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Absorption of zinc and retention of calcium: Dose-dependent inhibition by phytate

Kerstin Fredlund[a,*], Mats Isaksson[b], Lena Rossander-Hulthén[c], Annette Almgren[a], Ann-Sofie Sandberg[a]

[a]Department of Chemical and Biological Engineering/Food Science, Chalmers University of Technology, SE 412 96, Göteborg, Sweden
[b]Department of Radiation Physics, Sahlgrenska Academy at Göteborg University, SE 413 45, Göteborg, Sweden
[c]Department of Clinical Nutrition, Internal Medicine, Sahlgrenska Academy at Göteborg University, PO Box 459, SE 405 30, Göteborg, Sweden

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Abstract

The dose-dependent inhibitory effect of sodium phytate (*myo*-inositol-hexaphosphate) on absorption of zinc and retention of calcium was studied in man. No systematic study of this dose–response effect has been reported to this time. Forty subjects were served meals containing white wheat rolls without/with additions of phytate. Ten subjects were given test meals containing one or two of the studied levels of phytate and in addition all subjects were served meals to which no phytate was added. The zinc content was 3.1 mg (47 μmol) and the calcium content 266 mg (6.6 mmol). The rolls were labelled extrinsically with radioisotopes, ^{65}Zn and ^{47}Ca, and whole-body retention of both minerals was measured. Totally 105 meals were served, 36 meals in which no phytate was added and 9–10 meals on each level of phytate. The zinc absorption in meals to which either 0, 25, 50, 75, 100, 140, 175 or 250 mg of phytate-P (0, 134, 269, 403, 538, 753, 941 or 1344 μmol phytate) had been added was 22%, 16%, 14%, 11%, 7%, 7%, 7% and 6%, respectively (mean values). The addition of 50 mg phytate-P or more significantly decreased zinc absorption ($p = 0.01$) as compared to absorption from the test meals with no added phytate. The calcium retention at day 7 in the same meals was 31%, 28%, 27%, 26%, 22%, 19%, 14% and 11% (mean values). The addition of 100 mg phytate-P or more significantly decreased calcium retention ($p = 0.03$) compared to the test meals with no added phytate. It was concluded that the inhibitory effect of phytate on the absorption of zinc and the retention of calcium was dose dependent.

Keywords: Phytate; $InsP_6$; Zinc absorption; Calcium retention; Whole-body counting

Introduction

Inadequate intakes of essential micronutrients are common and deficiencies are a worldwide problem, especially in developing countries [1,2]. The most important source of minerals and trace elements on a global basis is unrefined cereals. All seeds, such as

*Corresponding author. Tel.: +46 31 772 38 24; fax: +46 31 772 38 30.
E-mail address: ann-sofie.sandberg@chalmers.se (K. Fredlund).

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cereals, peas, nuts, oilseeds and legumes contain phytate (*myo*-inositol-hexaphosphate = $InsP_6$) [3]. It is well known that phytate negatively affects the absorption of many essential elements such as iron, zinc and calcium but also manganese and magnesium [4–8]. The inhibitory effect on iron and magnesium absorption of phytate or inositol tri- to hexaphosphates ($InsP_3$–$InsP_6$) has been found to be dose dependent [5,8,9]. Iron absorption was strongly inhibited in meals containing even small amounts of inositol phosphates [5,9–11]. Iron absorption markedly increased when the content of phytate or $InsP_3$–$InsP_6$ in a meal was below 10 mg P [5,9].

The addition of sodium phytate to single meals significantly impaired zinc absorption [12]. The same was observed when phytate was added to the diet in a 63-day study [13]. Zinc absorption from cereal and soy protein meals was also found to correlate negatively to the content of phytate or $InsP_3$–$InsP_6$ [4,14–17]. Reducing the dietary $InsP_3$–$InsP_6$ level below 50 mg P resulted in a clear increase in zinc absorption [18]. Hydrolysis of phytate during bread fermentation, hydrothermal treatment or malting was found to significantly increase zinc absorption [4,19].

The early balance studies of McCance and Widdowson [20] showed a reduction in the apparent calcium absorption in subjects fed brown bread as compared with subjects fed white bread. Calcium absorption greatly improved when the brown bread was dephytinised [21]. When a radioisotope technique was used, it was found that calcium absorption was significantly higher when subjects were fed low-phytate diets than high-phytate diets [6,22–23]. In another isotope study, inositol phosphates did not appear to influence calcium retention [19].

The inhibitory effect of different levels of phytate on the retention of zinc and calcium in humans has not been systematically studied. The aims of the present investigation were to study the dose-dependent effect of adding different amounts of sodium phytate to a single meal and to determine the whole-body retention of zinc and calcium with radionuclide technique.

Subjects and methods

Experimental design

Forty subjects were served two or three meals each after an overnight fast. Height and weight were registered, and each subject′s background radioactivity was measured in a whole-body counter before the intake of a meal. Blood samples were drawn from the subjects in the fasting state for determinations of zinc and calcium in serum. The subjects were served test meals consisting of white wheat rolls to which known amounts of sodium phytate (25–250 mg phytate-P) were added immediately before serving. Four groups of ten subjects ate test meals containing each level of phytate. All subjects also received a meal to which no sodium phytate was added. The groups were served the meals in the following, not randomised, order: the first one 0 and 250 mg, the second 100, 50 and 0 mg, the third 75, 140 and 0 mg, the forth 25, 175 and 0 mg phytate-P. Water was served with the rolls. The zinc and calcium contents were adjusted to 3.1 mg (47 μmol) and 266 mg (6.6 mmol), respectively, by adding zinc chloride and calcium chloride to the dough. The rolls were labelled with approximately 0.2 MBq ^{65}Zn and 0.2 MBq ^{47}Ca per portion immediately before they were served. No food or drink was allowed for the following 3 h. The activities of ^{65}Zn and ^{47}Ca were then measured by whole-body counting three to six times over a 4-week period after each meal.

Subjects

Twenty-eight female and 12 male healthy volunteers 19–55 years of age (median 24 y) and with a body mass index of $22.3 \pm 2.3\,kg/m^2$ (mean ± SD), participated in the experiment. The subjects were recruited among the students at Göteborg University. One fasting blood sample was drawn from each subject.

Subjects were given written and oral information about the aims and procedures of the study. Subjects gave their written consent to take part in the study. The study was approved by the Ethics Committee and the Isotope Committee of Sahlgrenska University Hospital, Göteborg.

Radioisotopes and radiation exposure

The radioisotopes used in the study were ^{65}Zn, $T_{1/2} = 243.6$ d ($^{65}ZnCl_2$), purchased from Amersham plc (Amersham, Buckinghamshire, UK), and ^{47}Ca, $T_{1/2} = 4.53$ d ($^{47}CaCl_2$) from Risö National Laboratory (Roskilde, Denmark). Individual portions of the radioisotope stock solutions were diluted in deionised water in standardised plastic capsules. All portions were first measured in an activity calibrator and then added to the meals. The activity in the empty plastic capsules was then measured again to check for residual activity. The maximum activity given to a subject was in all 0.6 MBq of ^{65}Zn and 0.6 MBq of ^{47}Ca.

Using the dose coefficients recommended by ICRP [24], the committed effective dose of ^{65}Zn was 2.3 mSv and of ^{47}Ca 0.96 mSv, i.e. a total of 3.3 mSv. This dose is within the ICRP [25] guidelines for studies in volunteers.