Available online on 15.09.2025 at <http://jddtonline.info>

Journal of Drug Delivery and Therapeutics

Open Access to Pharmaceutical and Medical Research

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Review Article

Zinc balance and the chelating properties of phytic acid

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Article Info:

Abstract



Article History:

Received 11 June 2025
Reviewed 25 July 2025
Accepted 20 August 2025
Published 15 Sep 2025

Cite this article as:

Marukhlenko AV, Syroeshkin AV, Levitskaya OV, Galkina DA, Sundukov DA, Pleteneva TV, Zinc balance and the chelating properties of phytic acid, Journal of Drug Delivery and Therapeutics. 2025; 15(9):104-114 DOI: <http://dx.doi.org/10.22270/jddt.v15i9.7343>

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Objectives: Zinc deficiency is recognized as a significant global contributor to morbidity and mortality risk. In the absence of a reliable biological marker for determining the absorption coefficient of dietary zinc, a mathematical model is employed. This systematic review aimed to study this mathematical model and evaluate its potential to calculate the recommended dietary intake of zinc (RDI), compared to actual zinc balance in the human body.

Methods: This review analyzes scientific publications from 1980 to 2025 that focus on zinc balance in the bodies of healthy individuals aged 19 and older of both sexes. Special attention is given to experimental results that demonstrate the disruption of the balance between the RDI and the quantity of zinc excreted through the intestines.

Results: A systematic review of the literature has shown that the recommended dietary allowances for zinc intake, the absorption rate into the bloodstream, and the intestinal excretion of zinc—all critical factors for assessing zinc balance—exhibit substantial variations according to data from different research groups. The mathematical model used to determine the absorption coefficient and calculate dietary zinc intake norms has limitations, as it does not account for the polydentate nature of phytate ions.

Conclusions: The RDI of zinc is lower than the actual requirement and needs adjustments to increase it. The analysis of the zinc balance while considering the polydentate nature of phytic acid can help to make more accurate dietary selections and recommendations for zinc-based supplements, thereby maintaining homeostasis and preventing toxic levels in the body.

Keywords: zinc absorption and excretion, zinc homeostasis, phytic acid polydentency

Introduction

Zinc deficiency is acknowledged as a significant global risk factor for morbidity and mortality. It can result from dietary disorders and malabsorption syndromes, as well as from conditions such as liver disease, chronic kidney disease, sickle cell anemia, diabetes, and obesity ¹.

The zinc content in the organs and tissues of an adult male is approximately 2.2 grams, with about 63% found in muscle tissue, 20% in bones, 3% in the liver, and only 0.1% in plasma ¹⁻⁵.

The biological functions of zinc are diverse and can be categorized into three main roles: catalytic, structural, and regulatory. Zinc is a crucial component of over 250 enzymes and plays a significant role in regulating gene expression by stabilizing the secondary structure of numerous transcription factors ².

The use of zinc isotopes has enabled the identification of two metabolic pools that temporarily dominate the presence of this element within the body. Zinc is eliminated from the liver, pancreas, kidneys, and spleen within 12.5 days. In contrast, the eliminated of zinc from muscles, bones, and nervous tissue cells occurs over a longer period, ranging from 120 to 300 days ⁶⁻⁸.

The zinc ion does not exhibit oxidation-reduction activity in the body, as demonstrated by the Pourbaix diagram for this element (Figure 1), which indicates that in liquid biological medium, the pH values are limited to approximately 1 to 8 ⁹. The reducing properties of zinc can only become apparent when inhaling aerosols containing dispersed particles of metallic zinc (Zn⁰). The high reduction potential in aqueous environments ($E^{\circ} = -0.76 \text{ V}$) can become even more negative depending on the presence of organic components in the body ¹⁰. Under standard conditions and in the absence of bioligands, zinc compounds in aqueous solutions predominantly exist as

aqua complexes ($\text{Zn}(\text{H}_2\text{O})_4^{2+}$) or partially hydrolyzed cations ($\text{Zn}(\text{OH})(\text{H}_2\text{O})_3^+$).

