High phosphorus cost: What are the options?

There are several strategies with which to reduce exposure to historically high phosphate prices, such as formulating and feeding diets that meet the animal's requirement for phosphorus and utilizing phytase to its maximum economic advantage.

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THE price of feed-grade phosphorus supplements for animal nutrition has increased more than four-fold in the last few years, and further price increases are expected in the future.

The three dominant phosphorus supplements are:

(1) Dicalcium phosphate (22% calcium and 18.5% phosphorus), used prominently in swine and layer diets;

(2) Defluorinated rock phosphate (33% calcium and 18% phosphorus), used prominently in broiler and turkey diets (for pellet quality), and

(3) Mono-dicalcium phosphate (16% calcium and 21% phosphorus), used prominently in ruminant diets and in mineral and vitamin-mineral premixes.

In the U.S., these three products have roughly a 40%, 30% and 30% market share, respectively. Swine and particularly poultry are the biggest users of phosphorus supplements, with poultry accounting for more than 50% of total usage.

The price of feed-grade phosphates closely follows the price of fertilizer phosphates, and the latter have experienced marked price increases, especially in the last year.

Clearly, increased corn production (due importantly to ethanol demand) is a contributing factor on the demand side. Between 2008 and 2010, the U.S. Department of Agriculture predicts that corn prices will remain at around $5/bu. and soybean prices will be above $12/bu. Corn (and also alfalfa) production requires twice the phosphate quantity per acre as soybean (and also wheat) production.

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On the supply side, a lack of economical hydrogen sulfate is an important factor in the price increase of both fertilizer phosphate and feed-grade phosphates for animals.

Sulfuric acid is an indispensable ingredient in the manufacture of phosphate fertilizers, dical and monocal, and its price has skyrocketed nine-fold in the last year (Feedinfo News Service, Jan. 31, 2008). Sulfur (later processed into hydrogen sulfate) is a byproduct of the oil and gas discovery and refining industries, and little new activity in these industries has occurred in recent years. Thus, the shortage of economical sulfur is a prime reason for the lack of supply and, hence, price increase of both feed-grade and fertilizer phosphates.

The significant increases in all dietary inputs — energy, protein, minerals and vitamins — for livestock over the past several months have forced producers to evaluate any and all means of reducing feed costs while maintaining adequate animal growth performance.

Phosphorus is a noteworthy issue. Phosphorus (bioavailable) is required in amounts ranging from 0.60% to 0.25% in poultry diets (broiler chickens, turkeys and laying hens; National Research Council [NRC], 1994) and from 0.55% to 0.15% in pig diets (NRC, 1998). Most commercial-type diets are formulated using cereals and oilseed meals in which the bioavailability of the phosphorus is poor, thus requiring additional phosphorus supplementation.

Historically, inorganic phosphates have met that need cost effectively. Recently, however, the cost of monocalcium phosphate, for example, has increased from approximately $200 per ton just a few years ago to greater than $900 per ton currently, forcing pig and poultry producers to evaluate other options for meeting phosphorus needs and reducing diet costs.

The major source of supplemental phosphorus is inorganic phosphates, i.e., monocalcium, dicalcium and defluorinated phosphates. Their high phosphorus concentration (18-21%) and bioavailability (85-100%) make them sound sources of phosphorus for pigs and poultry. However, other than calcium and iron, these ingredients do not supply other nutrients that are required.

Byproduct ingredients such as meat and bone meal, poultry meal and dried distillers grains with solubles (DDGS) contain higher amounts of bioavailable phosphorus along with protein/amino acids, minerals, vitamins and energy. DDGS, however, has serious amino acid limitations and is also higher in fiber than either corn or soybean meal.

