

# Human Nutrition and Metabolism Research Communication

## Two Polyol, Low Digestible Carbohydrates Improve the Apparent Absorption of Magnesium but Not of Calcium in Healthy Young Men

(Manuscript received 25 July 2002. Initial review completed 3 September 2002. Revision accepted 1 October 2002)

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**ABSTRACT** The effects of nondigestible oligosaccharides including polyols on intestinal mineral absorption have been studied extensively in animal experiments, but their impact on mineral absorption in humans remains to be established. We investigated the effects of feeding two fermentable, low digestible carbohydrates, on the apparent absorption and balance of calcium (Ca) and magnesium (Mg) in humans. Nine healthy young men were given a control diet with dextrose or polyols, low digestible, fermentable carbohydrates (LHBC, HPFL) for 32-d periods according to a 3 × 3 Latin-square design. During the 18-d period of adaptation, the products were administered gradually in liquid form, up to a maximum of 100 g/d, which was then consumed for 14 d. Ca and Mg levels were measured in diets and in fecal and urine collections to assess apparent mineral absorption and balance. The relative apparent absorptions of Ca and Mg from the control diet were (means ± SEM) 33.3 ± 4.6 and 39.8 ± 2.7%, respectively. Ingestion of both low digestible carbohydrates significantly increased the relative apparent absorption of Mg by about 25%. LHBC, but not HPFL, ingestion increased urinary Mg excretion. Apparent absorption, urinary excretion and balance of Ca were not altered by the ingestion of either low digestible carbohydrate. Ingestion of the low digestible, fermentable carbohydrates, with balanced diets, improved apparent Mg absorption without significant effects on apparent absorption or retention of Ca in healthy young men. Further human studies are therefore still needed to confirm

the effects of these products in other populations. *J. Nutr.* 133: 90–93, 2003.

KEY WORDS: • calcium • magnesium • fermentation • polyol carbohydrates • mineral balance

There is now overwhelming evidence that low digestible carbohydrates are a necessary component of human and animal diets and play an important role in human health (1). Recently, attention has increasingly focused on fermentable carbohydrates, and more especially on fermentable polyols (sugar alcohols), currently used in various agro-food industries (2). Polyols, low digestible carbohydrates, are almost completely degradable in the large intestine by fermentation. Polyols are key food ingredients because they permit the development of sugar-free confectionery, which offers the benefits of noncariogenicity, reduced energy intake and low glycemia. Increasing not only dietary intake of Ca and Mg, but also their intestinal absorption, is of great interest for different categories of populations at risk of deficiency such as postmenopausal women, the elderly and diabetics (3). In previous animal studies, we showed that fermentable carbohydrates enhanced Ca and Mg absorption (4). This observation was recently confirmed by other authors (5). Moreover, the polyols, maltitol, lactitol and isomalt, were shown to enhance mineral bioavailability in rats (6). To date, no human data reporting the effect of polyols on mineral bioavailability are available. As part of a larger project concerning the effects of dietary fiber in human nutrition, we studied the consequences of an increased intake of two polyols. The criteria used were food tolerance, stool characteristics, nutrient digestibility, energy metabolism (7) and mineral balance. Here, we report the results of the ingestion of these polyols on the apparent absorption and the balance of Ca and Mg.

### SUBJECTS AND METHODS

**Subjects.** Nine healthy young men with no medical history of renal, vascular, digestive, endocrine or currently evolving disease were enlisted after a normal physical examination. The subject characteristics were as follows (means ± SEM): age, 20.0 ± 0.5 y; weight, 68.4 ± 2.7 kg; height, 1.76 ± 0.02 m; body mass index, 22.1 ± 0.5 kg/m<sup>2</sup>; lean mass, 58.5 ± 2.1 kg. Each subject received a complete explanation of the purpose and procedures of the investigation and signed an informed consent form. The study protocol was approved by the regional Medical Faculty Ethical Committee (CCPPRB no. AU205). The subjects had lunch and dinner at the Human Nutrition Laboratory throughout the control period. Breakfasts were provided that consisted of 20 g sweetened instant cocoa powder, 280 g semi-skimmed milk, 65 g sandwich loaf bread, 10 g butter and 60 g jam. In addition, the volunteers were given a 70 g milk roll for a snack. Extra