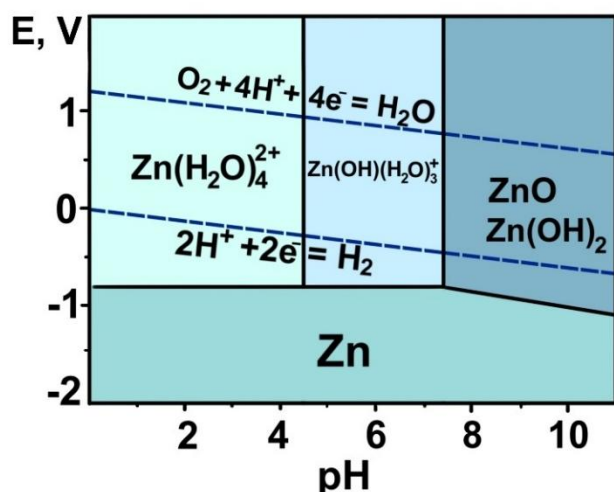


Figure 1: Pourbaix diagram for zinc in aqueous solution.

Both zinc deficiency and excess are accompanied by pathological symptoms ¹¹. The normal range depicted in the dose-response diagram corresponds to the maintenance of zinc homeostasis in the body (Figure 2). The risk of zinc deficiency is particularly high for vegetarians due to the low zinc content in plant-based foods, as well as for individuals with conditions that impair absorption in the gastrointestinal tract. Additionally, zinc absorption can be influenced by the excess of other trace elements, primarily copper and calcium ¹².

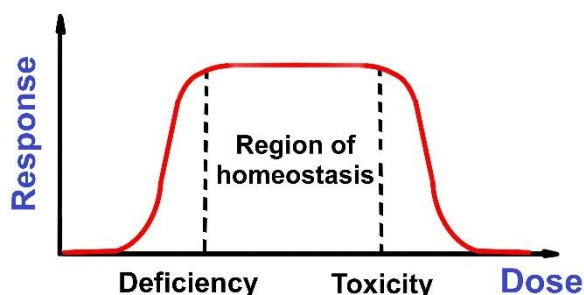


Figure 2: The classic dose-response curve. The homeostasis region is delineated by vertical dotted lines.

There is conflicting quantitative data in the literature regarding zinc homeostasis, which is regulated by the "bioavailability-excretion" system. For instance, the acceptable upper intake levels of zinc vary significantly. According to the World Health Organization (WHO), the recommended limit is 15 mg for adults of both sexes ¹³. In contrast, the European Food Safety Authority (EFSA) sets this limit at 25 mg per day ¹⁴, while the Food and Drug Administration (FDA) establishes it at 40 mg per day, although this value is disputed by other researchers ^{4,15}. Furthermore, the reported zinc losses during intestinal excretion vary considerably. Calculations using factor analysis indicate that intestinal excretion ranges

from 1.9 to 2.3 mg per day ⁷. However, numerous publications report significantly higher zinc losses, ranging from 7 to 19 mg per day, which are statistically indistinguishable from the amount of the micronutrient consumed ¹⁶⁻²².

To determine the reasons for the differences in acceptable upper intake levels, recommended daily intakes, and intestinal excretion of zinc, this review analyzes scientific publications from 1980 to 2025 that focus on zinc balance in the bodies of healthy individuals of both sexes aged 19 and older. Special attention is given to experimental results that illustrate the disruption of the balance between the reference values of dietary zinc and the quantity of zinc excreted through the intestines. Assessing zinc balance considering the polydentate nature of phytic acid will allow more accurate selection of diets and recommendation of zinc-based preparations, maintaining homeostasis and avoiding toxic levels in the body.

Methodology

Articles from the following databases were analyzed: Google Scholar (<https://scholar.google.com/> (accessed on May 1, 2025)), PubMed® (<https://pubmed.ncbi.nlm.nih.gov/> (accessed on May 1, 2025)), SpringerLink® (<https://link.springer.com/> (accessed on May 1, 2025)), Scopus® (<http://www.scopus.com/> (accessed on May 1, 2025)), and Web of Science™ (<https://www.webofknowledge.com> (accessed on May 1, 2025)). The keywords used for this study were: biological role of zinc, zinc homeostasis, zinc toxicity, dose-response curves for zinc compounds, zinc balance in the human body, zinc isotopes, trace elements, phytic acid, phytate anions, chelating properties of phytic acid, law of mass action for homogeneous and heterogeneous equilibria of zinc and phytic acid, zinc-containing drugs and dietary supplements. The articles selected provided specific information on the constants of equilibrium processes involving zinc ions and phytate anions from 1980 to April 2025. The results of studies on the intestinal and renal excretion of zinc, as well as the potential for using these results to calculate fractional absorption of zinc (FAZ), were included. Data on FAZ assessment using the double isotope absorption method were summarized. Additionally, the reasons for inaccuracies in balance assessments based on the determination of zinc content in feces, along with the impact of erroneous values of equilibrium constants in FAZ calculations through factor analysis, were analyzed.

