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POPULAR ARTICLE

Importance of phosphorus in animal nutrition

S. Raja*, M.Murugan, U.Lakshmikantan, P.Vasanthakumar and M.Selvaraju

Department of veterinary Gynaecology and Obstetrics,
Veterinary College and Research Institute, Namakkal 637002, TANUVAS, Tamil Nadu
**Corresponding author email id : argoraja@gmail.com*

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INTRODUCTION

The word phosphorus derives from the ancient Greek words (phoˆs) meaning "light" and (phorus) meaning "bearer." The origin of this name comes from the initial discovery of phosphorus in the 17th century, when a small sample of phosphorus purified from urine was found to spontaneously emit pale-green light in the dark without producing any heat. Phosphorus in the biosphere most commonly occurs in its pentavalent form, as phosphate (PO43^{-}) and it is in this form that it is most often found in living organisms

PHOSPHOROUS EXISTENCE IN BIOSPHERE

Soil phosphorus is exist in two forma namely Organic and inorganic. These two forms make the total soil phosphorus with the range of 2000 to 6000 pounds per acre

Inorganic phosphorus is categorised into three forms

1. Plant available phosphorus: it is composed of inorganic phosphorus and it is dissolved in water/solution and readily available for the plants
2. Sorbed phosphorus: this portion is attached to a clay substances, iron, aluminium, calcium oxides in the soil. It is released slow for plant uptake
3. Mineral phosphorus: it is composed of primary and secondary phosphates minerals in soil. It is released very slowl for plant uptake when the weather dissolves it.

Eg. for primary phosphate: apatite, strengite and variscite; Eg. for secondary phosphate: Iron, calcium, aluminium phosphates.

PHOSPHOROUS TRANSFORMATION IN NATURE

Once ethe phosphorus enters the soil through fertilizer, manure, plant fibre, animal debris it cycles through various process such as mineralization, immobilization, adsorption, precipitation, desorption, weathering and dissolution

Mineralization: conversion of organic to inorganic form by soil microbes

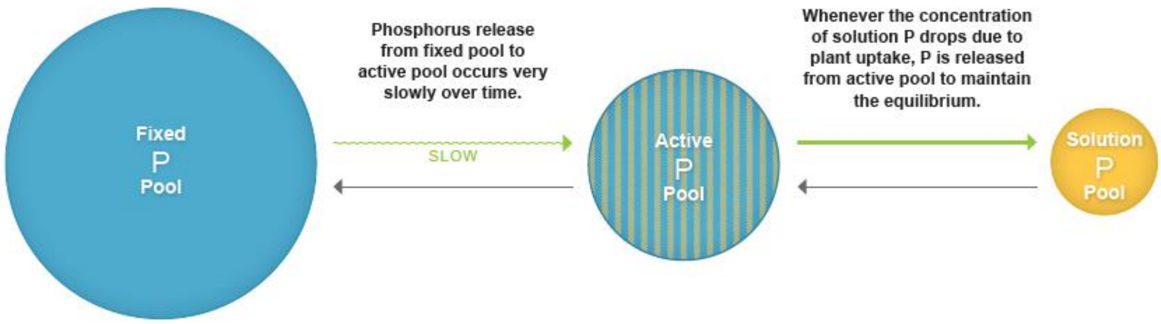
Immobilization: reversion of inorganic to organic form and absorption by soil microbes

Adsorption: process in which the phosphorus in solution gets binded to the soil particles; binding takes in clay particles, AlO, FeO

Desorption: adsorbed phosphorus are released back into the solution

Three pools of phosphorus existence

- Fixed or non liable pool: largest pool and it is unavailable for the plant uptake and it is comprised of primary minerals(Inorganic phosphorus) and organic portion that do not mineralize easily due to strong binding
- Active or liable pool: consist of secondary phosphate minerals and organic portion that mineralize easily
- Third pool is the smallest which contains inorganic phosphate minerals and small amount of organic portion



Pools of phosphorus existence in soil

PHOSPHOROUS EXISTENCE IN ANIMALS

Phosphorus is one of the most important minerals in animal nutrition. It is the second most abundant element in an animal body after calcium, with 80% of phosphorus found in the bones and teeth, and the remainder located in the body fluids and soft tissue.

