WP

NUTRITION

Decreasing the risk of phosp

Because of natural variations in feed materials, there is always a variation in the nutrient content of diets. A safety margin is therefore included. The use of mineral phosphate can be cost-effective in preventing under-supplementation. This can be concluded from a study released by the Inorganic Feed Phosphate group of the European Chemical Industry Council (Cefic).

Phosphorus (P) is a very important mineral in animal nutrition, especially for fast growing animals. An adequate supply of P is essential for optimal animal productivity and health. In addition, the ratio between calcium (Ca) and P, and the presence of vitamin D, are very important. The bioavailability of P, Ca and vitamin D in the diet has to be sufficiently high to achieve healthy growth of the animal. The P and Ca must also be selected from sources that have been shown to have a predictable and reproducible bioavailability. A decreased growth rate and impaired health will result if P intake is below the animals' requirements. P requirements are usually expressed as available or absorbable P.

Phosphorus sources

The largest part of the available P content in poultry diets originates from that found in vegetable (grain) feed materials. *Table 1* gives an overview of selected materials, including the total P content, the content of phytate-bound P and the available P. The possible effect of intrinsic or endogenous phytase is not taken into account in the overview.

Part of the available P in feeds is provided from mineral sources. A variety of inorganic feed phosphates are available on the market, each having a different P content and P digestibility. Since most diets are now formulated based on available P, it is important to know the P digestibility of different feed phosphates (*Table 2*). P digestibility can only be assessed by means of animal trials and, over the years, many experiments.

Phosphorus from phytate

Phytase has been commercially available since the early 1990s. It was originally developed as a tool to help reduce the levels of P excreted in manure into the environment by increasing the digestibility of phytate-bound P for monogastric animals. It is common practice to use one constant value for the amount of available P per unit of phytase (FTU).

Phytase, including commercially available phytase supplements, has the ability to break down inositol-6-phosphate (phytic acid or phytate) into inositol-1-phosphate, via the successive breakdown of inositol-5-, 4-, 3- and 2-phosphate. This means that 83% of the P can, in theory, be released. However, this will only occur under optimal conditions. In reality, the resulting product is a mix of inositol-6-phosphate right through to inositol-1-phosphate.

For an optimal enzymatic reaction, enough phytate substrate needs to be present. The increase in P digestibility by the use of 500 FTU per kg of feed is advised to be equivalent to 1g of mineral phosphate with a P digestibility of 80%. In theory, a minimum of 1/0.83 = 1.2g phytate P (IP) should be present (a maximum of five out of six phytate-bound P can be released when there is an excess of enzyme). In practice, however, the efficiency of the breakdown is less, meaning that the minimum amount of phytate P required to deliver 0.8g digestible P (dP) per kg of diet is not really known. Dutch research shows that the effect of phytase on the release of P is lower when the IP content in the feed decreases.

It should be noted that phytate-bound P content varies both within and across diets, depending on the feed materials used, and that this will have an effect on P release and thus on the dP content. It can be assumed that the content of phytate-bound P is sufficient in most diets for laying hens. However, in concentrated broiler diets, the content of phytate-bound P may be critical (*Table 3*). In these cases, an over-estimation of the effect of phytase may result.

It is also questionable whether P released from phytate is as digestible as P delivered by mineral P sources. Another Dutch trial shows that in practical situations for poultry, the

Table 1 - Level of total P, phytate-bound P and available P in some feed materials

Feed material	Total P (g/kg)	Phytate-bound P (g/kg)	Available P (% total P)
Wheat	3.1	2.0	38
Maize	2.7	1.8	30
Soybean meal	6.5	4.2	42
Sunflower seed (extracted)	11.6	9.3	27
Fish meal	25.6	0.0	74
Rape seed meal	10.9	8.2	33

CVB table, 2004

Table 2 - Range of apparent P digestibility of several mineral feed phosphates

Phosphate source	Total P (g/kg)	Poultry available P (%)
Monosodium phosphate	225	92
Monocalcium phosphate	225 - 229	85
Mono dicalcium phosphate	205 - 219	81 - 83
Dicalcium phosphate dihydrate	182	75 - 80
Dicalcium phosphateanhydrous	175 - 202	55 - 70

ID-DLO, 2001, 1996; Van de Klis & Versteegh 1996

horus under-supplementation

Optimising phosphorus utilisation

Since the development of microbial phytase about 15 years ago, as well as the ban on the use of meat and bone meal, the origin of digestible or available phosphorus can be subdivided as follows:

- From vegetable feedstuffs (and fish meal)
- From mineral sources
- Calculated from phytase.