Initially, 182 scientific articles were identified from the screened databases. After applying the inclusion and exclusion criteria, 89 documents were excluded. Consequently, 93 articles emphasizing the need for clarification of zinc dietary reference values were included in this review (Figure 3).

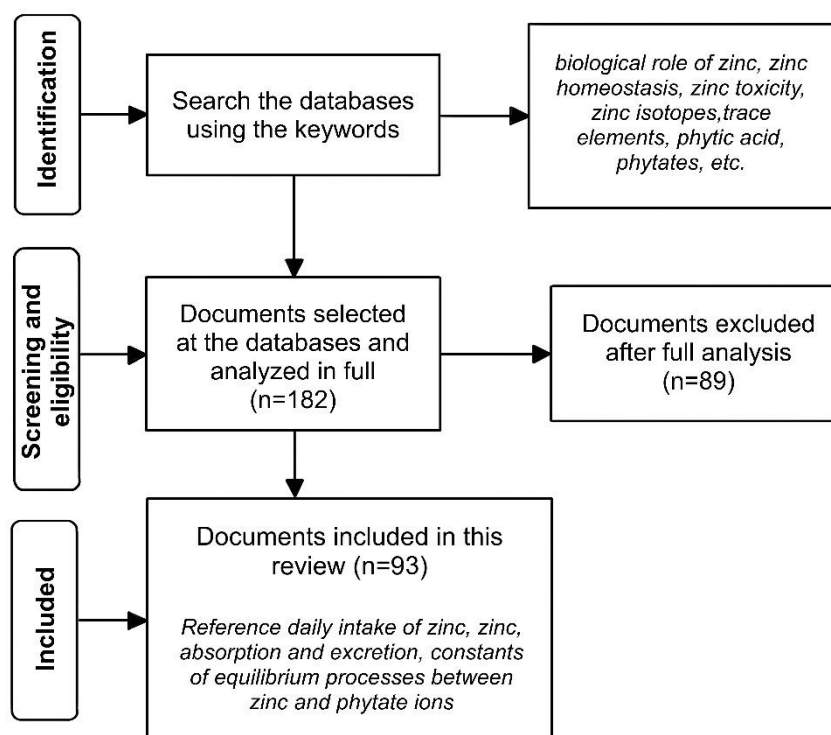


Figure 3: Diagram of illustrating the selection process scientific documents included in this review.

The results of the systematic review indicate that the zinc dietary reference values derived from factor analysis require clarification due to inherent limitations in the mathematical model employed. This model does not account for the polydentate nature of the phytate anion, which can bind between 3 and 12 zinc ions.

The importance of zinc dietary status for human health

The body does not possess a zinc storage system comparable to ferritin for iron, which could serve as an alternative source of zinc to maintain systemic balance

when external intake is insufficient ^{1,8,23,24}. To ensure that the body's zinc levels remain within the necessary range, it is essential to consume zinc-rich foods (Figure 4). In addition, zinc can be absorbed through aerosols or through the skin and oral mucosa when using zinc-containing ointments or toothpastes ^{11,25}. The amount of zinc absorbed in the gastrointestinal tract, referred to as fractional zinc absorption, can vary based on the quantity of zinc ingested, the presence of substances that inhibit or enhance absorption, and the individual's physiological condition, such as during pregnancy, breastfeeding, or the presence of certain illnesses.