From 80 to 85% of the bodies' phosphorus is located in the skeleton where it occurs as hydroxyapatite in a 1.0:1.7 ratio with calcium.

Phosphorus is ubiquitous in the bodies' soft tissues where it is essential for bone metabolism and a broad range of enzymatic reactions, especially those concerned with energy metabolism and transfer (i.e. ATP, ADP, AMP and creatine phosphate). Phosphorus is also essential for transfer of genetic information (i.e. DNA and RNA), and it is a vital component of the bodies' various fluid buffering systems. Phospholipids are necessary for maintenance of cell wall structure and integrity and as integral components of myelin which sheaths the nerves.

Blood serum and plasma Phosphorus concentrations are quite similar and reflect inorganic Phosphorus levels in the blood. Erythrocytes contain high concentrations of organically bound Phosphorus which can increase serum or plasma P, if whole blood samples are handled incorrectly.

FUNCTIONS OF PHOSPHORUS

Phosphorus plays a key metabolic role and has more physiological functions than any other mineral. These functions involve major metabolic processes such as:

- **Development and maintenance of skeletal tissue:** by far the greatest proportion of phosphorus is devoted to maintaining and supporting the skeleton, where it is co-precipitated with calcium in the form of hydroxyapatite. The skeleton acts not only as a support system but also as a reservoir of calcium and phosphorus from which the rest of the body can draw. It undergoes a continuous process of absorption and release of calcium and phosphorus, particularly during animal pregnancy and lactation and, for hens, during the laying period.
- **Maintenance of osmotic pressure and acid-base balance:** together with other minerals, phosphorus has a major role in the maintenance of osmotic pressure, buffer capacity and acid-base balance.
- **Energy utilisation and transfer:** phosphorus plays a vital part in energy regulation. Certain phosphates, such as ATP (adenosine triphosphate), are universal accumulators and donors of energy; they are present in all body cells and ensure both the storage of energy and its utilisation. ATP is of prime importance in muscular activity during which chemical energy is converted into mechanical energy.
- **Protein synthesis, transport of fatty acids, amino acid exchange:** phosphorus compounds are involved, directly or indirectly, in all major physiological functions. Phosphorylation is responsible for intestinal absorption, glycolysis and direct oxidation of carbohydrates, renal excretion, transport of lipids, exchange of amino acids, etc. Phosphorus is also a component of a large number of co-enzymes.
- **Growth and cell differentiation (DNA):** phosphorus forms part of the structure of nucleic acids, which are carriers of genetic information and regulate protein biosynthesis and immunity.

PHOSPHORUS REQUIREMENTS

An adequate supply of phosphorus, in a form that can be absorbed by the animal and is available for storage or use to support these physiological processes, is essential if optimal livestock health and productivity are to be achieved. This is often referred to as biologically “digestible” or “available” phosphorus.

In addition, an animal’s phosphorus requirement cannot be looked at in isolation, since both calcium and vitamin D are closely linked with it in many of the metabolic processes. For example, accretion of phosphorus in the animal's bones is also affected by the presence of calcium and vitamin D.

Consequently, in addition to adequate phosphorus levels, the calcium to phosphorus ratio (Ca:P), as well as suitable levels of vitamin D, are critical to balanced nutrition.

Rumen microbes have a phosphorus requirement apart from the animal's requirement which must be met for optimum rumen microbial activity to occur.

In spite of these results it seems unlikely that ruminal phosphorus levels would be maintained when blood inorganic phosphorus falls below 20 mg/l and animals exhibit clinical P-deficient symptoms. However, maximum microbial degradative and synthetic activities can be maintained if ruminal inorganic phosphorus levels are at least 75±100 mg/l

In contrast to carnivora where phosphorus is lost primarily in the P losses in herbivora occur largely in the feces. The amount of fecal phosphorus depends on diet phosphorus, and overall diet quality as well as the animals' physiological state. On phosphorus depletion diets growing cattle had fecal phosphorus levels that were more than 200% of their phosphorus intake, while cattle on P repletion diets had fecal phosphorus levels that ranged from 58 to 73% of phosphorus intake.