Supplemental phosphorus has been used in monogastric diets due the lack of endogenous phytase enzyme activity in the digestive tract of non-ruminant animals. Much of the phosphorus contained in cereals and oilseed meals is bound in the form of phytic acid, a molecule that is largely indigestible by monogastric animals. Dietary supplementation of microbial phytase can increase the bioavailability of phosphorus from cereals and oilseed meals, thereby reducing the need for inorganic phosphate supplementation.

Commercial phytases have been used in monogastric nutrition for almost 15 years. The first commercially available phytase was produced by the fungus *Aspergillus niger* (Natuphos). Research in pigs fed corn/soybean meal diets has shown that this phytase added to complete diets can release 0.06% phosphorus at inclusion rates of 500 phytase units (FTU) per kilogram of feed (Brana et al., 2006; Cromwell et al., 1995; Harper et al., 1997; Johnston et al., 2004) and up to 0.11% bioavailable phosphorus at 1,000 FTU/kg of feed (Cromwell et al., 1995; Pallauf et al., 1992; Simons et al., 1990).

In broiler chickens fed corn/soybean meal diets, this fungal-derived phytase has been shown to release about 0.05-0.06% phosphorus at 500 FTU/kg (Adedokun et al., 2004; Denbow et al., 1998; Tamim et al., 2004) and 0.07% phosphorus at 1,000 FTU/kg (Augspurger

Utilization of quantitative efficacy estimates of an *E. coli*-derived phytase

Experiment and dietary treatments	Growth rate, (g/d)	Gain:feed, (g/kg)	---Bone measure[1]--- strength (kg)	ash (g)	Phosphorus excretion (g/d)
Fent et al., 2005[2]					
1. Phosphorus adequate	808[a]	377	249.9[a]	9.0[a]	—
2. As 1 to 91 kg, no inorganic phosphorus thereafter	779[b]	374	212.5[b]	8.0[c]	—
3. As 1 minus 0.12% phosphorus + 500 FTU/kg phytase	804[ab]	378	266.5[a]	8.7[ab]	—
4. As 1 minus 0.20-0.10% inorganic phosphorus + phytase[3]	799[ab]	369	250.1[a]	8.4[bc]	—
5. As 1 minus all iP + 1,000 FTU/kg phytase[4]	775[b]	381	243.0[ab]	8.5[bc]	—
Pooled standard error of means	10[6]	3	8.7[7]	0.2[7]	—
Augspurger et al., 2006[5]					
1. Phosphorus-adequate	949	404	—	7.8[a]	6.70[a]
2. As 1 minus 0.13% phosphorus	889	405	—	6.1[c]	3.54[b]
3. As 2 plus 500 FTU/kg phytase	962	411	—	7.5[a]	3.70[b]
4. As 1 minus all inorganic phosphorus + phytase[3,4]	940	417	—	6.9[b]	2.06[c]
Pooled standard error of means	17	4[8]	—	0.1[6]	0.47[7]

[1]Metacarpals taken from four pigs per pen at the end of each trial. Bones were fat-extracted in Fent et al. (2005).
[2]These data represent means of six pens of barrows fed their experimental diets from approximately 12 to125 kg bodyweight.
[3]*E. coli*-derived phytase was supplemented to diets at 1,000 FTU/kg to approximately 50 kg, 500 FTU/kg to approximately 91 kg and 300 FTU/kg to the end of the trial.
[4]In these treatments, phytase supplementation was the only dietary means of meeting the requirement for available phosphorus. Up to 53 kg bodyweight in Fent et al. (2005) and 49 kg bodyweight in Augspurger et al. (2006), it was known that dietary available phosphorus concentrations were deficient relative to required concentrations to maximize bone mineralization (Augspurger et al., 2006; Fent et al., 2005) and growth rate (Fent et al., 2005).
[5]These data represent means of 12 replicate pens of gilts (PIC 337 x C22) fed their experimental diets from approximately 22 to129 kg bodyweight.
[6]Effect of dietary treatment, $P < 0.05$.
[7]Effect of dietary treatment, $P < 0.01$.

et al., 2003; Denbow et al., 1995; Pillai et al., 2006).