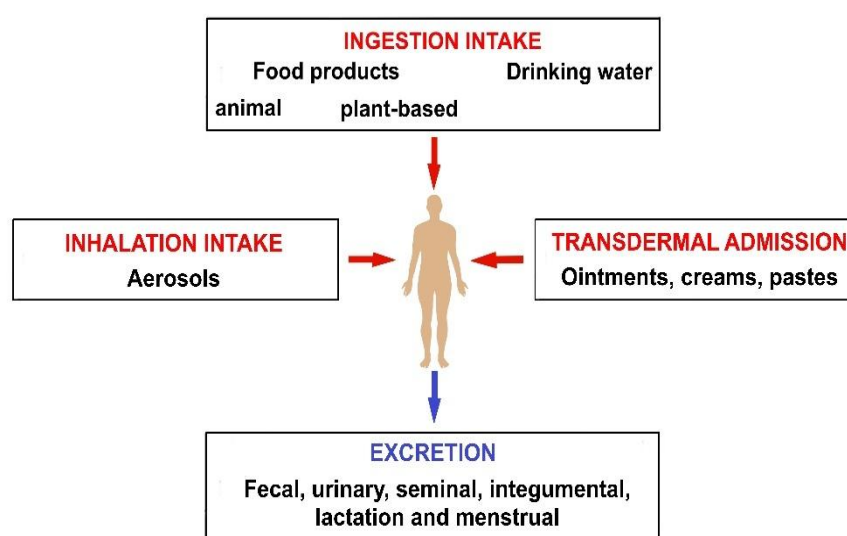


Figure 4: Routes of zinc intake and excretion.

The gastrointestinal tract plays a crucial role in maintaining zinc homeostasis in the body (Figure 5). Zinc (Zn^{2+}) absorption occurs in the lumen of the duodenum and proximal jejunum through active transport, which involves specific, saturable enterocyte transporters ^{2,26}. Intravenous zinc administration is employed to study its metabolism using isotopic methods ²³.

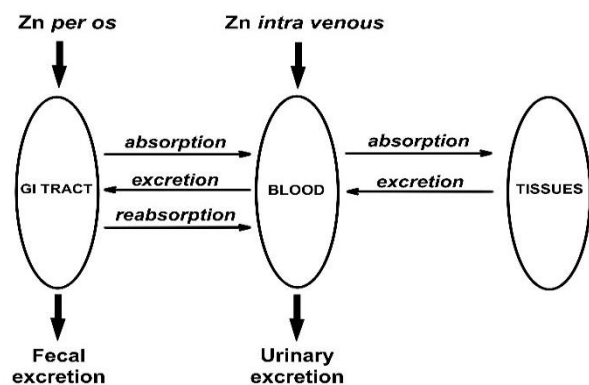


Figure 5: Zinc pathways in the body following oral intake and intravenous administration in isotope metabolism studies.

Determining human zinc requirements is based on factor analysis of zinc excretion processes and calculating the amount of zinc that must be absorbed to offset losses. The assessment of the necessary dietary zinc intake must consider the incomplete bioavailability of zinc from various human diets, as well as from fortified foods or supplements. A primary inhibitor of zinc absorption from food is phytic acid, which binds to or chelates positively charged zinc ions.

The primary pathway for zinc excretion is the gastrointestinal tract ^{2,26}. Zinc losses also occur through urine, ejaculate, sweat glands, skin, hair, and breast milk, as well as during menstrual flow; however, these losses are less significant ⁴.

The zinc content in various food products has been extensively studied and clarified. High levels of zinc are typically found in animal products, particularly seafood and red meat ^{23,27,28}. For instance, 100 grams of oysters contain between 16.6 and 39.3 mg of zinc (Table 1). In contrast, the zinc content in white meat is significantly lower, ranging from 0.98 to 3.40 mg per 100 grams.

Table 1: Phytate-to-zinc molar ratio in foods ^{11,23,27-35}

Food Group	Food	Zinc Content (mg/100 g)	Phytate Content (mg/100 g)	Phytate-to-Zinc Ratio *
Meat and Poultry	Beef, pig, lamb, chicken and turkey	0.8 – 5.4	0	0
Milk products and Eggs	Milk and cheese	0.4 – 3.0	0	0
	Eggs	1.1 – 1.4	0	0
Seafood and Fish	Oysters eastern	16.6 – 39.3	0	0
	Salmon, bass and seabass	0.3 – 0.9	0	0
Cereals and Whole Grains	White and brown rice	0.8 – 2.2	200 – 940	24.6 – 42.1
	Whole grain bread	1.6 – 2.1	430 – 1050	26.5 – 49.2
	Wheat bread	0.7 – 1.2	30 – 230	13.6 – 18.9
Legumes	White and green beans, lentil	0.3 – 4.3	471 – 718	16.4 – 154.6
Nuts and Seeds (dried, without oil)	Cashews, peanuts, pine nuts	2.5 – 5.9	200 – 772	7.8 – 12.9
	Pumpkin seeds	4.3 – 16.7	56 – 2370	1.3 – 14.0
	Sunflower seeds	5.0 – 6.1	2160 – 2830	42.9 – 45.7
Vegetables	Carrot, white cabbage, bok choy, cucumber, tomato and onion	0.1 – 0.8	0	0
Fruits	Apple, banana, apricot, pineapple, grape	0 – 0.3	0	0

* The phytate-to-zinc molar ratio was calculated using the formula $(\text{mg phytate}/660)/(\text{mg zinc}/65.4)$.