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**TABLE 1**  
*Menu composition*<sup>1,2</sup>

Day 1		Day 2	
Lunch	Dinner	Lunch	Dinner
Red beets, 71 g Tuna, canned, 33 g Salad dressing, 18 g Ground beef, 104 g Sunflower oil, 4 g Green beans, 210 g Butter, 5 g Babybel cheese, 20 g Sponge cake, 48 g Chocolate, dark, 20 g Bread, 58 g	Turkey breast, 67 g Sunflower oil, 3 g Boiled rice, 257 g Boiled courgette, 95 g Butter, 5 g Emmental cheese, 29 g Pineapple, canned, 105 g Bread, 58 g	Semolina, 57 g Chicken, 108 g Tomato sauce, 52 g Carrots, 38 g Sunflower oil, 5 g Butter, 5 g Yogurt, 125 g Sugar, 10 g Madeleine biscuits, 38 g Bread, 58 g	Raw tomatoes, 95 g Salad dressing, 43 g Tuna, canned, 86 g Pasta, egg, 156 g Emmental cheese, 18 g Brie cheese, 33 g Compote, 172 g Bread, 58 g
Day 3		Day 4	
Lunch	Dinner	Lunch	Dinner
Strasbourg sausage, 73 g Boiled potatoes, 306 g Butter, 10 g Blue cheese, 36 g Kiwi fruit, 160 g Bread, 65 g	Quiche Lorraine, 170 g Spinach, steamed, 262 g Light cream, 18 g Chocolate custard, 115 g Sponge fingers, 21 g Bread, 65 g	Turkey, 105 g Sunflower oil, 5 g Light cream, 20 g Mustard, 18 g Pasta, egg, 272 g Butter, 8 g Chabichou cheese, 28 g Custard, canned, 91 g Bread, 58 g	Raw tomatoes, 95 g Green beans, 95 g Boiled rice, 164 g Egg, hard boiled, 100 g Salad dressing, 40 g St. Nectaire cheese, 28 g Peas, canned, 112 g Bread, 65 g

<sup>1</sup> The amounts of the different components shown in this table are indicative of the actual consumed quantities, which were exactly weighed for each subject during each dietary period. Breakfasts were provided and composed of 20 g sweetened instant cocoa powder, 280 g semiskimmed milk, 65 g sandwich loaf bread, 10 g butter and 60 g jam. In addition, the volunteers were given a 70 g milk roll for a snack.

<sup>2</sup> The planned macro and micronutrients contents of the offered diets corresponded to the nutritional recommendations. The estimated gross energy intake from these diets was between 13 and 14 MJ/d.

food items such as alcoholic and energy-containing beverages were not allowed.

**Experimental design.** The subjects were offered three diets according to a Latin-square design (3 × 3) with three repetitions. Each experimental period comprised 32 d, starting with a daily progressive adaptation to a maximum of 100 g dry matter per day of the tested products (until d 18) followed by 14 d with a constant intake of the tested products. Duplicate meals were prepared by a staff member for each day of the experimental balance periods, including breakfast and snacks. The balance period involved food intake determination and total collection of feces and urine. Duplicate meals and all individual leftovers were homogenized, freeze-dried and analyzed separately. Urine and feces was collected during the last 10 d of each experimental period. The collected urine per subject was pooled and representative samples were saved in acid-washed bottles and stored at -18°C until analysis. Feces were collected in plastic pots, stored at -18°C, pooled, homogenized, freeze-dried and stored at -18°C until analysis.

