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The Function of Zinc in Animal, Plant, and Human Nutrition

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ABSTRACT

Zinc is a crucial micronutrient found in food that is essential for the development of all living organisms, it plays a vital role in gene expression and various physical processes, its deficiency can lead to disease onset and reduce crop yield, restrict plant development, and lower the quality of produced goods, zinc is also used in fertilizers and the handling of metals to protect them from oxidation. Additionally, Zinc is important in enhancing the human immune system, and its deficiency can result in hair loss, memory loss, skin disorders, and muscular weakness.

Keywords- Zinc deficiency, Animal Diseases, Plant Growth, Human Malnutrition.

I. INTRODUCTION

The availability of nutrients is important to a plant's ability to grow and develop, in order to function correctly, plants need a variety of nutrients, which can be further classified into macronutrients and micronutrients (McClements, D. J. 2023). These nutrients comprise Iron (Fe), boron (B), sulfur (S), magnesium (Mg), nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), zinc (Zinc) etc. (Bhatla, S. C., et al. 2018). Many nutrients affect the various biochemical processes occurring within the plant system; they also support plants in fighting against the multiple disorders that impact plant growth adversely (Shrivastava, P., & Kumar, R. 2015). Micronutrients are vital in reducing the severity of disease (Dresen, E., et al. 2023), which can also contribute to its inclusion in plants' biochemical and physiological processes (Saquee, F. S., et al. 2023), the majority of essential micronutrients are involved in a number of activities that could affect how plants react to infections (Niazi, P., et al. 2023, Dommisch, H., et al. 2018). Zinc is one of these micronutrients that has different or no effect on how vulnerable plants are to disease (Dordas, C. 2008). In the natural world, zinc is found in the +2 oxidation state (Rudra, P., et al. 2023). Two minerals, sphalerite (ZincS) and smithsonite are the main sources of zinc in the earth's crust (ZincCO3) (Daliran, F., et al. 2013). Zinc is important for the earth's living species since it plays a critical role in various biological processes when present in minute concentrations (Yin, J., et al. 2005). Zinc is involved in over 300 enzymatic reactions and plays a role in DNA synthesis, protein synthesis, wound healing, immune function, and sensory perception, among others, despite its importance, Zinc deficiency is a prevalent problem worldwide, particularly in developing countries (Ho, E. 2004). Zinc deficiency can lead to growth retardation, impaired immune function, cognitive deficits, and even

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death (Aryana, I. G. P. S., & Paramita, I. A. P. 2023), in recent years, there has been a growing interest in Zinc's role in animal, plant, and human nutrition (King, J. C., et al. 2015). To better understand how Zinc affects various biological processes and how to optimize Zinc intake to promote optimal health, this has led to a greater understanding of the mechanisms underlying Zinc's role in nutrition and the importance of Zinc supplementation in addressing deficiencies (Gać, P., et al. 2012). Animal studies have shown that Zinc deficiency can lead to reduced growth rates, poor reproductive performance, and impaired immune function (Salgueiro, M. J., et al. 2000). Plants also require Zinc for proper growth and development (Yadav, A. K., et al. 2023), Zinc deficiency can lead to reduced crop yields and poor nutritional quality (Mousavi, S. R. 2011). In humans, Zinc is critical for normal growth and development, particularly during fetal and early childhood development (Caulfield, L. E., et al. 1998). Zinc deficiency in humans can lead to stunted growth, impaired cognitive function, and increased susceptibility to infectious diseases (Deshpande, J. D., et al. 2013). Zinc's effects on growth and development, immune function, and cognitive function (Cunningham-Rundles, S., et al. 2005), Zinc's role in animal, plant, and human nutrition, highlighting the importance of this essential micronutrient in promoting optimal health across all domains of life (Lacey, J. M. 2013, Piot, P. 2008, Frassinetti, S., et al. 2006), this review will provide an overview of Zinc's role in animal, plant, and human nutrition, with a focus on recent advances in understanding how Zinc affects various biological processes (Yu, H., et al. 2023).

II. HISTORY OF ZINC

Zinc is a chemical element with the symbol (Zn) and atomic number 30 (Hameed, O. M., et al. 2023), when oxidation is erased, zinc takes on a shiny-greyish color and becomes a slightly brittle metal (Šajn, R., et al. 2023), it is the first element in the periodic table's group 12 category (Anastassakis, K. 2022). Andreas Sigismund Marggraf was a German chemist from Berlin, he isolated Zinc in 1746 by heating calamine and carbon (Tironi, M. (2023). Zinc has always been a significant mineral component in the manufacture of food, yet first, this significance was only gradually acknowledged (Reilly, C. 2008). Zinc was listed as a necessary nutrient for *Aspergillusniger* output by a Louis Pasteur student in 1869 (Rizzo, J., et al. 2023), Black mold is frequently caused by this fungus in several agricultural goods, including grapes, onions, and peanuts (Plascencia-Jatomea, M., et al. 2014).