As shown in Table 1, the amount of phytate (in moles) in plants is significantly higher than the amount of zinc, indicating that plant-based foods cannot serve as a reliable source of zinc. Furthermore, due to the chelating nature of the phytate anion, the number of free ligand atoms increases, which results in the binding of zinc ions found in seafood and meat products. At the same time,

among various plant products, pumpkin seeds stand out as a unique source of zinc for the human body ³⁵. The phytate content in roasted pumpkin seeds is 56.1 mg/100 g, while the total zinc content, determined by atomic absorption spectroscopy, is (16.7 ± 0.8) mg/100 g $(0.26 \text{ mmol}/100 \text{ g})$. Additionally, free zinc not associated with phytic acid accounts for 39% of the total zinc

content. The high bioavailability, calculated through the molar ratio $n(\text{Phyt}) : n(\text{Zn}^{2+}) = 1.6$, supports the recommendation of this plant product for zinc deficiency.

In a mixed diet, plant-derived phytic acid forms poorly soluble salts with zinc cations, making their absorption impossible. Consequently, because vegetarians and vegans tend to consume a predominance of plant foods, they are at a greater risk of zinc deficiency.

Imbalance Between Dietary Reference Values for Zinc Intake and Zinc Excretion Values

1. Dietary Reference Values for Zinc Intake

Various international expert groups provide reference values for zinc intake, and these recommendations exhibit significant differences. For instance, the WHO¹³ considers the *dietary reference value* to be between 6.7 and 15 mg per day. In contrast, the EFSA^{11,14} and the Intergovernmental Organization for Nutrition of Germany, Austria and Switzerland (D-A-CH)³⁶ set higher values, ranging from 9.4 to 16.3 mg per day and 7 to 16 mg per day, respectively. The calculated average values for the recommended daily intake of zinc for all age and gender groups also vary significantly (Table 2).

Table 2: The average recommended dietary intake of zinc according to international expert groups

Expert group *	Zn dose for all age and gender groups, mg/day	Ref
WHO	7.7	13
IOM	9.6	4
IZiNCG	6.2	24
EFSA	10.7	11,14
DGE	11.0	37,36
D-A-CH	11.0	36
ANSES	10.5	38
British Nutrition Foundation	8.3	39
Ministry of Health, Labour and Welfare	9.0	40
USDA	9.0	27
ICMR	15.1	41
Chinese Nutrition Society	15.0	42
Healthdirect Australia	10.8	43

* WHO - World Health Organization, IOM - Institute of Medicine, IZiNCG - International Zinc Nutrition Consultative Group, EFSA - European Food Safety Authority, DGE - German Society for Nutrition, D-A-CH - Nutrition Societies of Germany, Austria and Switzerland, ANSES - French Agency for Food, Environmental and Occupational Health & Safety, USDA - U.S. Department of Agriculture, ICMR - Indian Council of Medical Research.

Thus, the average values of the recommended daily doses of zinc from food are in the range of 6.2 to 15.1 mg/day.

There are significant differences in the maximum safe dose of zinc: according to WHO - it is 25 mg/day, while according to the FDA, it is 40 mg/day.

The results of research conducted at various centers examining the impact of average daily oral zinc intake—whether through food or dietary supplements—on different physiological functions of the body were also analyzed^{17,44-55}. The zinc doses utilized in these studies varied widely, ranging from 3.1 to 22.0 mg per day.

Thus, the differences observed in the dietary reference values for zinc intake necessitate careful analysis. The recommended doses of zinc administered *per os*, as presented in various literary sources, are based on a mathematical model that does not take into account such an important factor as the polydentate nature of phytate. In this case, the binding of the zinc ion to the phytate anion occurs in the molar ratio " $n(\text{Phyt}) : X \cdot n(\text{Zn}^{2+})$ ", where $X \geq 3$ ^{5,56-58}.

2. Zinc excretion from the human body

Zinc is primarily excreted from the body through feces and urine (approximately 80%), as well as through skin shedding, sweat, and seminal fluid (about 20%)¹. Given that the gastrointestinal tract serves as the main center for homeostatic regulation^{4,18,24,59-61}, the analysis of intestinal zinc excretion was conducted to evaluate zinc balance.