PHOSPHORUS DEFICIENCY

Without an adequate supply of phosphorus, an animal will suffer from a phosphorus deficiency, the consequences of which are varied, but in all cases affect the animal's physical well being, as well as its economic performance. The initial effect is a fall in blood plasma phosphate levels, followed by the response mechanism of calcium and phosphorus being withdrawn from the animal's bones. Apart from a generally lower resistance to infection, this often results in a loss of appetite and a reduction in live weight gain due to impaired feed efficiency.

Deficiency symptoms become more pronounced when conditions for animal husbandry are not ideal. For specific species, these include:

- Laying hens: reduced egg yield, as well as a reduction in shell thickness and hatchability; often accompanied by "cage layer fatigue syndrome" and osteomalacia. Maintaining a correct Ca:P ratio is essential to ensure that the skeleton of the bird develops sufficiently to support optimum egg yield.
- Broilers: leg weakness and bone breakage, as well as tibial dyschondroplasia, osteomalacia and rickets. Bone breakage causes major problems during both production and processing, affecting meat quality; birds developing rickets result in total economic loss.
- Sows: reduced fertility, posterior paralysis ("Downer Syndrome") and osteomalacia, leading to a shorter animal life cycle and reduced productivity.

- Fattening pigs: reduced growth rates and feed efficiency. Development of rickets results in total loss, while bone breakage during transport and processing affects meat quality and results in economic loss.

PHOSPHORUS HOMEOSTASIS IN DOMESTIC ANIMALS

Phosphorus homeostasis differs among monogastric animals and ruminants. In poultry and swine, P homeostasis is controlled by intestinal absorption and the kidney excretes excess P under the regulation of parathyroid hormone (PTH) and calcitriol. In ruminants, the excessive P in plasma is excreted by the salivary glands and the role of kidney in P excretion becomes minor. The major route of P excretion is through the gastrointestinal tract.

The bioavailability of dietary P: Animal feeds contain organically bound and free P. The organic compound binding P in grain legumes, oil-bearing plants and seeds (corns and soybean) is phytate, a six-carbon ring capable of binding six phosphate groups. At physiological pH (7.4) it has either one or two negatively charged oxygen atoms. The concentration of phytate P in feedstuffs depends on the part of the plant from which it is derived. In seeds and grains, phytate P is as high as 70% of total P whereas in non-storage organs of plant such as leaves it is almost zero. Phytate P can be dephosphorylated to less phosphorylated forms of inositol and finally to inositol by meso-inositol hexaphosphate phosphorydrolase (phytase),

Inorganic P in feeds: The major sources of free inorganic phosphorus in animal diets are supplemental minerals and animal by products. One group is the mono and di-calcium phosphates produced by reacting phosphoric acid with limestone. The concentration of limestone determines the amount of phosphate in the mixture

GENERAL MECHANISMS OF PI ABSORPTION

Intestinal inorganic phosphate (Pi) absorption occurs in 3 steps;

a) Pi crosses the lumen brush-border membrane and enters the enterocyte

b) intracellular Pi is transported from the lumen side to the basolateral side of the cytosol; and

c) Pi is transported across the basolateral membrane into the blood

Phosphorus absorption mechanism: Intestinal absorption proceeds via active and passive mechanisms, with the molecular identity of the passive component still unknown. The active absorption of phosphate depends mostly on the activity and expression of the sodium-dependent phosphate cotransporter NaPi-IIb (SLC34A2), which is highly regulated by many of the factors, The epithelia of the small intestine and renal proximal tubules contain Na+-dependent phosphate cotransporters responsible for the active transport of phosphate. These active transporters belong to the SLC34 and SLC20 families of solute carriers, with the SLC34 family probably playing a major quantitative role. In addition to the active component, the intestine also transports phosphate via a passive/paracellular pathway which identity remains unknown.

