of the claim that they were natural or contained high fiber, included various forms of oatmeal, granola, granola bars, and mixed-grain cereals. Different types of cereals were selected to represent different kinds of home preparation: old-fashioned (5–10 min of cooking), quick-cooking (1 min of cooking), instant (addition of boiling water), and ready-to eat. Additionally, the products were

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chosen to represent different manufacturers of the same product types. The products were brought to the laboratory and placed in plastic bags for storage. Samples were maintained at ambient temperature and stored for three months or less from the time of purchase to the time of analysis. Analysis was completed before the product expiration date on the package.

Just before analysis, a 20-g sample of each product was ground in a water-cooled Chemical Rubber Company micromill for 1 min. Portions of the ground products were weighed for proximate analysis—moisture, fat, protein, and ash—and for phosphorus and phytic acid determinations. All assays were done in triplicate except that of phytic acid, which was done in quadruplicate.

AOAC (1975) methods were followed to determine moisture, fat, ash, and total nitrogen. Phytic acid was determined using a modification of the extraction procedure of Wheeler and Ferrel (1971) followed by measurement of the phytic acid phosphorus using the colorimetric method of Ward and Johnston (1962). Three grams of sample was weighed into a 50-ml capped centrifuge tube. The sample was suspended in 30 ml of 3% trichloroacetic acid (TCA). The tubes were shaken for 45 min at room temperature. The samples were centrifuged at 4°C for 15 min at 15,000 rpm. Four milliliters of 1% $FeCl_3$ in 3% TCA was added to 10 ml of the supernate. The tubes were placed in a boiling water bath for 20 min. Two drops of 2% sodium sulfate in 3% TCA was added. The tubes were placed in the boiling water bath for an additional 15 min followed by centrifugation at 15,000 rpm, 4°C. The precipitate was washed once with 20 ml of 3% TCA and twice with 20 ml of distilled water and was centrifuged following each wash. The washed precipitate was digested with 3 ml of 1.5*N* NaOH and 2 ml of distilled water for 30 min in a boiling water bath. The ferric hydroxide was removed by centrifugation and the supernate transferred to a 100-ml micro-Kjeldahl flask. The organic material was digested in the presence of 0.5 ml of concentrated sulfuric acid plus 3 ml of concentrated nitric acid. Digestion was continued until white fumes hung in the neck of the flask—about 30 min. Following digestion, 20 ml of distilled water was added to the flask. The flask was placed in a boiling water bath for 90 min to hydrolyze pyrophosphates. The contents of the flask were transferred to a 100-ml volumetric flask and made up to volume with distilled water. Aliquots (2-ml) were pipetted into each of three test tubes. A standard curve containing 0, 25, 50, 75, and 100 μg of digested sodium phytate, three tubes of each level, was prepared. To each tube (both samples and standard) were added 2 ml of 6.6% ammonium molybdate, 2 ml of 7.5*N* sulfuric acid, and 2 ml of $FeSO_4 \cdot 7H_2O$. Each tube was vortex-mixed following each addition. The absorbance at 660 nm was read 20 min after the addition of the $FeSO_4$.

Total phosphorus was determined according to method 2 of Ward and Johnston (1962). The ash was dissolved in HCl and the resulting solution diluted to 100 ml. The colorimetric determination was as described for phytic acid phosphorus except that the standard curve was prepared from KH_2PO_4. Regression, correlation, and *t*-test were calculated according to Steel and Torrie (1960).

RESULTS AND DISCUSSION

The results of proximate analysis are presented in Table I. The data agrees with values for similar products listed in Handbook 8 (Watt et al 1963) or on product labels.

Moisture content ranged from 3.4% in Instant Quaker Oats and in Nature Valley Granola Bars to 11.6% in Oroweat Branola with apples and cinnamon. Moisture content was significantly different because of cereal type, with higher moisture content in cereals that require further cooking. Information in the rest of the discussion is on a moisture free basis.