The intestinal excretion values obtained from factor calculations in study⁶² were 2.29 mg/day for men and 1.87 mg/day for women. These findings align with data from international expert organizations, which were also derived using a mathematical model and summarized in the report⁵⁹: 0.8 mg/day (WHO); 2.57 mg/day (IOM); 1.54 mg/day (IZiNCG); 2.40 (EFSA). The WHO data on intestinal excretion appears to be significantly underestimated based on the provided values. Other excretion routes contribute even less to total zinc losses, amounting to losses through the skin and sweat at 0.4 mg/day^{1,14,28,36}. Renal excretion averages 0.63 mg/day for men and 0.44 mg/day for women^{17,36,49,50,63-67}. The average daily loss of zinc in ejaculate across various studies ranges from 114 µg to 301 µg⁶⁸⁻⁷⁰. Therefore, the total non-intestinal zinc loss in men is approximately 1.35 mg/day. Adding these values to the intestinal zinc losses enables us to estimate the zinc requirement for men at 3.54 mg/day⁵⁹. Differences in the results among research groups may stem from the inability to account for all the numerous factors influencing the outcome in the mathematical model.

At the same time, several publications (Table 3) report intestinal excretion results that significantly exceed the values discussed above. In some cases, intestinal losses surpass the amount of zinc introduced into the body, and the zinc losses were statistically indistinguishable from the daily intake^{16,17,19,21}.

Thus, the results of intestinal zinc excretion deserve attention and require an explanation for the observed discrepancies.

Table 3: Intestinal excretion of zinc

Characteristics of the experimental group	Zinc intake, mg/day	Zinc content in faeces, mg/day	References
Men, 28 ± 2 years Simulation of space flight - horizontal position	15.0 ± 1.3 (before the experiment) 12.5 ± 0.9 (during the experiment) 15.1 ± 1.1 (after the experiment)	13.9 ± 2.8	17
Men, 28 – 35 years	11.5 ± 6.4	9.75 ± 1.18	18
Men, 24 – 58 years	8.16 ± 0.08 3.41 ± 0.14 32.55 ± 0.51	7.16 ± 1.20 3.03 ± 0.56 28.62 ± 4.97	19
Men, 21 – 30 years	15.7	10.5 ± 2.9	20
Men and women	Mixed diet	2.67 – 19.90	21
Women, 33.2 ± 7 years	11.1 ± 1.3	8.7 ± 1.8	22
Women, 19 – 21 years	5.65 ± 1.49	1.9 – 11.4	16
Women, 50 – 63 years	6.73 ± 0.14 2.64 ± 0.10 31.37 ± 0.43	6.25 ± 0.24 2.30 ± 0.08 29.66 ± 0.58	71

The intestinal excretion of zinc correlates positively with the amount consumed; however, it is not a constant process and is influenced by various factors. These factors include differences in gender and age, as well as the type of food and diet before and during the experiment. Notably, one previously unaccounted factor affecting the results of zinc determination in dried fecal samples is the moisture content of the fresh biomaterial^{16,72}. In a large sample (n=125), it was demonstrated that drying samples with a moisture content ranging from 60% to 90% resulted in a decrease in zinc content from 0.6 mg/g to 0.1 mg/g. This indicates that zinc losses can range from 1.9 to 11.5 mg per day. In addition to zinc, a negative correlation is observed with calcium, manganese, copper, iron, and potassium, while a positive correlation was noted only for sodium.

Based on the zinc balance values presented in Table 3, it can be concluded that under the experimental conditions, zinc absorption was minimal, and its binding with phytic acid occurred in a molar ratio that differed from that proposed in the mathematical model.

Effect of Polydentate Phytates on Zinc Absorption

Zinc bioavailability is defined as the proportion of zinc that can be absorbed from dietary sources^{5,57}. The availability of zinc is influenced by the solubility and stability of its salts, as well as its coordination compounds with macromolecules or low-molecular-weight ligands, both in food²⁴ and in the intestinal lumen⁷³⁻⁷⁵. Phytates play a crucial role in the absorption of zinc (see Table 1). The bioavailability of zinc from a mixed or vegetarian diet that includes refined cereal grains is estimated to be between 26% and 34%. In contrast, only 18% to 26% of zinc is absorbed from a diet consisting of

unrefined cereal products⁷⁶. In response to low zinc intake over several weeks, zinc absorption can increase to 92%, but this is contingent upon the diet being low in phytate⁷⁷.

