



Phytic Acid As An Antinutrient And Pronutrient : A Review

Dr. Kiran Bharti*

Assistant Professor,

Department of Botany,

KLDAV PG College, Roorkee, Haridwar, Uttarakhand

ABSTRACT

Phytic acid (myo-inositol hexakisphosphate or IP6) is a biochemical compound found abundantly in seeds, grains, and legumes. It plays multiple important role in plants such as in metabolism, defense, tolerance towards stress, including its crucial importance in phosphorus storage and germination of seed. In spite of its significant potential in plants, phytic acid is not considered as favourable for animal and human nutrition due to its chelating interaction with minerals. This review intend to explore the biological importance of phytic acid in plants and environment as well associated challenges.

Keywords : phytate, antinutrient, chelate, pronutrient, bioavailability

1. Introduction

Phytic acid (myo-inositol hexaphosphoric acid) was first identified by Pfeffer in 1872 (**Oberleas , 1972**). It is the primary storage form of Phosphorus in plant seeds. About 80% of the total phosphorus in mature grains and legumes exists as phytic acid (**Lott et al., 2000**). It accounts for 1% to 5% of the total weight of edible legumes, cereals, oil seeds, and nuts etc. (**Reddy et al., 1982**). In small grained cereals, 90% of the seed phytic acid is present in the aleurone and the remaining 10% in the scutellum. In maize crop the localization is in contrast i.e 90 % in scutellum and 10% in the aleurone.

Phytic acid is biosynthesized primarily from glucose-6-phosphate after a series of steps of phosphorylation. It is mainly stored in protein storage vacuoles in the form of phytate salts (**Raboy, 2003**). The synthesis and deposition mainly occur during seed maturation. The various plant products that are rich sources of phytic acid are oil seeds, whole grains, and legumes etc. The yearly global production of phytic acid is estimated to be greater than 51 million metric tonnes which equals almost 65% of the elemental phosphorus sold worldwide for use in mineral fertilizers. (Lott, 2000).

In phytate form, Phosphorus has a low bioavailability in monogastric animals including human. This is due to little or no activity of an enzyme called as phytase which bearkdown phytate by hydrolyzing it. (**Sandberg and Andersson, 1988**).

Phytate-Mineral Interaction:

Phytate has a tendency to form complexes with divalent and trivalent cations, affecting their availability for absorption in the digestive tract (bioavailability). Hence it has a negative impact on bioavailabilty of important macro and micronutrients such as zinc, iron, calcium, copper, manganese, and magnesium etc. Phytic acid actually forms a mixed salt of potassium, calcium, magnesium or zinc and referred to as phytin and is deposited as globoid particles in single membrane vesicles together with

protein (**Lott, 1984**). The bioavailability of certain elements are essential to humans which if found in deficient quantity may create serious ailments in body. Zinc is a very important micronutrient playing vital role in DNA synthesis and formation of new cells by participating in cell division. It is required as a cofactor in over 300 enzymatic reactions including metabolism, digestion, nerve function etc. It is crucial for cognitive function learning abilities in children serves as antioxidant protecting cells from oxidative stress. Its role in modulating the immune system and reducing inflammation is further highlighted (**Gammoh and Rink 2017**)

Iron is essentially required for transport of oxygen by being an irreplaceable component of haemoglobin. It also plays a crucial role in development of brain, in synthesis of chemical messengers such as dopamine, serotonin etc. which are important for mood and cognitive functions. The role of Iron in cellular energy metabolism has also been reviewed (**Teh et. al. 2024**)

Calcium is vital for bone and dental health, contraction of muscles, clotting of blood, and nerve transmission. It also influences enzyme activity and hormonal secretion. Its important role in signalling pathways and metabolic health is also suggested (**Humbert et al. 2023**)

Magnesium is involved in over 300 enzymatic processes including energy production, DNA synthesis and muscle and nerve function and bone development. The role of magnesium in cardiovascular has also been suggested (**Song and Liu 2012**). Manganese supports enzyme functions, bone development and wound healing. It also plays roles in nutrient absorption, thyroid function and metabolism of fats, carbohydrates, and glucose. Its importance in neurological function and its potential protective effects against oxidative stress has also been suggested (**Aschner 2000**)

Phytate-Protein Interaction:

Phytate also interacts with proteins, affecting their digestibility and enzymatic activity. Phytate interactions with proteins are pH-dependent and can form complexes with protein at both acidic and alkaline pH (**Cheryan, 1980**). Phytate's interaction with proteins can affect changes in protein structure, decreasing enzymatic activity, protein solubility, and proteolytic digestibility. The inhibitory effect increases with the number of phosphate residues per myo-inositol molecule and the myo-inositol phosphate concentration. This inhibition may be due to the non-specific nature of phytate-protein interactions, the chelation of calcium ions essential for the activity of trypsin and α -amylase, or the interaction with the substrates of these enzymes.

