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EFFICIENCY AND SAFETY OF FORTIFICATION OF FOOD PRODUCTS WITH ZINC REQUIRED TO CONTROL ZINC DEFICIENCY DISORDERS

POLUMBRYK M.O., KRAVCHENKO V.I., KIRKOVA M.S.

ABSTRACT

The authors of the review present data on the physiological role, metabolism and biological availability of zinc in human body. Zinc is essential in pubertal development. It also has an antioxidant, anti-inflammatory, anticancer and possibly antidiabetic activity. A detailed analysis of zinc deficiency expansion in Ukraine and the World and main ways of its eliminating has been described. The most attention given to development of foods fortified with zinc.

Keywords: *zinc deficiency, pubescence, metabolic disorders, antioxidant activity, food fortification*

INTRODUCTION

Zinc mildly expanded in nature being 23rd most abundant element in Earths crust ($8{,}3\cdot10^{-3}$ by mass) [1]. Though, in human body it is the second element after iron and exists in a just one redox form (Zn^{2+}). Zinc widely used in human`s body enzyme synthesis with regard to small size of its ion and ability to readily complex with ligands [1,2]. The zinc biological functions are exceptional for whole organism. The main functions of this microelement are: growth, immunity, tissue repair, vitamin A metabolism, protection against oxidative damage, neuropsychological functions, bones mineralization, sexual maturation, apoptosis, cellular signaling, and hormone action, among others. It is known that zinc is necessary for DNA synthesis, cell growth and division (cytokinesis), protein synthesis, macronutrient metabolism and many others functions in whole body level. [1-4].

The most important description of zinc deficiency in humans related to a lack of pubertal development. Seminal fluid is particularly rich in zinc and the sperm accumulated zinc prior to ejaculation [2]. Zinc also important for normal fetal development and its deficiency lead to abnormalities in humans and animals. Maternal zinc deficiency lead has been linked with pregnancy associated morbidity including pre-term delivery [1,2,4].

The relationship between biochemical and physiological roles are still not fully understood. The biological role of zinc is a complex impact on plant, animals and humans development. The biological functions of zinc can be classified into three main categories: catalytic, structural, and regulatory [1,2,4]. The biochemical role of this element is related to metalloenzymes activity and metalloenzymes complexes activation. Zinc metalloenzymes are found in six enzyme classes: oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases. The more than 300 zinc-containing metalloenzymes, involved in nucleic acid, protein, carbohydrate, lipid, and vitamin metabolism are known to date [1,2].

The ability of this microelemet to stabilize the membranes and act as an antioxidant are shown that it play a significant role in injuries prevention induced be free radical activity in inflammatory processes[5]. Zinc manifestation can inhibit virus diseases. It assists therapeutic interventions in AIDS treatment and useful in hepatitis therapy as long as zinc can retard their growth and rhinoviruses. [4,5].

The fact that zinc is abundant in nature and thus widely distributed in diet suggested that humans cannot suffer from its deficiency. [1,2]. Prior to 1961, zinc deficiency in humans was unrecognized. It was until Prasad and coworkers described dwarfism syndrome and absence of sexual attraction in teenagers that they found in Iran [2]. In this country young men consume bread made from unleavened dough and too small amount of proteins of animal origin. Later Prasad found a similar syndrome in Egypt. [2]. The zinc deficiency appears mainly due to impaired food absorption induced by increased amount of dietary fibres and phytates. Following the IZiNCG (International Zinc Nutrition Consultative Group) technique, the global prevalence of zinc deficiency was estimated at 31%, ranging from 4–73% across subregions While zinc deficiency disorders are widespread in several developing countries, there is no data on the mild zinc deficiency prevalence in other countries. The mild zinc deficiency was found in children who were low of height their age living in Denver (Colorado, USA) [1,2]. In addition to children the elder people are a group at risk zinc deficiency.