The use of microbial phytase can result in a significant increase in digestible phosphorus if there is a sufficient amount of phytate (inositol hexaphosphate) present in the feed. There is clearly an effect in normal commercial poultry diets of the content of phytate-bound phosphorus in the diet and the amount of digestible phosphorus that can be released by microbial phytase. In certain feeding situations (e.g. concentrated broiler diets) the amount of phytate-bound phosphorus is often too low to achieve the optimal effect predicted by the phytase matrix value.

The content of microbial phytase and the release of phosphorus is not a linear relation. The current assumption that, in the range of 0 - 500 FTU, all phytase has the same matrix value (digestible P equivalence) is not true. A subdivision of phytase into two or three matrix values (for 0 - 250 FTU; for 250 - 500 FTU; and for >500 FTU) will improve estimation of the digestible/available phosphorus content in the diet and hence prevent under- or over-estimation.

The matrix values for microbial phytases are defined by the producers of the enzyme. These values, however, can only be achieved under optimal conditions (i.e. where the diets contain sufficient levels of phytate-bound P and the content of intrinsic phytase is low). Certainly for diets containing high levels of intrinsic phytase it is clear from the literature that the calculated digestible phosphorus value for phytase is approximately 30 - 35% lower in wheat or barley based diets, which contain high levels of intrinsic phytase.

The risk of under-supplementation of digestible/available phosphorus can be decreased by subdividing the release of P by phytase into two or three steps and by taking into account the content of phytate-bound P in the diet, as well as the level of intrinsic phytase. These strategies will have a minimal effect on the price of the feed.

maximum digestibility of P released was 50%. Therefore, a correction has to be made in the earlier calculation to take into account the presence of the minimum level of IP, resulting in the need for a minimum level of 1.2/0.5 or 2.4g phytate P.

The exact relationship between the minimum phytate-bound P content and the dP liberated by phytase is not precisely known. For endogenous phytase from wheat bran, it is advised that at least 5g phytate-bound P needs to be present to deliver 1g dP.

European legislation governs the amount of phytase allowed in animal feeds. This legislation also expresses the minimum concentration of phytate-bound P that should be present when phytase is used (*Table 3*). It is clear that care should be taken under practical conditions to ensure enough phytate-bound P in the feed to prevent over-estimation of its dP content.

Table 3 - Levels of phytate-bound P (g/kg) in commercial poultry diets (the Netherlands) and the corresponding minimum content according to current EU-legislation

	Phytate P (g/kg) in practical situations	Minimum advised IP content using 500 FTU
Broiler chicks	1.8 - 2.2	2.3
Laying hens	2.3 - 2.6	2.3

Dose-response curves

Most curves predicting enzymatic reactions show a so-called 'lag'; the first units having a strong effect followed by a lesser response for subsequent units (decreasing returns of scale). Common with all enzymes, the relationship between the amount of phytase and the amount of dP released is according to an asymptotic curve. However, for the purposes of feed formulation, it is not easy to work with such a relationship. For reasons of simplicity, formulators using phytase are advised to use one phytase equivalence value for all inclusion rates, assuming that between 0-500/750 FTU there is a linear dose-response relationship. However, as shown by *Figure 1*, the P equivalence in the first part of the enzymatic process is higher than in the second or third parts (based on different literature data). It is, therefore, advisable to work with two or three different equivalence values, depending on the inclusion rate (0 - 250; 250 - 500; 500 - 750 FTU).

Based on reviews for both poultry and pigs, the effect of the first 250 FTU can be set at 60 - 65% of the total matrix value with the effect of the second 250 FTU set at 35 - 40% of the total (*Figure 2*).

