Nondigestible Carbohydrates and Mineral Bioavailability

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ABSTRACT  Generally, fiber and compounds associated with fiber in cereal products (e.g., phytates) have been found to reduce the apparent absorption of minerals (such as calcium, magnesium, zinc and manganese) in humans, livestock and animal models. The effects of “soluble” forms of fiber (specifically pectins, gums, resistant starches, lactulose, oligofructose and inulin) on mineral absorption are more difficult to characterize. The addition of these soluble forms of fiber has been found in various studies to add viscosity to the gut contents, promote fermentation and the production of volatile fatty acids in the cecum, have a trophic effect on the ceca of animals and increase serum enteroglucagon concentrations. Thus it is not surprising that the addition of soluble forms of fiber to diets often has been found to improve absorption of minerals. This may reflect absorption of electrolytes from the large intestine. Future work should address the mechanisms by which ingestion of nondigestible carbohydrates improves mineral absorption in humans. J. Nutr. 129: 1434S–1435S, 1999.

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The addition of cereal fiber to human and animal diets has been found consistently to depress absorption and retention of calcium, magnesium and zinc, and usually to depress absorption of iron (Brune et al. 1992, Ink 1988, van der Aar et al. 1983). This depression of mineral absorption by cereal products was related more to the pectin than to the fiber content of the products (Brune et al. 1992). The size of the fiber particles (van der Aar et al. 1983) and the amount of calcium in the diet (Greger 1987) also modified the effect of cereal fiber on mineral absorption. The effect on mineral absorption of various soluble carbohydrates that are poorly digested in the small intestines of mammals was less consistent. These compounds include pectin, various gums, “resistant” starches and certain oligosaccharides.

Pectin and gums

Investigators have observed that the addition of pectin to diets generally did not alter the absorption of most minerals, except magnesium. (Baig et al. 1983, Ink 1988, van der Aar et al. 1983). Similarly various gel-forming gums (such as locust bean and karaya) have been found to have limited effects on the overall retention of minerals in human balance studies (Behall et al. 1987). However, Kim et al. (1996) demonstrated that certain types of pectin (i.e., low-molecular-weight pectins with a high degree of esterification) increased iron absorption.

Ingestion of pectin and gums produces several changes in the cecum that may influence mineral absorption. Rats chronically ingesting pectin and gums (such as guar and arabinogalactan) generally had a reduced cecal pH, increased cecal wall size and produced increased amounts of volatile fatty acids in the cecum (Demigne et al. 1989, Seal and Mathers 1989, Tulung et al. 1987). Demigne et al. (1989) reported that rats fed pectin had greater fluxes of potassium, magnesium and calcium from their ceca than rats fed fiber-free diets. Seal and Mathers (1989) noted an increased transfer of zinc across the colonic, but not duodenal or ileal mucosa.

The trophic effect of guar gum on the lower gut may be mediated by enteroglucagon (Gee et al. 1996). The release of enteroglucagon was not due to delayed absorption in the guts of rats fed guar gum because the ingestion of hydroxypropyl methylcellulose, a viscous nonfermentable polysaccharide, had no effect on plasma enteroglucagon concentrations or on ileal crypt cell size (Gee et al. 1996).

“Resistant” starches

Another group of nondigestible carbohydrates that may affect mineral absorption are native resistant and retrograded resistant starches. Schulz et al. (1993) found that although ingestion of both types of resistant starch lowered the cecal pH and increased the calcium concentrations in the liquid phase of the cecal contents, only ingestion of the native resistant starch lowered the ileal pH and increased the calcium and magnesium concentrations in the liquid phase of the ileal contents. Only rats fed the native resistant starch had improved calcium and magnesium absorption.

Lactulose and related sugars

Ingestion of lactulose (Brommage et al. 1993) and to a lesser extent lactose (Behling and Greger 1990) has been associated with improved absorption of calcium, magnesium...
and/or zinc. The effect of these disaccharides could not be related to the effects of their component sugars (Behling and Gregor 1990; Brommage et al. 1993).

Ingestion of these resistant sugars resulted in cecal hypertrophy, reduced pH of cecal contents and increased concentrations of volatile fatty acids in the ceca (Demigné et al. 1989). However, Brommage et al. (1993) demonstrated that ingestion of lactulose, other resistant sugars and oligofructose stimulated calcium absorption as much in rats with a cecectomy as in controls. They hypothesized that, by distending the walls of the small intestine, these osmotically active sugars increased the permeability of the intracellular junctions to passive absorption of minerals.

**Fructooligosaccharides and inulin**

Several investigators have demonstrated that rats fed oligofructose and/or inulin absorbed more calcium and magnesium than control rats despite an increase in total fecal mass (Delzenne et al. 1995, Ohta et al. 1994). Chronic ingestion of inulin or oligofructose decreased or prevented the loss of bone mass, calcium and phosphorus from the bones of gastrectomized rats (Ohta et al. 1998) and the loss of bone mineral density by ovariectomized rats (Taguchi et al. 1994).

The improved absorption of minerals in rats fed inulin and oligofructose was associated with decreased pH of ileal, cecal and colonic contents, hypertrophy of cecal walls, and increased concentrations of volatile fatty acids, bile acids, calcium, phosphate, and to a lesser extent magnesium in the cecal contents (Levrat et al. 1991, Ohta et al. 1994). Ohta et al. (1994) reported that although ingestion of oligofructose improved calcium and magnesium absorption in normal rats, only magnesium absorption was increased in cecectomized rats. This suggested that the effect of fermentation in the cecum was particularly important for calcium absorption.

Cecal fermentation and absorption may be more important in rats than humans. Van den Heuvel et al. (1998) observed no effect of ingestion of oligofructose and inulin on calcium and iron absorption in human adults, but did observe an increased absorption of calcium in adolescents upon oligofructose ingestion (van den Heuvel et al. 1999). Coudray et al. (1997) noted that inulin improved the absorption of calcium, but not the absorption of magnesium, iron and zinc in humans.

Future work should address the mechanisms by which ingestion of nondigestible carbohydrates improves mineral absorption. The relative importance of the mechanisms may vary with the type and amount of nondigestible carbohydrate and of the mineral in the diet.

**LITERATURE CITED**