DIGESTIBILITY AND METABOLISM OF PHOSPHORUS

The flow of organic and inorganic materials thorough the alimentary tract in ruminants

Phosphorus was assumed to exist in 3 forms:

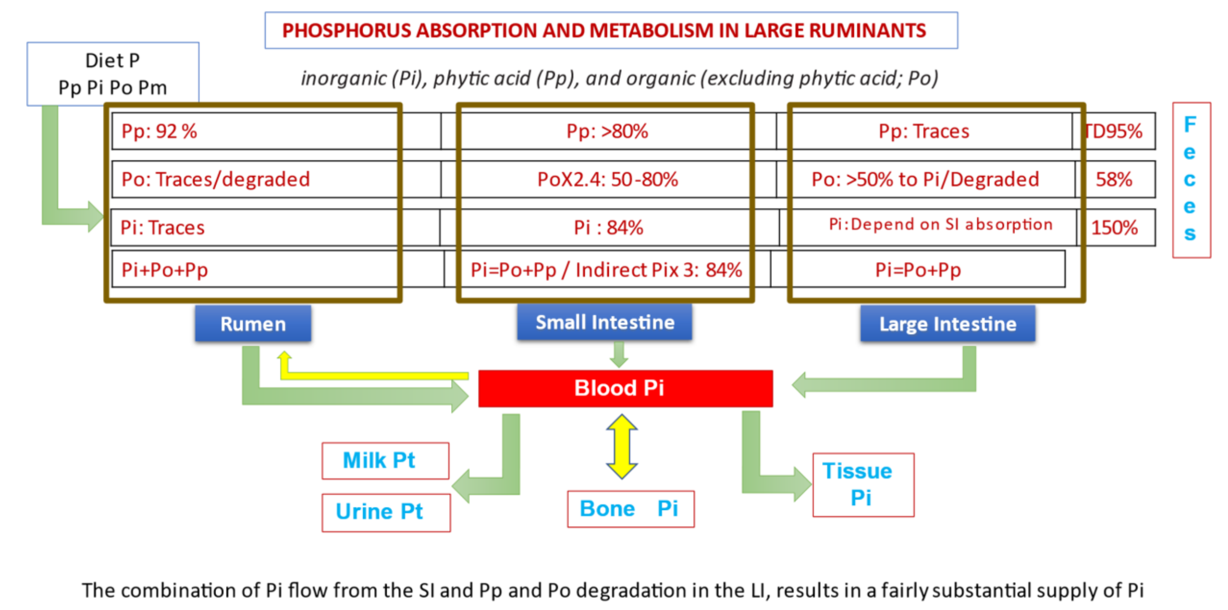
1. inorganic (Pi),
2. phytic acid (Pp), and
3. organic (excluding phytic acid; Po)

All the three forms were assumed to be present in the digestive tract with absorption of Pi into blood.

IMPORTANCE OF PHOSPHORUS METABOLISM IN CATTLE

Absorption of Pi from the SI averaged 84% of that flowing from the rumen, an apparent Pi digestibility of 41.6% in the SI, which is the effective absorption coefficient for the SI. The combination of Pi flow from the SI and Pp and Po degradation in the LI, results in a fairly substantial supply of Pi. The apparent total-tract digestibility of Pp, Po, and Pi based on dietary inputs were 95, 58, and 150%, respectively. The latter is a function of conversion of Pp and Po to Pi exceeding Pi absorption from the digestive tract. Absorption of Pi from the LI is a relatively new concept its contribution to the overall animal supply is minor compared with SI absorption,.

Po and Pi arise within the system as a result of Pp and Po degradation; it is informative to look at apparent intestinal digestibility of Po an Pi which are 27 and 85%, respectively; Po digestion being no more than 50% of supply, whereas apparent Pi absorption is quite extensive; however, the apparent absorption is much less due to a large recycling flux into the rumen, and SI absorption is regulated to resist deficiencies and excess.



Modified from Feng et al. Journal of Dairy Science Vol. 98 No. 10, 2

CONCLUSION

Phytate is greater than 90% available in the animal, but surprisingly, nonphytate organic P was not digested in the SI although it was extensively degraded in the rumen and LI. Phosphorus release from phytate appears to be much faster than degradation of lower inositol phosphate molecules, and thus the rate-limiting step is not at phytase. LI absorbs 15% of the Pi supply available in that compartment. Phosphorus balance is primarily regulated by changes in absorption rate from the SI and recycling of blood Pi to the rumen, and these fluxes are configured to absorb much more P than required and recycle the unused portion to the rumen.

Changing total P concentration in the diet had a greater effect on total P excretion than changing any fraction of P in the diet. Total P excreted was not very sensitive to altering phytase activity, but it did affect P balance. Absorption appears to be an important site of regulation.

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