Nitrogen content ranged from 1.67 to 3.10% in Nature Valley Bars and Instant Ralston, respectively. Nitrogen content was significantly different by cereal type. Oats contained more nitrogen than the granola products did. High levels of fat and other ingredients added to granola dilute the nitrogen in the oats, a major ingredient of granola.

Fat content ranged from 2.23% in Roman Meal to 23.1% in Quaker 100% Natural Cereal. Fat content was significantly different by cereal type, with granola containing 17.8–23.1% fat. The high fat level in granola comes from fat used as an ingredient as well as from the oats and should be a concern for persons who are trying to reduce intake of either calories or fat.

Ash content ranged from 1.6% in Oroweat Branola with apples and raisins and in Nature Valley Bars to 2.9% in Instant Quaker Oats with bran and raisins. Ash content was significantly different by cereal type, with granolas containing less ash than the other cereals. The lower ash content in granola results from dilution by the high levels of fat and sugar.

Total phosphorus content ranged from 0.21 in Nature Valley Bars to 0.56% in Safeway Quick Oats. Oat cereals contained more phosphorus than did granola, again a result of dilution by low phosphorus fat and sugar in the granola. Phosphorus content was not significantly different among the groups of cereals.

Phytic acid content ranged from 0.13% in Quaker 100% Natural Cereal to 1.42% in Roman Meal. Phytic acid content was significantly different among the cereal types. The mixed grain

TABLE I
Proximate Compostion (%) of Mixed-Grain Cereals, Oat Cereals, and Granola[a]

Product	Water	Nitrogen	Ash	Fat
Mixed grain cereals				
Roman Meal	8.1 ± 0.12	2.63 ± 0.00	2.74 ± 0.14	2.23 ± 0.03
Oroweat Branola				
Seven-grain	9.2 ± 0.11	2.52 ± 0.11	2.19 ± 0.11	4.38 ± 0.17
With apple, raisins, and cinnamon	11.6 ± 0.17	2.16 ± 0.00	1.60 ± 0.02	3.14 ± 0.13
Instant Ralston	9.2 ± 0.03	2.60 ± 0.48	3.12 ± 0.48	3.12 ± 0.92
Oat cereals				
Quaker Instant with bran and raisins	3.4 ± 0.11	2.14 ± 0.06	2.91 ± 0.08	4.50 ± 0.17
Quaker Old Fashioned	6.4 ± 0.12	2.99 ± 0.02	2.04 ± 0.19	11.71 ± 0.08
Safeway Quick	7.0 ± 0.14	3.01 ± 0.02	2.11 ± 0.14	9.45 ± 0.08
Granola				
Nature Valley	3.9 ± 0.07	1.89 ± 0.02	1.83 ± 0.01	17.78 ± 0.12
Nature Valley Bar	3.4 ± 0.11	1.67 ± 0.09	1.60 ± 0.13	19.45 ± 0.18
Pioneer Vita Life	4.0 ± 0.07	2.48 ± 0.09	1.86 ± 0.01	19.13 ± 0.14
Quaker 100% Natural	3.6 ± 0.10	2.09 ± 0.08	1.81 ± 0.06	23.07 ± 0.14
Bulk	4.9 ± 0.04	2.34 ± 0.08	1.88 ± 0.07	18.40 ± 0.32
F[b]	73.49**	10.73*	7.85*	220.57**

[a] Each value is the mean ± standard deviation of three analyses, moisture free basis.
[b] F by analysis of variance; * = 0.05 level of significance, ** = 0.01 level of significance.

cereals had higher levels of phytic acid than did the oat cereals or granolas. The low level of phytic acid in Quaker 100% Natural Cereal is remarkable. Quaker 100% Natural has a level of total phosphorus similar to those of the other granolas, and why it had such a low level of phytic acid is not clear.

Harland and Prosky (1979) reported that the levels of phytic acid in various cereals are: 2.40% in oatmeal, 0.77% in oats, 1.83% in shredded wheat, 1.53% in Special K, and 1.38% in infant cereals. Common (1940) found 0.21–0.31% phytic acid in oats. In the present study, oatmeal contained 0.64–1.03% phytic acid—less than reported by Harland and Prosky (1979) and more than reported by Common (1940). Whether these reports represent real differences in phytic acid content or differences due to analytical techniques is uncertain.

