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Phytic Acid: Key Benefits and Constraints

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Phytic acid, also known as *myo* inositol hexakisphosphate (IP6), is a naturally occurring phosphorus storing compound found in many plant-origin foods, especially in seeds, nuts, grains, and legumes. It is the major storage form of phosphorus in plants. It is mainly found in aleurone layer, however in case of maize it is found in germ. The biosynthesis of phytic acid involves several enzymatic steps and the sequential addition of phosphate groups onto inositol molecules. The initial step in phytic acid synthesis starts with glucose-6-phosphate, which is converted to inositol-3-phosphate, which is the precursor for the synthesis of inositol, the backbone of phytic acid. Inositol-3-phosphate is further converted to inositol by a series of enzymatic reactions. Inositol is a cyclic sugar alcohol and serves as the core structure for phytic acid. Inositol is sequentially phosphorylated into phytic acid. This is a critical step in the synthesis of phytic acid. Phosphate groups are received from the plant's metabolism and are added to specific positions on the inositol backbone. Phytic acid comprises of six phosphate groups attached to the inositol ring, giving it the characteristic hexakisphosphate structure. Phytic acid, upon synthesis, is stored in form of globoids into vacuoles. It serves as a reserve of phosphorus for the germinating seeds. During seed germination, phytic acid is broken down into inositol and phosphate, making phosphorus available for the developing plant.

Accumulation of phytic acid in grains ensures that the developing plant has continuous supply phosphorus for its initial germination and growth. Later on, during the grain filling period, phytic acid is again synthesized and accumulated into developing grains

Antinutritional effects of phytic acid

Phytic acid is known to have antinutritional effects in human and animals. These effects are primarily due to its ability to bind to essential minerals, forming salt complexes known as phytates or phytins, and reducing their bioavailability. Since phytic acid has negatively charged phosphorus group, it can chelate or bind to essential minerals such as calcium, magnesium, iron, and zinc. When phytates form complexes with these minerals, they only become available upon hydrolysis of phytic acid, thus they become less soluble and, as a result, less available for absorption in the intestinal tract. Humans and monogastric animals lack phytase activity, (an enzyme, which hydrolyses phytic acid into phosphate groups and inositol ring) so they are unable to utilize the phytic acid being fed to them. This can potentially lead to mineral deficiencies if plant origin foods make a significant part of the diet. The presence of phytic acid in foods like grains, legumes, and seeds can inhibit the absorption of calcium and contribute to a risk of calcium deficiency. Phytic acid is a well-known inhibitor of non-heme iron absorption, which is the form of iron found in plant-based foods. Iron deficiency is a common concern, particularly in populations with high phytic acid consumption, as it can contribute to anemia. Phytic acid can also impair the absorption of zinc, an essential mineral for various biological processes, including immune function, growth, and wound healing. Zinc deficiency can be a concern in areas where diets are predominantly composed of phytic acid-rich foods.

Key benefits of phytic acid in plants

Though phytic acid is known to have many antinutritional effects in humans and non ruminents, it plays several important roles in plants, particularly in grain development and germination and in the overall biology of the plant. Here are the key functions of phytic acid in plants –

Phosphorus reservoir: Phytic acid is the primary storage form of phosphorus in seeds, especially in grains, nuts, and legumes. During seed development, plants accumulate phytic acid to provide a source of phosphorus for the developing plant. This stored phosphorus is vital for the initial stages of seed germination and early seedling growth.

Seed germination: Phytic acid's role in storing phosphorus is vital for the germination of seeds. During germination, enzymatic break down of phytic acid release phosphate groups, which are essential for energy transfer and growth processes. This stored phosphorus ensures that the developing seedling has an immediate source phosphorus.

Regulation of key minerals: Phytic acid can help plants in regulating the availability of essential minerals in the soil. It can sequester excess or toxic metals like iron, lead, and cadmium, reducing the risk of metal toxicity to the plant. Additionally, it can influence the solubility and uptake of minerals by plant roots.

Seed quality: Phytic acid content in seeds can be a factor in determining seed quality. In agriculture, the phytic acid content is an important consideration, as it can affect the nutritional value of the seeds and their potential as food or feed for humans and animals.

Nutrient recycling: When plant material containing phytic acid decomposes, it releases phytic acid into the soil. In the environment, phytic acid can serve as a slow-release source of phosphorus.

Health benefits of phytic acid

Phytic acid, despite its antinutritional effects, also has beneficial roles and health-related properties. Here are some key health benefits of phytic acid:

Antioxidant properties: Phytic acid exhibits antioxidant activity. It can scavenge free radicals and reduce oxidative stress, potentially helping to protect cells and tissues from damage caused by reactive oxygen species. This antioxidant property may contribute to various health benefits.

Reduced risk of certain diseases: Some studies suggest that a diet rich in phytic acid-containing foods, such as whole grains, legumes, and nuts, may be associated with a reduced risk of certain diseases. For example, a higher intake of phytic acid has been linked to a lower risk of colon cancer.

Balance blood sugar levels: Phytic acid may have a modest impact on blood sugar levels. It can slow down the absorption of carbohydrates in the digestive tract, potentially leading to more stable blood glucose levels. This property can be helpful for individuals with diabetes or those at risk of developing diabetes.

Prevention from heavy metal toxicity: In addition to binding essential minerals, phytic acid can also bind to heavy metals, such as lead and cadmium. This chelation property may help reduce the absorption and toxicity of heavy metals, potentially protecting against heavy metal-related health issues.

Anti-inflammatory effects: Some studies suggest that phytic acid may have anti-inflammatory properties, which can be beneficial for conditions associated with chronic inflammation. These effects are still being researched, but they hold promise for various health applications.

Summary

Since phosphorus has been key mineral for life, phytic acid has equally important function in seed development and germination.it acts as major reservoir of phosphorus in grains. Phytic acid is synthesized in a series of enzymatic reactions, where *myo* inositol is converted into phytic acid having anionic phosphate groups attached to it. During germination and development, phytic acid is hydrolysed by phytase enzyme and supplies back the phosphorus required during the process. Due to anionic nature, it has strong chelating properties towards essential cations such as Ca^{2+}, Mg^{2+}, Fe^{3+}, Zn^{2+} etc. Due to chelation of key micronutrients, their bioavailability is reduced in human and non-ruminants, when fed with phytic acid rich diet, since they are unable to hydrolyse the phytic acid fed to them. Despite these antinutritional aspects, phytic acid has important role in plant life as well as have some health benefits to human. It is vital for seed germination, signal transduction and energy metabolism, whereas for humans it prevents from certain diseases.