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ПРОБЛЕМНАЯ СТАТЬЯ

LOOKING AT AN ALTERNATIVE TO ZINC FORTIFICATION

ОБ АЛЬТЕРНАТИВЕ ОБОГАЩЕНИЮ ПИЩИ ЦИНКОМ

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ABSTRACT: Phytate and zinc homeostasis are closely allied. Phytate affects the efficiency of zinc absorption, playing major role in development of zinc deficiency in humans and monogastric animals. A usual solution to prevent zinc deficiency is to fortify food with zinc. However, there is a possible alternative way: to reduce phytate in diet by use of phytase enzyme.

РЕЗЮМЕ: Гомеостаз цинка тесно связан с потреблением фитата. Фитат снижает эффективность всасывания цинка, играя главенствующую роль в развитии дефицита цинка у человека и моногастрических животных. Обычно для предотвращения дефицита цинка используют обогащение им пищевых продуктов. Однако возможен альтернативный путь: снижать количество фитата в рационе с помощью фермента фитазы.

Phytate and zinc homeostasis are closely allied. In the absence of phytate, the study of zinc nutrition and homeostasis is an academic curiosity. With phytate, a natural constituent of all plant seeds, the compromise of zinc homeostasis is a serious and universal problem throughout the world. The initial demonstration that phytate (phytic acid) decreased zinc homeostasis was considered an effect on absorption at that time (O'Dell and Savage, 1960) (Table 1). This was later extended to swine and rats (Oberleas et al., 1962, Oberleas et al., 1966) (Fig. 1). It was subsequently demonstrated to cause zinc deficiency in other species including man (Oberleas, Harland, 2008). Thus, when one studies zinc nutrition and metabolism, it is necessary to study both zinc and phytate. There is very little zinc deficiency in monogastric species, including man, in the absence of phytate.

It is easy to conceive that phytate may affect the efficiency of absorption of zinc. First, zinc is largely ionic in the duodenum and proximal ileum where zinc is absorbed. Second, zinc forms stable complexes with phytate at about pH 6, the approximate pH of the upper small intestine. Third, and what is frequently overlooked, zinc is unique in being the sole trace element that is recycled via the pancreas (Oberleas, 1983). The zinc is secreted as part of metallothionein I. Metallothionein I can complex up to 7 atoms of zinc per molecule of protein. With several proteolytic enzymes secreted by similar physiology, the zinc is essentially ionic shortly after reaching the duodenum (Onosaka et al., 1988, De Lisle et al., 1996). With such large amounts of zinc being resecreted, the zinc available for complexation by dietary phytate becomes 2 to 4 times the amount of zinc that would be consumed in a day (Oberleas, 1996) (Fig. 2). The relative solubility of various trace element cations in the presence of phytate has been studied in vitro without resorting to saturation kinetics. These studies have shown that of the essential trace elements, zinc binds more tightly at pH 6 the approximate pH of the duodenum. Considering the conditions and the biochemistry involved, this makes zinc deficiency the most prevalent deficiency worldwide (Oberleas, Chan, 1997) (Fig. 3).

Zinc deficiency can then be described in terms of phytate and zinc in the diet. This has best been expressed in terms of a phytate : zinc molar ratio (Oberleas, 1975) (Fig. 4). It has been determined that the critical molar ratio is about 10 in which molar ratios below 10 provides zinc homeostasis whereas as molar ratios is become greater than 10 the zinc deficiency becomes increasingly more severe (Lo et al., 1981). Thus it is possible to study zinc deficiency in a population without invasive techniques (Oberleas, 2005) and not too difficult to estimate that as much as 70% of the worlds population may be affected by zinc deficiency.