Zinc deficiency disorders occur in some regions of Ukraine. It was found that children aged from 6 to 12 ages, living in four subregions of Chernigiv region are suffering from zinc deficiency due to decline in adequacy of zinc intakes [6]. Fortunately it is not lead to a goiter spread [6]. The results obtained from other trials suggested that prevalence of zinc deficiency between Ukrainian children with gastrointestinal tract pathologies estimated at 28,8 % [7]. Unexpected data obtained from trials carried on experimental animals and humans working at industrial plants of Zaporizhzhya region [8]. It has been found that zinc in blood plasma in humans, who worked 2 month at plants decreased by 18,6 % compared to control group [9]. Despite the water and soil pollution by metals including zinc in Ukrainian industrial cities, workers are at a group of risk of zinc deficiency. This may be due to a reduction of zinc absorption caused by increased concentration of other microelements, such as iron, which act as zinc antagonists.

Zinc participated in the antioxidant defense system of the body by several ways [1,2,4,9]. An increased likelihood of oxidative stress in humans with zinc deficiency indicated on the potential anticancer activity of this microelement [9]. Several epidemiological trials pointed to a link between declined zinc consumption and risk of diabetes [10,11]. It is well known that zinc act as an insulin mimetic. The data of other clinical trials do not confirm a positive role of oral zinc supplementation in patients with type 2 diabetes [12]. Thus, the effect of diet supplementation with zinc on humans with diabetes required further investigations. It is generally assumed that zinc consumption promoted absorption of dietary fibers, caffeine, milk products and other important nutrients.

FOODS AS A SOURCE OF ZINC

Zinc readily bounded to proteins in biological systems, so that protein containing foods are the main source of zinc in a diet. [1,2]. However, there is great variability, from egg whites, which have almost no zinc, to oysters, at 750mg kg^{-1} [1,2].

The physiological function of these high concentrations in oysters is unknown, though the zinc is concentrated in cells thought to serve a phagocytic/host defense function. [1]. Grains and legumes may be relatively rich sources, but bioavailability is limited owing to their phytate content. On the other hand, animal proteins appear to enhance zinc absorption.

In general, the risk of inadequate intake of dietary zinc within a population may be associated with the nature of the food supply, and its content and relative bioavailability of zinc. Animal source foods, in particular shellfish, small whole fish, beef, and organ meats such as liver and kidney, are rich sources of zinc. Furthermore, the zinc contained in animal source foods is more highly bioavailable than from plant source foods; the presence of certain amino acids (e.g., histidine, methioinine), or perhaps other unidentified factors, may facilitate the intestinal absorption of zinc from animal flesh foods [1,2]. Plant source foods, such as most fruits and vegetables including green leaves, and starchy roots and tubers, have relatively low zinc content. While whole grains and legumes have moderate to high zinc content, these foods also contain large quantities of phytate (phytic acid or myo-inositol hexaphosphate), the most potent identified dietary inhibitor of zinc absorption [1].

The molar ratio of zinc and phytates in foods is a measure of zinc bioavailability. Plants synthesize phytate in the ripening process, which forms chelates with zinc. These compounds don't absorb in small intestine. Populations with a heavy dietary reliance on unrefined cereals or legumes, complemented with only small amounts of zinc-rich animal source foods, will have lower intakes of bioavailable zinc. Although milling cereal grains removes large amounts of phytate, it also removes large amounts of zinc. Thus, consumption a large amount of refined cereals, such as rice) or starchy roots and tubers, for example potatoes doesn't provided adequate zinc intake[1,2].

A few countries from developing regions have implemented a policy for the fortification of staple foods with zinc. Mexico established a program whereby wheat and corn (maize) flour producers could add zinc to their products (20 mg/ kg flour). Indonesia has also implemented a national program for the fortification of wheat flour, which includes addition of zinc. Several countries are adding zinc (and other micronutrients) to foods that are distributed in programs targeted to specific, vulnerable population groups. For example, in Chile and Argentina milk powder for use by young children is fortified with zinc, while in Mexico a milk powder-based supplement with added zinc is directed towards young children as well as pregnant and lactating women. As yet, there is an absence of information on the effectiveness of these programs to improve population zinc status. There is an absence of information on the effectiveness of these programs to improve population zinc status to date.