Common (1940) found that 60–68% of the total phosphorus was present in the form of phytic acid in oats, oatmeal, ground oats, and barley. Quaker 100% Natural Cereal had 10% of the phosphorus as phytic acid, whereas the range was from 35–82% in the rest of the cereals (Table II). The percent of total phosphorus present as phytic acid was not significantly different by cereal group, indicating no consistent effect from processing, or lack of processing, of the cereals.

The correlation between phosphorus and phytic acid (r = + 0.60) was significant at the 0.05 level. Such a relationship has been observed in beans (Lolas and Markakis 1975) and in whole triticale grain (Singh and Reddy 1977) and was implied in the report of Common (1940).

In a review on phytate and zinc bioavailability (Anonymous

TABLE II
Phytic Acid, Phosphorus, and Phosphorus as Phytic Acid in Mixed-Grain Cereals, Oat Cereals, and Granola[a]

Product	Phytic Acid (% of cereal)	Phosphorus (% of cereal)	Phytic Acid Phosphorus (% of total P)	Phytic Acid Phosphorus (% of cereal)
Mixed grain cereals				
Roman Meal	1.42 ± 0.04	0.592 ± 0.016	67	0.395
Oroweat Branola				
Seven-grain	1.17 ± 0.01	0.547 ± 0.004	60	0.326
With apple, raisins, and cinnamon	0.49 ± 0.05	0.346 ± 0.018	40	0.137
Instant Ralston	1.06 ± 0.06	0.357 ± 0.011	82	0.295
Oat cereals				
Quaker Instant with bran and raisins	0.99 ± 0.07	0.334 ± 0.012	81	0.276
Quaker Old Fashioned	0.64 ± 0.02	0.527 ± 0.020	34	0.178
Safeway Quick	1.03 ± 0.01	0.560 ± 0.001	52	0.287
Granola				
Nature Valley	0.57 ± 0.01	0.351 ± 0.015	46	0.159
Nature Valley Bar	0.49 ± 0.02	0.206 ± 0.010	67	0.137
Pioneer Vita Life	0.70 ± 0.05	0.432 ± 0.010	46	0.195
Quaker 100% Natural	0.13 ± 0.01	0.370 ± 0.019	10	0.036
Bulk	0.72 ± 0.05	0.412 ± 0.006	49	0.201
F[b]	12.89*	5.46	0.99	

[a] All values are mean ± standard deviation of three assays (phosphorus) or four assays (phytic acid), moisture free basis.
[b] F by analysis of variance, * = 0.05 level of significance.

TABLE III
Serving Size, Phytic Acid, Amount of Zinc Needed for 6:1 Phytate-Zinc Molar Ratio, and Calculated Phytate-Zinc Molar Ratio in Servings of Mixed-Grain Cereals, Oat Cereals, and Granola

Product	Serving Size[a] (g)	Phytic Acid (mg per serving)[b]	Zn Needed for 6:1 Phytate-Zn Molar Ratio (mg per serving)	Calculated Phytate-Zn Molar Ratio[c]	
Mixed grain cereals					
Roman Meal	33	426	7.02	26:1	
Oroweat Branola					
Seven-grain	28.3	297	4.90	21:1	
With apple, raisins, and cinnamon	28.3	122	2.01	9:1	
Instant Ralston	28.3	272	4.49	19:1	
Oat cereals					
Quaker Instant with bran and raisins	42.5	408	6.73	19:1	
Quaker Old Fashioned	28.3	170	2.80	12:1	
Safeway Quick	28.3	269	4.44	19:1	
Granola					
Nature Valley	28.3	156	2.57	1:1	(21:1)[d]
Nature Valley Bar	23.6	136	2.24	8:1	(19:1)[d]
Pioneer Vita Life	28.3	190	3.14	12:1	(26:1)[d]
Quaker 100% Natural	28.3	37	0.61	3:1	(9:1)[e]
Bulk	28.3	192	3.17	14:1	(26:1)[d]

[a] One ounce equals 28.3 g.
[b] As is moisture basis.
[c] Based on 4.86 mg of zinc per 100 g of cereal, the maximum value reported in the literature (Deeming and Weber 1979).
[d] Based on 0.718 mg of Zn per serving for granola (Allen and Klevay 1980).
[e] Based on 0.393 mg of Zn per serving (Allen and Klevay 1980).