Now that the mechanism of zinc homeostasis is understood and involves both zinc and phytate together even in an otherwise estimated adequate intake, we can attack the problem two ways. The obvious is to supplement diets with zinc in excess of the estimated capacity of the dietary phytate as de-

Table 1. ***First demonstration of phytate effect on homeostasis of zinc for chick growth (weight at 4 weeks, g)***

Casein-gelatin protein diet			Soybean protein diet		
Trials	1	2	Trials	1	2
Basal (B)	460	447	Basal (B)	162	122
B + 55 ppm Zn	469	446	B + 15 ppm Zn	382	391
Casein-gelatin + Phytate	206	153	B + 55 ppm Zn	473	440
Casein + Phytate + 55 ppm Zn	473	395	Soy protein + Phytate	97	94

Note: Initial n = 10;
Source: O'Dell, Savage, 1960

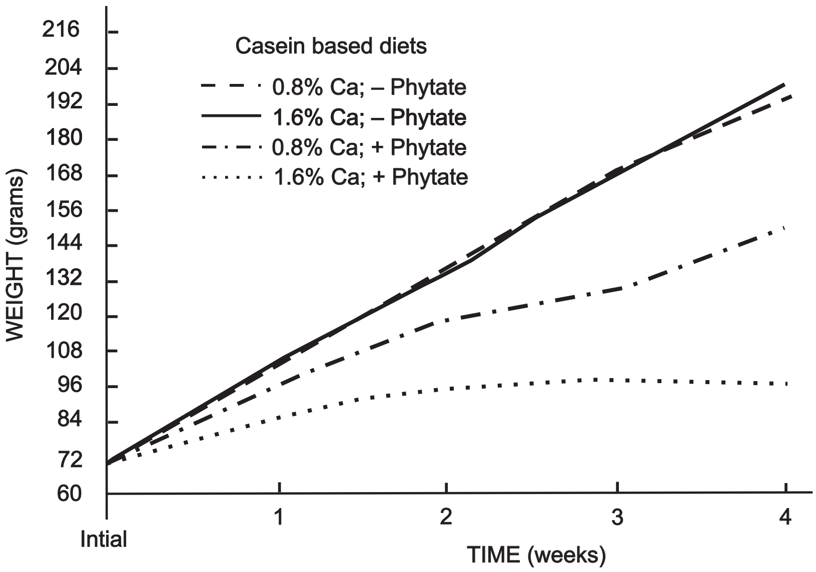

Fig. 1. *Growth of rats fed casein protein diets with and without phytate and with two levels of dietary calcium (adapted from Oberleas, 1964)*

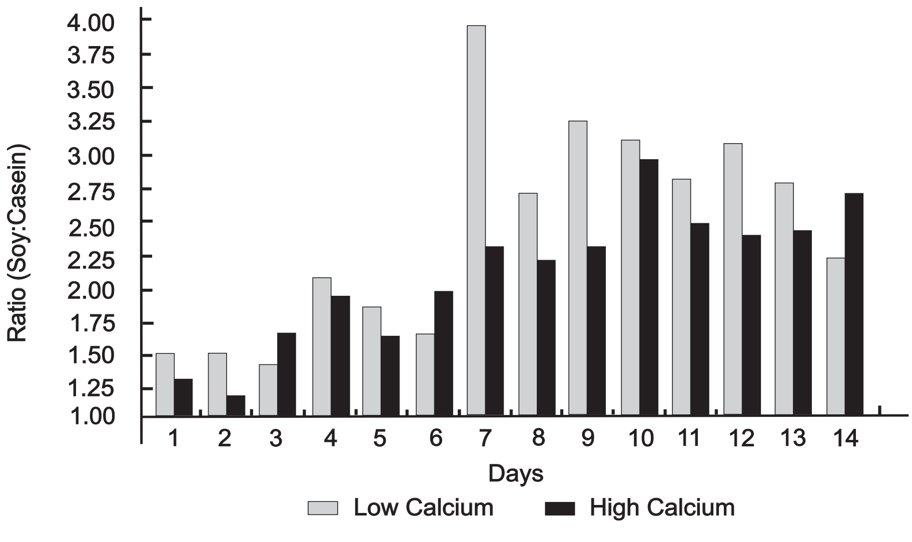

Fig. 2. *Effect of phytate on endogenously secreted zinc by rats at 0.8 or 1.6% calcium. Radioactive ^{65}Zinc was injected intraperitoneally following 3 weeks of adaptation to diets containing isolated soybean protein then reallotted to casein or isolated soybean protein diets (Oberleas, 1996)*