III. IMPORTANCE OF ZINC

The body only requires trace amounts of Zinc, nearly 100 enzymes rely on it to carry out essential chemical reactions (Frei, A., et al. 2023), it plays a significant role in the production of DNA, cell development, protein synthesis, tissue repair, and maintenance of a strong immune system (Maret, W., & Sandstead, H. H. 2006). One of the key elements in the metabolism of carbohydrates is Zinc, which activates the majority of the enzymes needed for this process (Cakmak, I., et al. 2023). Several vital plant enzymes are produced by the Zinc (Peng, Y., et al. 2023), which is an essential component in numerous enzymes, it also starts a wide range of enzymatic processes (Nagajyoti, P. C., et al. 2010). For various enzymes, it serves as a co-factor in terms of structure, regulation, and physics (Guarnera, E., & Berezovsky, I. (2023), it is necessary to numerous biological functions (Flatmark, T. 2000). It is crucial for the normal operation of numerous enzymes and is involved in DNA transcription (Moore, L. D., et al., 2013).

Additional Zinc activities include regulating the synthesis of auxins, chlorophyll, and growth-promoting substances as well as catalyzing the oxidation process in plant cells, which is important for the transformation of carbohydrates (Zewide, I., & Sherefu, A. 2021). In plant tissues, a low Zinc concentration leads to a buildup of amino acids and a decrease in the amount of sugar since Zinc is necessary for the creation of protein and starch, a buildup of carbohydrates in plant leaves occurs when there is a Zinc deficit because various enzymes in which Zinc plays a significant role are diminished (Alsherif, E. A., et al. 2023), Zinc contributes to the development of pollen tubes, further assisting pollination (Brown, P. H., et al., 1993, Mohamed, H. I., et al. 2016, Toor, M. D., et al. 2022).

IV. IMPACT OF ZINC ON ANIMAL

Zinc is regarded as a key component of 200 enzymes, with metabolic functions including glucose metabolism, protein synthesis and metabolism, nucleic acid metabolism, epithelial tissue integrity, cell division and repair processes, transport, and consumption of Vitamin A and Vitamin E (Younas, Z., et al. 2023). In the immune system, zinc has a fundamental part; hormones (e.g. reproductive) play a significant role; Sexual maturity, reproductive potential, and notably estrus (Kant, S., et al. 2023).

Many proteins, enzymes, and transcription factors are involved in the binding of zinc, and in exchange for their functionality, they are dependent upon zinc (Negi, S., et al. 2023). Zinc is an essential element for the health of animals, it is engaged in biochemical processes that maintain life (Ciosek, Ż., Kot, K., & Rotter, I. 2023). Priority functions include cellular respiration, oxygen consumption by cells, DNA and RNA expression, preservation of cellular membrane integrity, trapping of free radicals, and defense against lipid peroxidation (Kanakari, E., & Dendrinou-Samara, C. 2023).

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The nutritional health of farm animals is the backbone of their performance and reproduction (Jesuyon, O. M., et al. 2023), micronutrients play a role in a variety of bodily processes, including the metabolism of carbohydrates, proteins, and nucleic acids, the synthesis of other hormones, the intracellular detoxification of free radicals, and reproductive steroid synthesis (OGUNNUSI, O. J., et al. 2023). Male reproductive problems can result from excess or deficiency, which can affect things like libido and spermatogenesis (Liu, T. 2023). Additionally, it has an impact on females' reproductive health, embryonic development, survival, postpartum recovery, milk production, and the growth and survival of their offspring (Peixoto-Gonçalves, C., et al. 2023). Animals with a zinc deficiency can easily recognize it through changes in taste perception, synthesis issues, restricted limb bone growth, and eye infections (Lu, C. W., et al. 2023).

V. ZINC DEFICIENCY PROBLEMS IN ANIMALS

A zinc deficiency can lead to loss of appetite, slowed growth and reproduction, and compromised bone and skin tissue health (Islam, M., et al. 2023). Zinc is a key nutrient for animals, working mostly or entirely in enzyme systems and being involved in protein synthesis, carbohydrate metabolism, and many other biochemical reactions (Salim, H. M., et al. 2008, Soetan, K. O., et al. 2010, Ciosek, Ż., et al. 2023, Islam, M., et al. 2023).