The term "phytate" refers to a mixture of hexa-, penta-, tetra-, and triphosphates of myo-inositol, along with its magnesium, calcium, and potassium salts^{5,78}. Research has shown that tetra- and triphosphates have minimal impact on zinc absorption, while hexa- and pentaphosphates of inositol significantly reduce zinc availability *in vivo* studies^{79,80}.

International expert groups that regulate dietary zinc doses assess its bioavailability using the molar ratio of «mg phytate/660 mg/mmol : mg zinc/65.4 mg/mmol» (Figure 6).

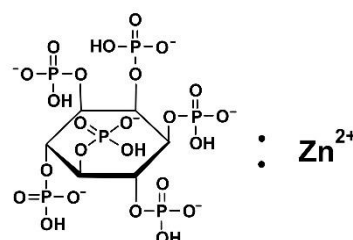


Figure 6: The equimolar ratio of Phyt : Zn²⁺ is utilized in the conventional assessment of zinc bioavailability.

Using the molar ratio Phyt : Zn²⁺, which is based on the assumption of equimolar interaction among the components, typical Central European diets categorize zinc absorption as low, moderate, or high (Table 4). In this context, moderate absorption, approximately 30%, corresponds to a molar ratio ranging from 5 to 15. When the molar ratio falls below 5 or exceeds fifteen,

bioavailability is classified as high or low, respectively. It is important to note that these classifications are conditional, as evidenced by discrepancies in data from other researchers^{5,81}. For instance, even in the absence of phytate, the proportion of absorbed zinc does not exceed 21%. Within the molar ratio range of 5 to 15, absorption

decreases to between 11% and 16%, and at molar ratios greater than 15, it ranges from 4% to 11%. The values of the FAZ indicate the binding of a significantly larger number of zinc ions compared to the case of equimolar interaction

Table 4: Characteristics of zinc availability by the molar ratio Phyt : Zn²⁺ ^{4,11,13,28}

Phytic acid content in food products	The necessary amount of zinc				n(Phyt) : n(Zn ²⁺)	Bioavailability, %
	m, mg	n, mmol	n, mmol	m, mg		
Low	330	0.5	>0.1	>6.7	<5	50 (high)
Moderate	660	1	0.07 – 0.1	4.6 – 6.7	5 – 15	30 (moderate)
High	990	1.5	<0.07	<4.6	>15	15 (low)

It is important to consider that phytic acid (H₁₂Phyt), also known as D-myo-inositol-1,2,3,4,5,6-hexakis-dihydrophosphoric acid, is an ester of the cyclic hex-atomic alcohol myo-inositol and six residues of orthophosphoric acid. It should be noted that phytic acid acts as a polydentate ligand⁵. At physiological pH values, the charge of the phytate anion — and consequently the number of bound zinc ions — can vary:



Indeed, solid zinc phytates, represented as Zn₆H₂LCI₂·xH₂O, were isolated, demonstrating the binding of zinc to the phosphates of the phytate anion in a stoichiometric ratio of zinc: phytate = 6:1⁵⁶. The low solubility of the salts is evidenced by the equilibrium constant for salt dissociation, which is $K = (2.6 \pm 0.2) \times 10^{-47} \text{ mol}^7/\text{L}^7$. Additionally, calorimetric studies confirm the strong binding of zinc at two sites within the phytate anion. The formation constants of the complexes in solution at 37 °C are $1.8 \times 10^6 \text{ L/mol}$ and $8 \times 10^4 \text{ L/mol}$. The negative Gibbs free energy value for the Zn : Phyt = 3:1 complex ($\Delta G = -29.1 \text{ kJ/mol}$) significantly deviates from the equilibrium value⁵⁷. The solubility of the resulting zinc phytates decreases as pH increases, and at pH levels of 6 to 7.4, their bioavailability is significantly reduced^{81,82}. The impact of phytate on zinc homeostasis in the body is evident not only in its binding to dietary zinc but also in the formation of complexes with

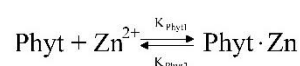
endogenous zinc in the intestinal lumen, which inhibits its reabsorption⁷³.

Based on the information provided regarding the polydentate nature of the phytate anion, it is essential to emphasize that the commonly accepted method for calculating zinc bioavailability, which relies on the molar ratio Phyt : Zn²⁺ requires modification. Since phytic acid phosphates can bind a minimum of three zinc ions, a coefficient of $X \geq 3$ should be incorporated into the molar ratio. Consequently, the ratio will be expressed as $n(\text{Phyt}) : X \times n(\text{Zn}^{2+})$. For instance, in a scenario where one phytate anion binds three zinc ions, the dietary reference dose should be tripled to ensure that the degree of bioavailability aligns with the established concept (see Table 4).

