



Phytate and phytase in poultry nutrition

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ABSTRACTS

There is a distinct possibility that phytate negatively influences protein and energy utilisation in poultry and, as these influences would be ameliorated by phytase, there are substantial, practical implications. Despite several thousand scientific papers and a rapidly growing market the use of phytase and the importance of phytate in practical poultry nutrition remains an area of some confusion. Initially phytases were offered as a means to improve the digestible phosphorus concentration of monogastric rations by the stepwise removal of orthophosphate from the myo-inositol ring of phytate. However, it was gradually understood that the digestibility of other minerals (notably calcium), carbohydrates and amino acids were also variably influenced by the ingestion of phytase (and phytate). The mechanisms at work are not entirely clear but recent evidence suggests that phytate is an antinutrient, beyond its effect on digestible phosphorus and influences secretory and absorptive processes in the gut.

Key words: Phytate, Phytase, Poultry, Nutrition

INTRODUCTION

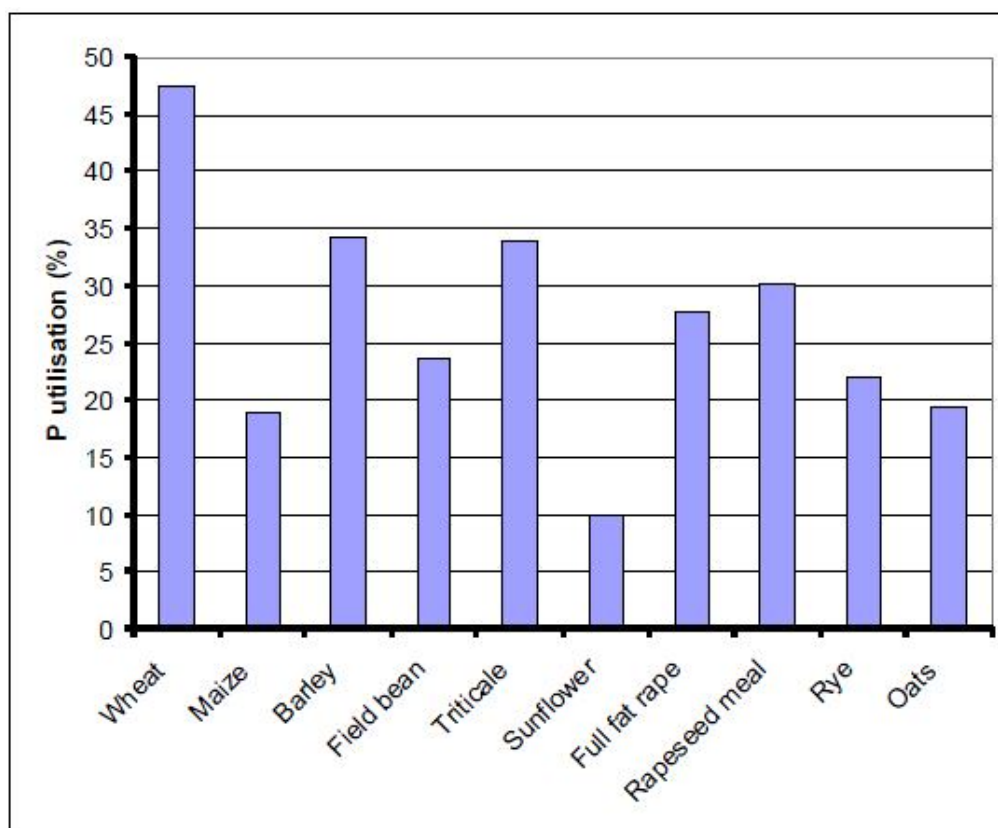
Plant ingredients used to formulate diets for pigs and poultry may contain from 0.7 to 3.5% of phytates (myo-inositol hexakisphosphates) in a form of poorly soluble Ca-Mg, K-Mg, or mono-ferric and zinc salts of phytic acid (Cowieson, 2008; MAENZ, 1999; SELLE, 2007). The digestibility/availability of these salts for monogastrics is very limited, and they will predominantly be excreted. Phytates, therefore, contribute to the phosphorus (Ps) pollution in regions where land and water resources are limited and animal production in tensive like in the Netherlands. The concentration of total and phytate-phosphorus in plant material has been reported by several authors (Eckhout & De Paepe, 1994; Selle et al, 2003; WYSS, 1999) and varies considerably from source to source. For example, the phytate-P concentration of wheat (~0.22%), soybean meal (~0.45%) and rice bran (~1.58%) are quite different and thus will have considerable consequences on the total phytate-P concentration in poultry diets depending on their relative inclusion concentrations. Importantly the total phytate-P concentration may be misleading and it

is the 'reactivity' and 'susceptibility' of the phytate under digestive processes that dictates both the antinutritive effect of the phytate and the phytase response.