VI. IMPACT OF ZINC ON PLANT GROWTH

Zinc is necessary for the growth of both animals and humans (Basta, M., et al. 2023), it is needed for plant nutrition and involves multiple enzyme processes, metabolic and redox reactions, enzymes involved in energy transfer, protein synthesis, and nitrogen metabolism (Tariq, A., et al. 2023). These enzymes play an important role in biochemical reactions, such as carbohydrate metabolism, photosynthesis, and sugar conversion into starch (Li, C., et al. 2023), it is also concerned with protein and auxin metabolism, pollen formation, biological membrane integrity, and such enzymes related to infection resistance caused by any pathogen (Cakmak, I., et al. 2023). Zinc influences hydrogenase activities, carbonic anhydrase, ribosomal function stability, and cytochrome synthesis (Saxena, V., et al. 2023).

Plant enzymes are activated by zinc (Sun, Q., et al. 2023), those involved in glucose metabolism, cell membrane integrity maintenance, protein synthesis, auxin control and synthesis, and pollen development (Boradkar, S. G., et al. 2023). Tolerance to environmental challenges in plants is accomplished by the expression of certain genes, and the maintenance and regulation of such gene expression is necessary (Álvarez-Aragón, R., et al. 2023).

Zinc deficiency in plants caused several anomalies that may be seen as apparent indicators of deficiency such as stunted development, decreased leaf size, chlorosis of the leaves, and spikelet sterility (Kirkby, E. A., et al. 2023). Micronutrient deficiency, such as Zinc deficiency, has an impact on the quality of mature and harvested agricultural products; infection induced by fungal or disease assaults is increased, and plant sensitivity to harm caused by greater light and temperature intensities is also raised (Saquee, F. S., et al. 2023, Magray, J. A., et al. 2023).

VII. THE ROLE OF ZINC IN DROUGHT-STRESSED PLANTS

Drought stress is one of the most concerning abiotic stresses on crop production because it affects all living things that are present on the surface of the earth (Irfan, M., et al. 2023), because of erratic rainfall and changes in the climate, drought stress on plants is becoming an increasingly common problem (Sarkhel, S., et al. 2023), the rapid increase in atmospheric temperature has increased the crop's exposure to drought-related stress (Cotrina Cabello, G. G., et al. 2023). The extent of the drought stress is unstable because it depends on a variety of variables, including the distribution and amount of rainfall, evapotranspiration, and the soil's capacity to retain moisture (Suna, T., et al. 2023). Drought stress lowers crop productivity, which impacts plant water uptake, leaf water status, and gas exchange rates (KHOULOUD, Z., et al. 2023).

Drought is another factor that has a severe impact on agricultural crop yield (Rahman, K. U., et al. 2023). It negatively affects plant processes such as the synthesis of proteins, nucleic acids, lipids, and carbohydrates, which slows down the growth and output of crops (Boamah, P. O., et al. 2023). There are numerous options available to alleviate drought stress, but the foliar spray is the best and most tranquil way to handle it (Al-Khayri, J. M., et al. 2023). Zinc is a necessary element that is fundamental to numerous biological activities taking place on the crust of the earth (Ranaweera, D., et al. 2023). Also, using zinc significantly lessens the detrimental effects of water shortage on plant growth, hence reducing photo-oxidative damage (Javed, M. S., et al. 2023).

VIII. IMPACT OF ZINC ON HUMANS

Life cannot exist without zinc, which is the 23rd most prevalent element in the earth's crust and has an atomic mass of 65.37 and an atomic number of 30 (Mittal, N., et al. 2023). Pure zinc is a bluish-white, glossy metal that is generally amphoteric in nature

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(Kaur, K., et al. 2014). Zinc is colorless and diamagnetic, therefore most spectroscopic techniques cannot detect it (Hirsch, M., et al. 2023). Zinc is vital because approximately 300 proteins involved in growth, reproduction, development, eyesight, and immune function depend on it for their structural or catalytic roles (Icbudak, H., et al. 2004).

Zinc is therefore the second-most important vital metal for human, only behind iron in terms of quantity (Huang, W., et al. 2023), Zinc needs for the diet range from 230–460 mol (15–30 mg) kg–1 dry mass of food (Shams Tabrez, K., & Malik, A. 2021). Zinc is such a vital component for human health that even a slight shortage can have severe effects (Mohamad, N. S., et al. 2023). Lack of Zinc in people results in symptoms such as anorexia, loss of appetite, and loss of smell and taste, among others, it have an impact on the immune system, leading to arteriosclerosis and anemia (Greydanus, D. E., & Smith, Z. R. 2020).

Zinc deficiency impairs hemostasis because it causes abnormal platelet aggregation, fewer T cells, and a diminished T-lymphocyte response to phytoestrogens. Indeed, the only naturally occurring lymphocytic mitogen is zinc (Singh, P. K., et al. 2019). Due to its role as a cofactor in the production of numerous enzymes, DNA, and RNA, Zinc is a necessary element that carries out a number of different roles in the body (Żwierełło, W., et al. 2020). Zinc deficiency has been associated with problems during pregnancy and childbirth, development impairment, and congenital abnormalities in the developing fetus (Naik, V. D., et al. 2022).