Figure 1 - The effect of several levels of phytase on the relative increase in dP content in poultry diets of different compositions

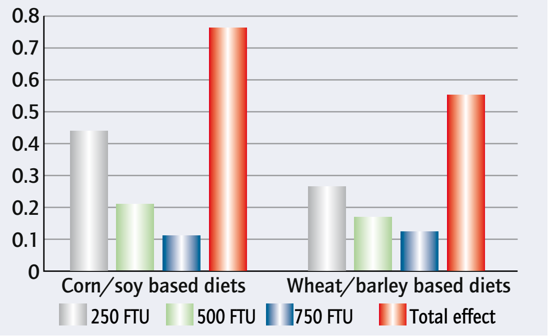


Figure 2 - Relative dP matrix value (%) of microbial phytase by using one value for 500 FTU or by subdividing it into two values

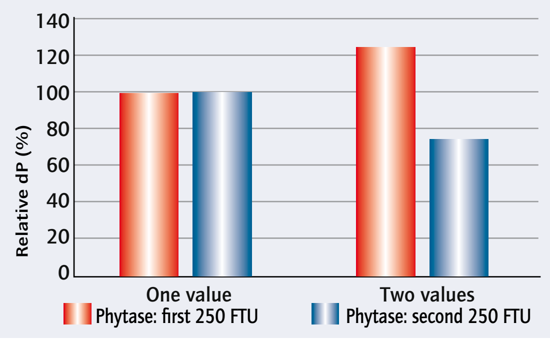
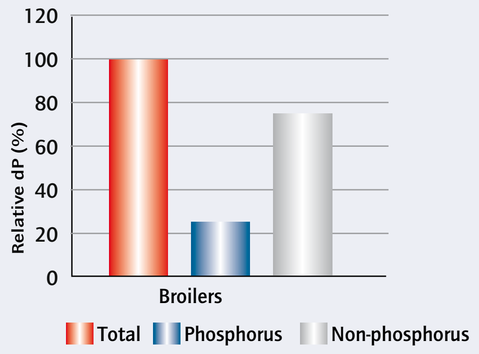


Table 4 - Effect on different dosages of phytase on dP equivalent value (g dP) in three different reviews based on studies with low and high intrinsic phytase activity

Reference	Phytase dosage (FTU/kg diet)				
	250	500		750	
	Total effect	Partial effect	Total effect	Partial effect	Total effect
Diets with low intrinsic phytase					
Düngelshoef and Rodeshutscord, 1995	0.46	0.25	0.71	0.12	0.83
Kornegay, 2001	0.49	0.26	0.75	0.13	0.88
Johansen and Poulsen, 2003	0.44	0.21	0.65	0.11	0.76
Diets with high intrinsic phytase					
Johansen and Poulsen, 2003	0.26	0.17	0.43	0.12	0.55

Working with two or three different P equivalence values for the effectiveness of phytase will therefore assist in preventing any over-estimation of the dP content of the feed.

Figure 3 - Total economic value of phytase (100%), the relative economic p value, and the relative economic value of the non-phosphorus part in poultry diets



Phytase matrix values for digestible phosphorus

As mentioned above, the term phosphorus equivalence value is used to quantify the replacement or substitution value of phytase and is defined as the amount of inorganic P that can be produced by a given amount of phytase.

The value can be calculated from the increase in P digestibility with the use of phytase. It is also called the phytase matrix value, which is used in 'least cost' optimisation models for feed formulation. However, the value of phytase not only depends on the increase in P digestibility. According to several researchers and often advised by phytase producers, phytase also has a secondary nutritional effect. It not only increases P digestibility, but also the digestibility of Ca. It may also result in the improved digestibility of protein (amino acids). Improvements in the digestibility of both Ca and amino acids can be included in the phytase matrix value for 'least cost' optimisations.

Matrix value for poultry

For poultry, an available P value of 0.8g is usually advised (using 500 FTU/kg for broilers and 300 FTU/kg for layers). However, the amount of available P generated by the use of phytase varies widely between experiments, with the amount produced by 500 FTU/kg depending mainly on the feed composition. Based on literature, the effect of 500 FTU/kg can be calculated to be about 0.5 - 0.8g available P in broilers.

The recommended dosage of phytase, as stated earlier, is normally 500 FTU/kg to deliver 0.8g dP for broiler diets. It should be realised, however, that the relationship between units of phytase and liberation of P is not linear, but according to decreasing returns of scale. Because of this, and based on several review studies (*Table 4*), the P equivalence value of phytase can be predicted to be between 0.65 - 0.75g dP at this inclusion rate, clearly less than 0.8g dP. It should also be pointed out that this is only true for diets with low intrinsic or endogenous phytase. For wheat/barley based diets containing high levels of endogenous phytase, the matrix value has to be set some 30 - 35% lower (0.43 - 0.55g dP). ■