The error that occurred, which is related to the omission of the polydentate nature of phytic acid, arises from the fundamental mathematical model used, particularly in the calculation of the FAZ⁸³. Since a reliable marker for assessing zinc status in individuals is lacking^{36,59,84,85}, the recommended zinc intake for adults is derived from factorial calculations^{61,62,86,87}. The development of a mathematical model to estimate zinc absorption based on the zinc and phytate content of the diet has been ongoing for several decades^{24,88-93}. Total daily dietary zinc intake (TDZ), total daily dietary phytate intake (TDP), and maximum absorption (A_{max}) were incorporated into the equation:

$$\text{FAZ} = \frac{0.5}{\text{TDZ}} \times \left(A_{\text{max}} + \text{TDZ} + K_p \times \left(1 + \frac{\text{TDP}}{K_{\text{Phyt}}} \right) - \sqrt{(A_{\text{max}} + \text{TDZ} + K_p \times \left(1 + \frac{\text{TDP}}{K_{\text{Phyt}}} \right))^2 - 4 \times A_{\text{max}} \times \text{TDZ}} \right),$$

Given the complexity of mathematical modeling in biological systems, the authors based their approach on the law of mass action to describe the equilibria of zinc ion binding to phytic acid (Phyt) or the receptor protein (R). Consequently, for the reaction that forms the compound Phyt * Zn, the following expression can be written:



$$K_{\text{Phyt}} = K_{\text{Phyt1}}/K_{\text{Phyt2}} = [\text{Phyt} \cdot \text{Zn}] / [\text{Phyt}] \cdot [\text{Zn}^{2+}]$$

In this context, Phyt refers to phytic acid, Zn²⁺ denotes the zinc cation, and Phyt*Zn represents the zinc complex

with the phytate receptor. K_{Phyt} is the equilibrium constant for the formation of this complex. A similar constant, K_P , is used to describe the equilibrium for the formation of the zinc compound with the carrier protein (P).

The developers of the mathematical model acknowledge that objective limitations compel them to consider a simplified version in which the phytate anion or carrier protein binds only one zinc ion. However, they remain optimistic that future modifications to the model will account for the polydentate nature of the phytate anion and the carrier protein molecule. Consequently, the current model does not accurately represent the interaction between the zinc ion and phytic acid or the carrier protein.

Conclusions

Due to the absence of a reliable biological marker, a mathematical model is employed to determine the coefficient of dietary zinc absorption. However, this model does not account for the polydentate nature of the phytate anion, which can bind between 3 to 12 zinc ions. As a result, the recommended dietary intake of zinc is often lower than the actual requirement. This discrepancy necessitates continual upward adjustments in dosage, leading to inconsistencies in the dietary reference values established by various research groups. Consequently, all parameters used to assess zinc balance—such as the recommended dietary intake of zinc, the degree of absorption into the bloodstream, and intestinal excretion of zinc—exhibit significant variations across different studies. To clarify the differences in the recommended daily intake of zinc, a review was conducted on the chelating properties of phytic acid and the results of zinc balance within the "oral intake - intestinal excretion" framework. Evaluating zinc balance while considering the polydentate nature of phytic acid will facilitate more accurate dietary recommendations and the selection of zinc-based supplements, thereby maintaining homeostasis and preventing toxic levels in the body.

Acknowledgments: This publication has been supported by project №033328-0-000 (RUDN University).

Conflicts of Interest: The authors have no conflicts of interest associated with the material presented in this paper.

Author Contributions: Conceptualization: Syroeshkin AV, Pleteneva TV. Data curation: Pleteneva TV, Marukhlenko AV. Formal analysis: Pleteneva TV, Marukhlenko AV. Funding acquisition: Syroeshkin AV, Levitskaya OV. Methodology: Pleteneva TV, Marukhlenko AV. Project administration: Syroeshkin AV, Pleteneva TV. Visualization: Marukhlenko AV, Galkina DA. Writing - original draft: Pleteneva TV, Marukhlenko AV. Writing - review & editing: Pleteneva TV, Marukhlenko AV, Levitskaya OV, Syroeshkin AV.

Funding: The authors declared that this study has received no financial support.

Ethical approval: This study does not involve experiments on animals or human subjects.

Data availability: All data generated and analyzed are included in this research article.

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