Zinc is a trace element that is well-known around the world and has an important function in human bodies (Kaur, L., et al. 2023). On the other hand, it is essential for the growth and development of microorganisms, and it is equally important for both plants and animals (Pandey, V. K., et al. 2023). It is almost always present in our body's tissues and other secretions in higher concentrations; of the total Zinc present in our body, 85% is found in bones and muscles, 11% is found in the liver and our skin, and the remaining 5% is found in some other tissues (Szűcs-Somlyó, É., et al. 2023), the highest Zinc concentration is found in the prostate and eye in an adult body (Ugbonta, P. N., et al. 2023, Liberal, Â. et al. 2022).

According to estimates, a third of the world's population is at risk of zinc insufficiency (Parashar, R., et al. 2023). This risk is predominately experienced by children (under the age of five) because they require more zinc to complete their growth and development (Gupta, S., et al. 2020), more than 500,000 children every year die from Zinc deficiency (Islam, M. R., et al. 2023). One of the main causes of economic loss in poor nations is a lack of micronutrients, particularly Zinc, when the cost of providing healthcare for people rises, productivity falls, which has an impact on the gross national product (Ait Ouakrim, D., et al. 2023).

IX. PROBLEMS OF ZINC DEFICIENCY IN HUMANS

Individuals are eating a lot of cereals, which means that their bodies aren't getting enough zinc, which causes anemia (Cordain, L. 2012), for a typical human, a daily zinc intake ranges from 3 to 16 milligrams (King, J. C. 1986), many disorders in the human body are caused by improper Zinc consumption (Roohani, N., et al. 2013), the entire mortal community is suffering by around 30% as a result of Zinc scarcity (Gondal, A. H., et al. 2021). Growth retardation, male hypogonadism in teens, rough skin, low appetite, mental lassitude, delayed wound healing, cell-mediated immunological dysfunctions, and aberrant neurosensory alterations are all symptoms of a moderate zinc shortage (Silver, P. J., et al. 2023, Nasir, A. 2010).

Table 1: Problems of zinc deficiency in humans, plants, and animals.

Problems of Zinc Deficiency	*Humans*	Plants	Animals
Weak immune system	Reduced resistance to disease	Reduced disease resistance	Reduced disease resistance
Delayed wound healing	Reduced growth and development	Reduced growth and development	Delayed wound healing
Growth and development issues	Reduced crop yields	Reduced growth and development	Growth retardation
Skin problems	Reduced plant growth and quality	Skin lesions and dermatitis	Skin lesions and dermatitis
Loss of appetite	Reduced root growth and nutrient uptake	Anorexia and reduced feed intake	Reduced feed intake
Impaired vision	Reduced photosynthesis and chlorophyll synthesis	Reduced vision and blindness	Reduced vision and blindness
Mood disorders	Reduced plant growth and yield	Reduced behavior and activity levels	Aggressive behavior

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Reproductive issues	Reduced fertility and sexual maturation	Reduced fertility and seed production	Reduced fertility and reproductive performance
Hair loss	N/A	Reduced hair quality and shedding	Reduced coat quality and shedding
Diabetes	Increased risk of developing diabetes and metabolic disorders	N/A	N/A

X. SOURCES OF ZINC

Oysters are one of the best sources of zinc, providing over 400% of the daily recommended value in just one serving, Beef, pork, and lamb are good sources of zinc, with beef providing around 36% of the daily recommended value per 3.5 ounces, seafood sources of zinc include crab, lobster, and shrimp. Legumes like chickpeas, kidney beans, and lentils are good sources of zinc, providing around 10-20% of the daily recommended value per serving. Pumpkin seeds, cashews, and almonds are good sources of zinc. Yogurt and cheese are good sources of zinc, with cheddar cheese providing around 28% of the daily recommended value per 3.5 ounces. Whole grains like wheat, quinoa, and oats contain some zinc (Dang, V. K., & Walker, L. O. 2021, Drummond, K. E., & Brefere, L. M. 2021, Thiruppathi, G., et al. 2023, Morzelle, M. C., et al. 2016, Ebbage, J., & Insights, C. 2015, Ray, P. K. 2023). It's important to note that the bioavailability of zinc from plant-based sources is lower than from animal-based sources, so vegetarians and vegans may need to consume more zinc-rich plant foods or consider taking a zinc supplement.

XI. CONCLUSION

Zinc is a vital element for the nutrition of humans, animals, and plants. It plays an essential role in healthy sexual development in humans and animals, while its deficiency can reduce testicular size in males. Additionally, Zinc provides plants with resistance to various diseases that can negatively affect agricultural yields. Humans also use Zinc as a crucial healing vitamin to treat a range of illnesses.

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