**Experimental diets.** Four daily balanced menus were distributed in rotation to subjects during each balance period (Table 1). The planned macro- and micronutrients contents of the offered diets corresponded to nutritional recommendations. The estimated energy intake from these diets was between 12.0 and 12.5 MJ/d, including the tested products. The tested products were provided by the Roquette Frères Company (Lestrem, France). The maltitol syrup Lycasin@HBC (LHBC<sup>2</sup> diet) consisted of 50% of maltitol and 50% of a hydrogenated polysaccharide fraction of Lycasin@HBC (HPFL

diet); the latter was also tested. In this study, the tested products were diluted in water and offered in six equal doses at breakfast (1000 h), lunch (1600 h) and dinner (2200 h) to prevent a bulky input of fermentable carbohydrates in the large intestine. Information on food tolerance and net energy value of these products and their impact on nutrient digestive utilization may be found in Sinaud et al. (7).

**Analytical methods.** Food intake was monitored by collection of duplicate meals by the laboratory staff. Composite samples of food were prepared using metal-free materials. About 0.5 g of tested products or diets or 0.25 g of feces were dry-ashed at 500°C for 10 h and the dry residue was added to HCl (6 mol/L), diluted adequately and analyzed for Ca and Mg. Urine was analyzed directly with dilution in 1 g/L of lanthanum chloride solution. Ca and Mg were assayed by flame atomic absorption spectrometry (Perkin-Elmer 560, Paris, France) with an air-acetylene flame and hollow cathode lamps at wavelengths 422 and 285 nm, respectively. Mineral levels were calculated from standard curves of mineral solutions (Merck, Lyon, France). Analytical quality was checked using total diet control standards (NIST) for dietary mineral measurements, home constructed human feces for fecal mineral measurements and Seronorm® urine (Nycomed, Oslo, Norway) for urinary mineral measurements. The Ca measurements were 102 ± 2, 97 ± 4 and 99 ± 3% of certified values for these three quality controls. The Mg measurements were 101 ± 3, 98 ± 2 and 99 ± 4% of certified values for the three quality controls. All measurements were performed at least in duplicate. Cecal short-chain fatty acid (SCFA) levels were determined by gas-liquid chromatography (8).

**Calculations.** Absolute apparent absorption (mg/d) was calculated as follows: daily mineral intake - daily mineral fecal excretion. Relative apparent absorption (%) was calculated as follows: 100 × [(daily mineral intake - daily mineral fecal excretion)/(daily mineral intake)]. Mineral retention (mg/d) was calculated as follows:

<sup>2</sup>Abbreviations used: FOS, fructo-oligosaccharide; HPFL, hydrogenated polysaccharide fraction of Lycasin@HBC; LHBC, Lycasin@HBC; SCFA, short-chain fatty acids.

(daily mineral intake) – (daily mineral fecal excretion + daily mineral urinary excretion).

**Statistical analysis.** Data were analyzed statistically according to a Latin-square design (3 × 3) with three repetitions. Comparisons between experimental diets were made by ANOVA using the general linear model procedure of Statistical Analysis Systems (9), according to the following model:  $\mu + \alpha \text{ diet} + \beta \text{ repetition} + \delta \text{ subject} + \epsilon$ . For each experimental treatment, the data are presented as adjusted means  $\pm$  adjusted SEM. Differences were considered significant at  $P < 0.05$ .

## RESULTS

**Calcium.** Total daily Ca intake was from 1200 to 1300 mg for each of the three experimental periods. The tap water Ca concentration was 0.62 mmol/L, the consumption of which represented about 2.5% of daily Ca intake. Ca fecal excretion was similar in all three treatments and varied from 840 to 860 mg/d. Consequently, both absolute (mg/d) and relative (%) apparent Ca absorptions were unaffected by diet treatment. The relative apparent absorption of Ca was between 32 and 37%. Neither daily Ca urinary excretion (~180 mg) nor daily Ca retention (230 mg) differed among the three experimental treatments.