Phytate can be a huge problem in if the staple food crops are grown in mineral deficient soil as it will depress the bioavailability of even the limited amount of mineral present in the grains or seeds of such crops. Phytic acid has attracted attention due to its dualistic nature—being both advantageous for plants and disadvantageous for human nutrition.

3. Benefits of Phytic Acid in Plants

Phytic acid serves as a major phosphorus reservoir in seeds. During germination, phytase enzymes degrade Phytic acid, supplying phosphorus for cellular metabolism and seedling growth (**Lott et al., 2000**). It is considered to possess strong antioxidant activity by chelating transition metals such as Fe^{2+} and Cu^{2+} , thereby preventing oxidative damage to DNA and cell membranes (**Graf and Eaton, 1990**). This function is particularly important under environmental stress conditions. It also facilitates to remove from free radicals in human body in similar way. If left unobserved free radicals can contribute to the development of certain diseases and cancer.

By forming insoluble complexes with toxic metals like lead and cadmium, Phytic acid helps mitigate metal toxicity in plants grown in contaminated soils. This chelation mechanism can be advantageous in phytoremediation strategies. (**Guayjarernpanishk and Sampanpanish, 2024**)

Phytic acid contributes to plant defense by modulating signaling pathways associated with pathogen response. It also plays roles in drought and salt stress tolerance by influencing osmotic balance and ion homeostasis.

Phytic acid indirectly contributes to osmoregulation under drought or salinity stress by influencing ion balance and water retention. Inositol (a product of PA metabolism) is a known osmoprotectant. Phytic acid also helps stabilize protein complexes and membranes under heat and desiccation stress. The antioxidant nature of phytic acid helps protect stored seeds from oxidative rancidity, thus improving seed longevity and viability during storage. This is critical for seed banks, grain storage, and agriculture in arid regions.

4. Role of Phytic acid as Nutraceutical

Phytate plays an important role in preventing development of kidney stones by abstaining the formation of calcium oxalate and calcium phosphate crystals (**Grases et al., 2004**). Few studies found it having anti-diabetic properties (**Omoruyi et al., 2013**). It has also been found beneficial against coronary heart disease (**Jariwalla et al., 1990**). It has also been found to have anticarcinogenic against various kinds of cancers.

5. Phytic acid as an Antinutrient

Phytic acid is labelled an anti-nutrient due to its strong chelation of essential dietary minerals like iron, zinc, calcium, and magnesium, reducing their bioavailability (**Sandberg, 2002**). This is particularly concerning in populations relying heavily on cereal-based diets.

Monogastric animals (e.g., poultry, pigs, and humans) lack endogenous phytase enzymes to break down PA, leading to poor phosphorus utilization. As a result, PA-rich feed contributes to phosphorus excretion and environmental pollution (**Eeckhout & De Paepe, 1994**).

Since phytic phosphorus is not readily bioavailable, a significant portion of dietary phosphorus is wasted unless supplemented with exogenous phytases or low-phytate crops (**Raboy, 2009**). This inefficiency adds cost and complexity to food and feed industries.

6. Efforts to mitigate the nutritional drawbacks of Phytic acid

Various preparation methods such as milling, soaking, germinating, fermenting, and incorporating vitamin C are discussed as ways to reduce phytic acid content in foods and improve mineral absorption. Breeding low-phytate cultivars with reduced phytic acid concentration and opting for Transgenic approaches to suppress key enzymes in the PA biosynthesis pathway could be another great alternative to prevent phytic acid in the crop itself.

Application of microbial phytases in food processing and animal feeds to improve mineral bioavailability has also been suggested (**Pedersen, 2013**).

7. Conclusion

Phytic acid is an essential molecule in plant biology, contributing to nutrient storage, stress tolerance, and detoxification. However, its negative implications in human and animal nutrition warrant biotechnological interventions. Future research should balance the ecological and physiological roles of Phytic acid in plants with the need for improved mineral nutrition in consumers.