Chemical characteristics of phytate

A variable but large proportion of the phosphorus (P) in plant material is in the form of phytate-P (myoinositol hexakis phosphate) (GREINER, 2000; Eeckhout and De Paepe, 1994; Selle et al., 2003). Phytate-P is largely unavailable for utilisation by poultry due to a lack of effective endogenous phytase, the enzyme responsible for the hydrolysis of phytate. Inositol hexaphosphate is extremely electrostatically reactive having 12 dissociable protons with pKa values that range from about 1.5-10. At pH below 1.1, phytate will be neutrally charged and so relatively unreactive. However, between pH 1 and 2 phytate will lose 6 protons, becoming negatively charged and so able to react with basic amino acid residues of dietary protein.

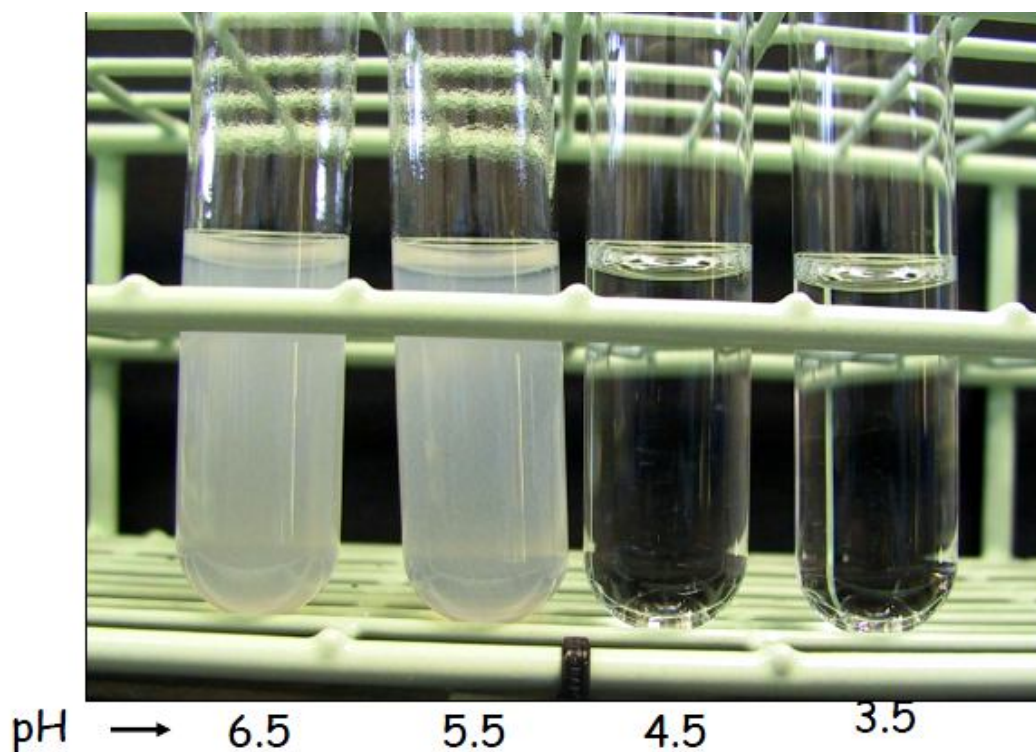
Direct Consequence of Phytate(Oloffs et al, 2000)



In addition to a new appreciation for the effect of phytate and phytase on digestive physiology, a rapidly growing market has attracted a variety of new phytase technologies with various proteolytic and thermal stability and improved kinetics. With increasingly effective phytases available it is more important than ever that the full range of effects are accommodated in diet formulation to ensure that value is optimized and the risk of nutrient imbalances reduced.