**Magnesium.** Total daily Mg intake was from 320 to 330 mg for each of the three experimental periods. The tap water Mg concentration was 0.37 mmol/L, the consumption of which represented about 5% of total Mg intake. Mg fecal excretion was lower when the polyols were consumed than when dextrose was consumed (Table 2). Consequently, both relative and absolute apparent Mg absorptions were greater after ingestion of HPFL and relative apparent absorption was greater after intake of LHBC than after dextrose intake (Table 2). Eight out of nine subjects had higher apparent Mg absorption when fed the HPFL diet than when fed the control diet, and six of nine subjects had higher apparent Mg absorption when fed the LHBC diet than when fed the control diet. This

improvement in apparent Mg absorption was accompanied by a significant increase in Mg urinary excretion when given the LHBC treatment (Table 2).

## DISCUSSION

We examined the effect of ingestion of 100 g/d of LHBC or HPFL, two polyol, low digestible, fermentable carbohydrates, on apparent absorption and balance of Ca and Mg in healthy young men. The products were introduced gradually, 20–100 g/d, over an 18-d period and divided into six equal doses. This large dose was used to enable us to determine satisfactorily the energy value of these products (7). This study design mimics consumption of confectionery and avoids possible adverse effects. Both studied products were accepted by the volunteers with no difficulty. The main result of this work was that these polyols significantly improved apparent Mg absorption, whereas the intestinal absorption and balance of Ca were not altered.

Since 1977 the potential beneficial effects of fermentable carbohydrates on mineral absorption and status, in particular Ca and Mg, have been largely investigated by our group (10,11) and by other workers (5,12). The animal studies clearly showed a beneficial effect of fermentable carbohydrates on intestinal absorption of Ca and Mg, although this effect is less marked for Ca than for Mg and often depends on experimental conditions.

The positive effect of fermentable carbohydrates on intestinal mineral absorption is attributed mainly to the high production of SCFA (13), which produces a decrease in the luminal pH and an increase in the concentration of ionized minerals in the cecum. Consequently, the mineral solubility is increased and the active and passive diffusion of minerals across the intestinal cells is enhanced. As a consequence, these fermentation-induced changes theoretically ought to improve the intestinal absorption of nearly all minerals in the hindgut. However, in this study, apparent Mg absorption was increased, whereas that of Ca was unchanged. The intestinal absorption mechanism and site of Mg largely differ from those of Ca, which may explain the different impact of fermentable carbohydrates on the apparent absorption of these two minerals.

The absorption efficiency of dietary Ca depends on two major factors: its regulation by physiological factors including hormones and its interaction with the other dietary constituents (14). A possible explanation for the lack of an effect of fermentable carbohydrates on Ca intestinal absorption in this study is downregulation of its active intestinal absorption in the upper part of intestine after several weeks of fermentable carbohydrate intake (15). We speculate that fermentable carbohydrate feeding increased Ca intestinal absorption in the lower parts of the intestine, but fermentable carbohydrate feeding for several weeks may result in a “feedback” effect decreasing Ca intestinal absorption in the high parts of the intestine. Experimental data obtained from rat studies seem to confirm such an adaptation effect. Chonan and Watanuki (16) noted that galacto-oligosaccharide supplementation increased apparent Ca absorption in ovariectomized rats at the beginning (9 d) but not at the end of their experiment at 28 d. In human studies fructo-saccharides and lactulose increased intestinal Ca absorption in adolescent and postmenopausal women when the supplementation lasted only 9 d (17,18), whereas other studies conducted in adults showed no effect after a 21-d supplementation (19,20). Lack of an effect on the absorption of Ca is also likely attributable to the status and requirement of the subjects; this is more probably attributable

**TABLE 2**

*Energy intakes and effects of long-term ingestion (32 d) of two polyol, low digested carbohydrates, LHBC and HPFL, on absolute and relative apparent magnesium absorptions and retention in healthy young men<sup>1,2</sup>*