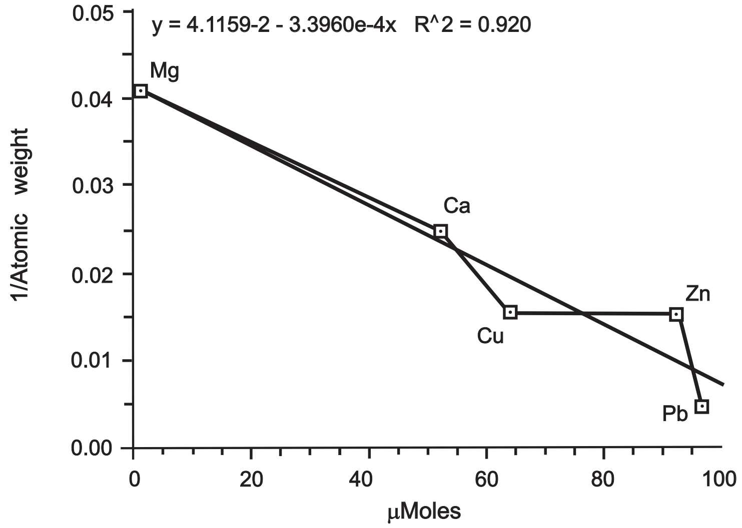

Fig. 3. *In vitro demonstration of various elements at 2:1 molar ratios expressed as relative solubility at pH 6. Distinctly demonstrates the greater insolubility of zinc phytate relative to other elements of interest (Oberleas, Chan, 1997)*

$$\frac{\dfrac{\text{g/kg phytate}}{660}}{\dfrac{\text{g/kg zinc}}{65.4}} = \text{Phytate : zinc molar ratio}$$

Fig. 4. *Formula derived to evaluate the phytate : zinc molar ratio that defines zinc deficiency without invasive techniques (from data contained in Oberleas,1975); 660 — phytate molecular weight, 65.4 — zinc atomic weight*

fined above. Worldwide, this would require several tons of zinc ore daily. The alternative is to reduce the phytate to a level such that the molar ratio of phytate : zinc is less that 10. Phytase enzymes are currently mass-produced from a biotechnologically modified fungus of *Aspergillus niger (Aspergillus ficuum)*. The enzyme is produced in large quantities, by fermentation, for feeding to swine and chickens to improve the absorption and utilization of phosphorus from phytate. At the same time these phytases also increased the absorption and utilization of dietary calcium (Kornegay, Yi, 1996) (Fig. 5). A few

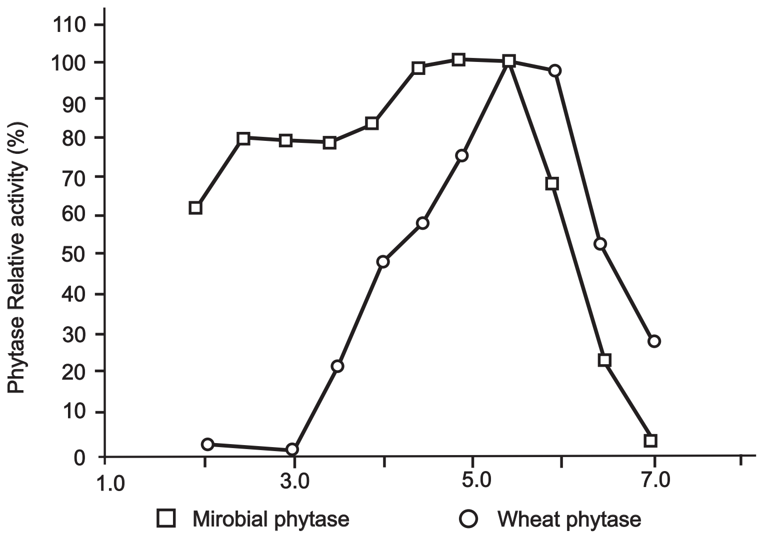

Fig. 5. *Relative activity of phytase produced by modified Aspergillus niger compared with that contained in wheat (from Kornegay, Yi, 1996)*

studies have been done with rats, swine and chickens that show that microbial phytase is efficient in improving the utilization of zinc and phosphorus in these species (Pallauf, Rimbach, 1996). Phytase enzyme suitable for human consumption is currently available in most European Countries, Canada, United States, China and possibly other countries of the world.

In summary, zinc deficiency can easily be determined to be the most prevalent deficiency worldwide, much of it with such subtle symptoms that diagnosis is difficult.

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