Phytate reduces the digestibility of Ca

Diet	Regression of Ca requirement for chicks
Purified (Phytate-free)	0.50%
Corn-SBM-Rice polishings (High phytate)	0.95%
Corn-SBM-Rice polishings (Phytase treated)	<0.62%

Phytate Solubility with Ca⁺⁺**Antinutritive effects of phytate and consequences on digestion**

In dietary ingredients phytate exists as a salt of K and Mg and is relatively unreactive (LONNERDAHL *et al.*, 1999; VAINTRUB, 1991). However, when feed is exposed to the low pH conditions in the proximal gut, phytate becomes soluble as H⁺ ions replace K and Mg (BANKS, 2004). Though protonated, phytate still carries a net negative charge and can react electrostatically with basic amino acid residues in dietary protein. The extent of this reaction depends on the concentration and solubility of phytate, ambient pH, the isoelectric point of the protein, and also its tertiary and quaternary structure (i.e. the degree of steric hindrance between reactive amino acids and phytate).

The effect of microbial phytase on of P (phosphorus)

Since 1990, several experiments with exogenous microbial phytases were reported to quantify their effect on the apparent digestibility/availability of P. A survey of a larger part of these studies has been presented by Zhang et al. (2000). The effect of microbial phytase (NatuphosB) on the apparent digestibility of P was investigated in a dose-response experiment on growing pigs from 20 to 55 kg body weight. Six doses of phytase (from 0 to 2000 FTU.kg⁻¹) were used in two types of grower diets (based either on maize-soybean meal or phytate-rich by-products).

Gastric suitability

Phytases are most active in the gastric region of the intestinal tract, principally as a result of the low pH being favorable for soluble, unchelated phytate (Zhang et al., 1996). This environment is intensely proteolytic, however, and for the phytase to be effective it must be capable of functioning at low pH and resisting hydrolysis by pepsin. The E.coli derived enzymes have been shown to exhibit a pH profile which is marginally superior to that of the Aspergillus and Peniophora phytases, and moreover to be the most stable to pepsin attack.

Thermostability

Most commercially used phytases are not intrinsically thermostable enough to survive the harsh conditions encountered when feed is steam conditioned then pelleted. Three approaches have been employed in order to circumvent this problem; 1) Genetic modification to produce a more thermo tolerant enzyme; 2) Coating the enzyme with a barrier to prevent contact of the enzyme with steam; 3) Spraying the enzyme onto feed after the pelleting process. To date, all of these solutions have limitations. The genetically modified products available are stable enough for most but not all pelleted feeds. The coated products may survive the pelleting process perfectly well, but then the coating incurs a delay in the release of the product and as a result performance per unit of enzyme in the animal is compromised. Post pellet application of a liquid is a good, but costly solution, and the accuracy of application is difficult to ensure on a consistent basis. The main consideration for users is that consistent delivery of enzyme to the animal is essential if the nutrient matrices suggested are to be delivered. Whilst the assay can be used as a direct QC in this regard to uncoated and liquid enzymes, care must be taken to ensure that the assay correlates with the bioefficacy of the product when using coated enzymes. The danger is that in order for the coating to protect the enzyme from the pelleting process, it will inevitably delay the rate of release in the intestine. Given that phytases are limited to the gastric region for their activity, and hence are under a time constraint (clearly implied by the log-linear dose response relationship (Rosen, 2001)), any delay in release will effectively reduce the efficacy of the enzyme. As a result it is quite possible that the analysis of the phytase activity present in the feed bears no relationship to the bioefficacy of the product if a coated product is used (GREINER, 2001).

Factors influencing the response to phytase

There are a multitude of factors which have been shown to influence the response to phytase including Ca levels, Ca: ratio, vit D levels, organic acid presence, interfering metal ions, feeding/lighting programs and many others (Roberson, 2002; Selle & Ravindran, 2007). These have been reviewed elsewhere but the most relevant recent findings which have may play a significant role in mitigating the value of phytases

when applied commercially include Pellet binders, calcium content of drinking water and the use of high levels of zinc along with phytase when diets are heat processed.

Conclusions

The biological effect of phytase is very much dependent on the associated anti-nutritive effect of phytate. Removal of this nutritional obstacle has a substantial impact on the nutritional value of the diet both in terms of mineral bioavailability and energy and protein efficiency. However, there are a variety of factors which influence the scale and consistency of the response to phytase and these should be carefully considered in ration formulation. Substantial economic benefits arise when phytase has been appropriately accommodated in the diets of monogastric animals and the use of phytases, and ancillary enzymes is likely to continue well into the future.

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