1979), the author stated that the nutrition community should be aware of the complications that could result from the use of high-phytate textured vegetable protein in place of animal protein. Phytate, from soy protein or other sources, decreases the availability of zinc, and high levels of calcium aggravate the effect (Rackis and Anderson 1977).

The 1974 recommended daily allowance of zinc for adults was 15 mg (NAS 1974). Haeflin and Rasmussen (1977), Sandstead (1973), and Walker and Page (1977) have documented the difficulty of getting 15 mg of zinc in self-selected and institutional diets. They observed a range of zinc intake of 5–29.9 mg per day. In addition, a level of 1% or more phytic acid in the diet interferes with mineral availability (Erdman and Forbes 1977). Of the cereals evaluated in this study, Roman Meal, Oroweat Branola-7-Grain Cereal, Instant Ralston, Safeway Quick Oats, and Instant Quaker Oats with bran and raisins, all with 1% or more phytic acid, have the potential to interfere with the availability of minerals. A phytate-zinc molar ratio of 6:1 has been proposed as a level permitting adequate availability of zinc (Harland and Prosky 1979). The amount of zinc required to give a phytate-zinc ratio of 6:1 is presented in Table II. The range is from 0.61 mg of zinc per 100 g of cereal for Quaker 100% Natural Cereal to 7.02 mg for Roman Meal.

Calculations of the zinc content of cereals as reported in the literature suggest that they contain from 0.5 mg to 1.4 mg of zinc per serving or 1.36–4.86 mg/100 g of cereal (Deeming and Weber 1979, Haeflin and Rasmussen 1977, and Harland and Prosky 1979). Allen and Klevay (1980) report amounts of zinc ranging from 0.17 to 15.2 mg/100 g of ready-to-eat cereals. Granola had 3.29 mg of zinc and Quaker 100% Natural Cereal had 1.94 mg of zinc per 100 g. Only cereals that had been fortified with zinc, except for one, had more than 3.3 mg/100 g.

Assuming 4.86 mg of zinc per 100 g, the molar ratio (the ratio of moles of phytate per serving to moles of zinc per serving, Table III) is less than 6:1 only in Quaker 100% Natural Cereal. If the molar ratio for Quaker 100% Natural Cereal is calculated using the zinc content reported by Allen and Klevay (1980), it is 9:1. Because the actual zinc content may be less than 4.86 mg/100 g, the ratios may be greater. Thus, the cereals have the potential to interfere with zinc nutrition. The actual problem may be somewhat lessened by the moist-heat cooking of the mixed cereals and oatmeal, although the cooking time is short as compared to that for rice and beans (Tabekhia and Luh 1980, Toma and Tabekhia 1979).

The National Dietary Goals and Guidelines (Senate Select Committee 1977) recommended consumption of increased amounts of high-fiber food and decreased consumption of dairy products and meat. Meat is one of the major sources of dietary zinc. High-fiber foods are frequently high-phytate foods (Harland and Prosky 1979). Like the increased use of high-phytate textured vegetable protein, the increased consumption of cereals containing high levels of phytic acid presents a nutritional problem. The nutrition community should be aware of the possibility of zinc depletion as phytate consumption increases and dietary zinc consumption decreases. We need to monitor the zinc status of populations who choose to follow the National Dietary Goals and Guidelines, of populations who consume high-phytate cereals on a regular basis, and especially, of elderly populations in whom an additional difficulty may be caused by inefficient absorption of nutrients. Dietitions and consumers should be educated to make dietary compensations that increase zinc intake or to use zinc supplements. Alternately, cereals manufacturers could fortify their products with zinc, as some have already done.

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