Several strategies apart from the use of pharmacological supplements and food fortification have been suggested for the improvement of dietary zinc status in developing country settings [13,14]. It is found that fortification of flour with $0,5\text{-}1 \cdot 10^{-2}$ % $ZnSO_4$, plays an important role in achieving adequate zinc intake and absorption in zinc-deficient people [13]. It also appears that consuming zinc-fortified bread improves iron absorption. It has been suggested that milk and milk products are potential carriers of zinc [13]. They play significant role due to intake by all population groups that at risk of zinc deficiency and a big nutritive value. The most part of zinc associated with milk caseins, and in lesser extent to whey and fat fractions. The effectiveness of cheese fortification with zinc sulfate, gluconate and aspartate has been investigated. It was shown that utilization of milk, fortified with zinc in cheeses Squacquerone and Caciotta manufacture doesn't require significant changes of technological process. In these cheeses total amount of zinc varies within the range 136-151 mg/kg [14].

RECOMMENDED INTAKE AND ZINC TOXICITY

Food and Agriculture Organization (FAO)/World Health Organization (WHO) Expert Committee used the factorial approach to estimate human zinc requirements [2]. As shown in Table 3, the FAO/WHO give three sets of recommendations, depending on the zinc bioavailability of the diet. The US Food and Nutrition Board figures fall between those given for moderate- and low-availability diets. Both groups also set upper limits for intake, based largely on the risk of impairing copper status [2]. These values are almost similar.

In general, the risk of inadequate intake of dietary zinc within a population may be associated with the nature of the food supply, and its content and relative bioavailability of zinc. Animal source foods contain of certain amino acids (e.g., histidine, methioinine), or perhaps other unidentified factors, may facilitate the intestinal absorption of zinc from animal flesh foods. Other nutrients and compounds, such as sugars, picolinic and citric acid, red wine consumption also improve zinc status. Several microelements, particularly calcium and iron are antagonists of zinc, because of intestinal absorption competition [15]. Dietary fibres and phytates, which usually contained cereals inhibited zinc intestinal absorption.

Table 1

Recommended intakes of zinc, mg

Age group		USA and Canada	WHO/FAO depending on level of nutrient bioavailability		
			High	Moderate	Low
Children (1-3 years old)		3	2,4	4,1	8,3
Adolescents (14-18 years old)	Female	9	4,3	7,2	14,4
	Male	11	5,1	8,6	17,1
Дорослі (>19 років)	Female	8	3,0	4,9	9,8
	Male	11	4,2	7,0	14,0
Pregnant women	3 trimester	11	6,0	10,0	20,0
Lactating women	0-3 months	12	5,8	9,5	19,0

Toxicity of zinc from food sources has still not determined to date. Acute gastrointestinal symptoms and headaches have been reported after ingestion of amounts about 10–20-fold higher than the recommended intakes [2]. Chronic ingestion of these large amounts has been shown to impair immune response and lipoprotein metabolism [1,2]. However, the key danger of excessive zinc intake is reduced copper status. Surprisingly, sometimes it may be clinically useful, especially for the individuals with Wilson’s disease, a condition of copper toxicity. The upper limit of zinc intake has been set in several countries, because of treat to copper status [1,2].

CONCLUSIONS

Thus, increased zinc intake is potentially dangerous for human health reversibly impact on reproductive, immune and nervous systems, metabolism of macronutrients and many others. The absence of reliable biochemical marker and correlation with certain diseases or disorders significantly reduced means of zinc detection. The impact of zinc consumption on humans with diabetes is still controversial. Perhaps a future goal might be to better characterize the recommended level of microelements, including iodine, iron, zinc, magnesium, selenium and others in human organism. An improvement in functional food technologies may eventually lead to an adequate intake of these microelements. Such food products have very strong future prospects, particularly for the groups at risk and populations with restricted sources of animal foods.

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Maksym POLUMBRYK, PhD, Department of life safety of National university of food technologies
Address: Ukraine, Kyiv, Volodymyrska St. 68, 01033
mx_pol@yahoo.com

Victor KRAVCHENKO, professor, V.P. Komisarenko Institute of endocrinology and metabolism National academy of medical sciences of Ukraine
Address: Kyiv, Vyshgorodska St. 69, 04414

Maryna KIRKOVA, assistant professor, Department of general and inorganic chemistry of National university of food technologies
Address: Ukraine, Kyiv, Volodymyrska St. 68, 01033