REFERENCES

1. Aschner, M. 2000. Manganese : Brain transport and emerging research needs. *Environment Health Perspectives*, 108 (3) : 429 – 432
2. Cheryan M. 1980. Phytic acid interactions in food systems. *Critical Reviews in Food Science and Nutrition*, 13:297-335.
3. Eeckhout, W and De Paepe, M. 1994. Total phosphorus, phytate-phosphorus and phytase activity in plant feedstuffs. *Animal Feed Science and Technology*, 47(1-2), 19–29.
4. Graf, E and Eaton, J. W. 1990. Antioxidant functions of phytic acid. *Free Radical Biology and Medicine*, 8(1), 61–69.
5. Grases, F., March, J.G., Prieto, R.M., Simonet, B.M., Costa-Bauza A., Garcia-Raja A *et al.* 2000. Urinary phytate in calcium oxalate stones formers and healthy people. *Scandinavian Journal Urology and Nephrology*, 34:162-164.
6. Humbert A., Lefebvre, R. Nawrot, M , Caussy, C., Rieusset, J. 2023. Calcium signalling in hepatic metabolism: Health and Diseases. *Cell Calcium*. <https://doi.org/10.1016/j.ceca.2023.10278>
7. Jariwalla, R.J, Sabin, R., Lawson, S., Herman, Z.S. 1990. Lowering of serum cholesterol and triglycerides and modulation of divalent cations by dietary phytate. *Journal of Applied Nutrition*, 42(1) :18-28
8. Lott, J.N.A. 1984. Accumulation of seed reserves of phosphorus and other minerals. In Murray, D. R *ed Seed Physiology*. Academic Press. pp. 139-166.
9. Lott, J. N. A., Ockenden, I., Raboy, V., and Batten, G. D. 2000. Phytic acid and phosphorus in crop seeds and fruits: A global estimate. *Seed Science Research*, 10(1): 11–33.
10. Oberleas, D. 1972. Phytates. In: *Toxicants occurring naturally in foods*. National Academy of Sciences, Washington, D. C.: 363-371.
11. Song, Y., Liu, S. 2012. Magnesium for cardiovascular health: time for intervention. *The American Journal of Clinical Nutrition*. 95: 269-270
12. Omoruyi, F.O., Budiaman, A., Eng, Y., Olumese, F.E., Hoesel, J,L, Ejilemele, A *et al.* 2013. The potential benefits and adverse effects of phytic acid supplement in streptozotocin-induced diabetic rats. *Advances in Pharmacological Sciences*. DOI: [10.1155/2013/172494](https://doi.org/10.1155/2013/172494)
13. Raboy, V. 2003. Myo-Inositol-1,2,3,4,5,6-hexakisphosphate. *Phytochemistry*, 64(6): 1033–1043.
14. Reddy, N.R., Sathe, S.K. and Salunkhe, D.K. 1982. Phytates in legumes and cereals. *Adv Food Res*, 28:1-92.
15. Sandberg, A. S. 2002. Bioavailability of minerals in legumes. *British Journal of Nutrition*, 88(S3): 281–285.
16. Sandberg, A. S. and H. Andersson. 1988. Effect of dietary phytase on the digestion of phytate in the stomach and small intestine of humans. *Journal of Nutrition*. 118:469-473.
17. Teh, M.R, Armitage, A.E. and Drakesmith, H. 2024. Why cells need iron: a compendium of iron utilisation. *Trends in Endocrinology and Metabolism*. 35 (12) : 1026-1049.
18. Gammoh, N. Z. and Rink L. 2017. Zinc in infection and inflammation. *Nutrients* 2017 Jun 17;9(6):624. doi: [10.3390/nu9060624](https://doi.org/10.3390/nu9060624)
19. Pedersen, H.B, Madsen, C.K, Holme, I. B. and Dionisio G. 2013. Increased understanding of the cereal phytase complement for better mineral bio-availability and resource management. *Journal of Cereal Science*, 59(3): 371-381.
20. Guayjarernpanishk, W , Sampanpanish P.,2024. Efficiency of sodium phytate in the remediation of As, Mn, and Cu contamination in acid mine drainage using water hyacinth. *Heliyon* (10). doi.org/10.1016/j.heliyon.2024.e26590.