A phytase derived from an *Escherichia coli* strain isolated from the gut of pigs has been shown to release significantly greater amounts of phosphorus from diets for monogastric animals. Indeed, additions of 250 FTU/kg of one of these *E. coli*-derived phytases (OptiPhos) to phosphorus-deficient diets fed to pigs resulted in calculated phosphorus-release values of about 0.13% phosphorus (Augspurger et al., 2007c; Fent et al., 2004). At 1,000 FTU/kg, the total release from the diet was calculated to be 0.20% (Augspurger et al., 2004, 2007b; Fent et al., 2004).

Work in broiler chickens has shown similar outcomes, with 250 FTU/kg releasing approximately 0.10% phosphorus (Augspurger and Webel, 2006; Augspurger et al., 2007a; Pillai et al., 2006) and 1,000 FTU/kg releasing approximately 0.20% phosphorus in both broilers and turkey poults (Applegate et al., 2003; Augspurger and Baker, 2004; Augspurger and Webel, 2006; Augspurger et al., 2003; Pillai et al., 2006). With second-cycle laying hens, this *E. coli* phytase at 150 FTU/kg has been shown to totally eliminate the need for supplemental inorganic phosphate (Augspurger et al., 2007c).

The efficacy of 1,000 FTU/kg phytase from an *E. coli*-derived phytase to replace approximately 20 lb. of monocalcium phosphate per ton of complete feed means that pig producers could eliminate dietary supplementation of inorganic phosphate to corn/soybean meal diets beginning in the early finishing period.

Maximum replacement of inorganic phosphate with the phytase maintained growth rates and bone mineralization of growing-finishing pigs relative to those fed diets with supplemental inorganic phosphate (Augspurger et al., 2006; Fent et al., 2005).

In fact, maximum replacement of inorganic phosphate with the enzyme in the work of Augspurger et al. (2006) increased gain:feed ratios (3%) and reduced phosphorus excretion rates by a remarkable margin (69%) relative to inorganic phosphate-supplemented controls (Table). Replacement of 0.20% inorganic phosphate in broiler chickens (hatch to six or seven weeks) by 1,000 FTU/kg of *E. coli*-derived phytase maintained both growth performance and bone mineralization compared to broilers fed diets supplemented with inorganic phosphate in multiple experiments (Pillai et al., 2006).

The option to replace up to 20 lb. of monocalcium phosphate per ton of complete broiler or pig feed offers significant flexibility in diet formulation. Replacing phosphate supplements with an efficacious phytase product in an early finisher diet for pigs could add 8 kcal of metabolizable energy per pound of complete feed. Each scenario offers the opportunity to replace significant amounts of inorganic phosphate, thus reducing diet cost without negatively affecting performance and skeletal health.

In most formulation schemes, the cost of phytase inclusion must be weighed against the value of inorganic phosphate removal, the latter also including the cost of phytase as well as more limestone and corn but less fat in each ton of feed.

Conclusions

Several strategies can be used to reduce exposure to these historically high phosphate prices. Formulate and feed diets that meet the animal's requirement for phosphorus but no higher. Large safety margins cannot be economically justified. Utilize phytase to its maximum economic advantage. Often, *E. coli*-derived phytase up to 1,000 FTU/kg of a complete diet can replace any need for inorganic phosphate.

The high phosphorus concentration of DDGS reduces the need for inorganic phosphate.

Also, phosphorus contained in the phospholipid fractions of fat and in the nucleic acids contained in yeast and other fermentation byproducts is every bit as bioavailable as that in inorganic phosphates.

Finally, when purchasing phosphate supplements, they should be valued on the basis of cost per unit of phosphorus, not cost per unit of product. For the most part, the relative bioavailability of phosphorus (i.e., relative to potassium phosphate) in dical, monocal and defluor is about the same — and is quite high (90-95%).

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