Intake/effect	Dextrose	LHBC <sup>3</sup>	HPFL
Gross energy intake, MJ/d	12.97 $\pm$ 0.77	13.22 $\pm$ 0.62	13.81 $\pm$ 0.58
Metabolized energy intake, MJ/d	12.50 $\pm$ 0.57	11.97 $\pm$ 0.58	12.50 $\pm$ 0.53
Mg Intake, mg/d	322 $\pm$ 11	320 $\pm$ 13	330 $\pm$ 12
Fecal Mg excretion, mg/d	189 $\pm$ 12 <sup>a</sup>	165 $\pm$ 13 <sup>b</sup>	166 $\pm$ 12 <sup>b</sup>
Absolute apparent Mg absorption, mg/d	133 $\pm$ 23 <sup>b</sup>	159 $\pm$ 19 <sup>ab</sup>	189 $\pm$ 24 <sup>a</sup>
Relative apparent Mg absorption, %	39.8 $\pm$ 2.7 <sup>b</sup>	48.5 $\pm$ 3.0 <sup>a</sup>	50.5 $\pm$ 2.7 <sup>a</sup>
Urinary Mg excretion, mg/d	115 $\pm$ 9 <sup>b</sup>	143 $\pm$ 9 <sup>a</sup>	129 $\pm$ 9 <sup>ab</sup>
Mg retention, mg/d	18 $\pm$ 9	13 $\pm$ 10	35 $\pm$ 9

<sup>1</sup> Values are the adjusted means  $\pm$  adjusted SEM,  $n = 9$ . Means in a row with superscripts without a common letter differ,  $P < 0.05$ .

<sup>2</sup> The subjects were offered three experimental diets according to a Latin-square design (3 × 3) with three repetitions. Each experimental period constituted 18 d, with a daily progressive adaptation to a maximum of 100 g dry matter/d of the tested products followed by 14 d with a constant intake of these products.

<sup>3</sup> LHBC, lycasin@HBC; HPFL, hydrogenated polysaccharide fraction of Lycasin@HBC.

to a higher requirement or less feedback than to the longer duration of the treatment in men.

Intestinal Mg absorption occurs mainly in the lower parts of the intestine, especially in the jejunum and ileum (21). The mechanisms involved in intestinal Mg absorption are a saturable process and passive diffusion. The component of intestinal Mg absorption from the distal part of the intestine by passive diffusion is very large. The results of this study clearly showed a significant increase in the relative apparent Mg absorption during the consumption of both fermentable polyols. This was accompanied by an increase in urinary Mg excretion during LHBC intake, in which the kidney is the organ that most closely regulates Mg metabolism. This increase confirms the positive effect of fermentable carbohydrates on apparent Mg absorption. In previous work in which chemical balance was employed, we showed that 40 g/d of inulin tended to increase apparent Mg absorption in young men by ~10% (22).

Recently, in an isotopic study, we showed that short-chain oligosaccharides increased intestinal Mg absorption in postmenopausal women (12%) (23). Van den Heuvel (24) investigated the effect of 15 g/d of FOS consumption, for 9 d, on Mg absorption in adolescents by measurement of urinary excretion of orally administered <sup>25</sup>Mg. Moreover, this study failed to show an effect of FOS, although the observed increase in urinary excretion of <sup>25</sup>Mg was 18% after FOS ingestion. To our knowledge, this is the first time that such a beneficial effect of a sugar alcohol on apparent Mg absorption has been demonstrated in humans.

In conclusion, a significant positive effect of two low digestible fermentable carbohydrates, LHBC and HPFL, on apparent Mg absorption was demonstrated in this study. The improvement in intestinal Mg absorption may be of special interest for people with large Mg needs or at risk of Mg deficiency. Although both products were without effect on Ca absorption and balance, fermentable carbohydrate feeding may improve intestinal absorption of Ca only in populations who show a high need for this mineral, such as adolescents, or in populations with impaired mineral absorption, such as women during late menopause and older populations. Further human studies are therefore still needed to confirm the effects of these products in other populations.

## ACKNOWLEDGMENTS

The authors acknowledge the cooperation of the subjects for their contribution. They also thank Guy Manhiot for kitchen assistance, and Jean Vernet for help with statistics.

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