ENVIRONMENTAL ISSUES

The Possibility for Reducing Water Pollution Resulting from Concentrated Animal Feeding Operations and the Impact of Phytase

EXPERT REVIEWED

Oluyinka A. Olukosi
Olayiwola Adeola
Department of Animal Sciences
Purdue University

Introduction

According to a recent US Environmental Protection Agency (EPA) report, the level of phosphorous and nitrate pollution can be high in some areas of Indiana[1]. Water pollution arising from phosphorus in manure that emanates from concentrated animal feeding operations may be responsible for eutrophication of water bodies, poor water taste, and foul odors.

Poultry, swine, and pre-ruminant calves have limited ability to digest phytate, the storage form of about 80% of total phosphorus in plant-based feedstuffs. The resulting excess phosphorus excretion in manure, upon application to farmlands, can leach into and pollute water bodies. Even so, a 1989 report to EPA on the cost-effectiveness of Best Management Practices to reduce non-point phosphorus pollution of water bodies indicates that animal exclusion is not necessarily the most cost effective among the available options. Since 1989, however, the use of phytase in feeds has gained increasing popularity in poultry and swine industries. Phytase, an enzyme that is added to the feed to break down phytate, can reduce phosphorus excretion by up to 60%; decreases in nitrogen excretion from phytase supplementation of feeds have also been reported.

This paper examines how producers, through the use of phytase, may reduce both environmental concerns and the potential effects concentrated animal feeding operations (CAFO) related pollution may have on human health.

Monogastric Animals and Enzymes

Although non-ruminant livestock can utilize a number of plant-based feedstuffs, nutrients from these feedstuffs are never completely digested nor utilized by the animals. All animals produce a host of enzymes (chemical substances that break down complex nutrients into simpler and more usable nutrients) that enable them to utilize nutrients from both plant and animal-based feedstuffs. Some of these enzymes are produced by the animal itself or by resident microorganisms in the intestinal tract of the animal. Non-ruminant animals, in comparison to ruminant animal, have less diversity as well as quantity of microorganisms in their digestive tract.

In particular, non-ruminant animals have limited ability to hydrolyze and use phytate-phosphorus, the form of phosphorous

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commonly found in plants, hence it is largely excreted. In addition, phytate also binds other minerals and protein rendering them refractory to digestion and increasing their excretion. As such, producers must add inorganic phosphorous to non-ruminant diets to fully meet the needs of the animal. In doing so, much of the phytate is excreted in the manure. When using biotechnology procedures, however, it is possible to enhance the utilization of phytate-phosphorus by supplying the animals with phytase produced by microorganisms. Phytase can reduce environmental pollution that may result from CAFO through three principal ways. These are examined in this publication.

Phytase Use Improves Animal Growth

Following adequate nutrient intake, animals grow and give valuable products such as meat, milk, egg, or wool. It is desired that animals use their feed with high efficiency because this will translate into less feed per unit product and less manure per unit feed provided. The efficiency with which animals utilize the feed given to them can be assessed using such measures as growth, feed intake, and gain to feed ratio (this expresses the unit weight gain per unit feed consumed). Generally, higher gain to feed ratio is desired because this translates to consumption of less feed per unit weight gain. Evidence abounds that the use of phytase in pigs, broilers, and layers accelerates weight gain and increases gain to feed ratio. Research has shown[2] that addition of phytase increased weight gain by approximately 19%, feed intake by 9%, and gain to feed ratio by 8% in chickens.

However, it should be noted that the full benefit of phytase supplementation in feed is only realized when animals are given feed that is minimally supplemented with ingredients containing inorganic phosphorus. It is both expensive and unnecessary for animal producers to give their flock a diet that is adequate in phosphorus and still supplement with phytase. In addition, this practice is counter-productive because phytase is added to make more phosphorus available; hence, when phytase use is coupled with further phosphorus supplementation, the quantity of available phosphorus in relation to calcium is increased causing a nutrient imbalance as well as increasing soluble phosphorus in the manure. When demonstrating the proven benefit of phytase supplementation, it is important to stress to animal producers the scenario in which phytase supplementation is beneficial, that is, one in which inorganic phosphorus supplementation is minimized.

Phytase Increases Phosphorus Utilization and Reduces Phosphorus Excretion

A more direct way in which phytase use can reduce environmental concern in swine and poultry operations is by its enhancing phosphorus utilization and reducing phosphorus excretion. Without the use of phytase, the availability of phytate phosphorus in the most commonly used feedstuffs (corn and soybean meal) is very low. Evidence in literature[2,3] suggests that the proportion of phytate phosphorus in total phosphorus excreted by poultry excreta can be as high as 56%. However, supplementing phosphorus-deficient diets with phytase reduces total phosphorus excretion[4,5] by as much as 61%. This is achieved in at least two ways: namely by enhancing digestion and retention of phosphorus as well as by reducing the need for inorganic phosphorus supplementation.

Digestion and retention of phosphorus are both important means by which phosphorus is removed from the feed and incorporated into the animal body for use. In broilers, phytase can degrade more than 38% of dietary phytate. Studies with pigs and poultry using a variety of feed ingredients with phytase supplementation have consistently shown improvement in phosphorus digestion and retention above the level observed in phosphorus-deficient diets but comparable to (and sometimes even higher than) levels observed in phosphorus-adequate diets. Both the total manure excretion and phosphorus content in the manure have been shown to be reduced by phytase supplementation.

In a similar vein, the use of phytase significantly reduces the amount of phosphorus that needs to be supplemented in animal feed in the first place. Young, growing animals have a high requirement for phosphorus to maintain rapid bone and tissue growth and development. Traditionally, the need for phosphorus is met by supplementation with inorganic phosphorus sources. Although highly digestible, these sources are not 100% digested and utilized. The quantity of phosphorus in the manure of animals is directly related to the quantity of inorganic phosphorus that was supplemented. When the level of phosphorus supplementation is reduced, the quantity of phosphorus excreted is proportionally reduced, but supplementing the reduced phosphorus diet with phytase can further reduce phosphorus excretion by additional 30%. Furthermore, evidence suggests that the excretion of both total and water-soluble phosphorus is reduced by phytase supplementation.

Phytase Use and Nitrogen Utilization

Yet a third way in which phytase may reduce environmental pollution is by reducing nitrogen excretion. Although phytase is primarily targeted to phytate, the fact that phytate also binds other nutrients including protein and other digestive enzymes makes phytase an important link in reducing nitrogen excretion. Although, this effect has not been consistently proved, results of several studies show that phytase can reduce nitrogen excretion by up to 40% in pigs and poultry[2]. Reduction in nitrogen excretion may result from improved utilization of protein, and increased digestibility and retention of amino acids. By improving protein and amino acid utilization, there is a reduction in the release of ammonia to the environment. Additional benefits resulting from enhanced nitrogen utilization include improvement in litter quality.

Lessons We Can Learn from Others

It is neither possible nor practical to eliminate animal production because of the essential roles that animals play in our existence. However, it is possible to harness the currently available cutting-edge technologies to enhance animal production and simultaneously reduce environmental impact. The foregoing discussion has highlighted a few ways in which phytase can play a role in this regard.

Currently, phytase has become a mandatory feed additive in many parts of the world and a few states in the United States including Maryland and Virginia. Proven benefits of phytase supplementation demonstrated by improved growth rate of animals, reduced feed requirement per unit of product, significantly reduced need for expensive phosphorus supplement, and reduced negative impact of animal production on the environment will facilitate the use of phytase in non-ruminant animal feeding as a highly-sought-after nutritional practice in concentrated animal feeding operations.

References

1. Little Pine Creek and Indian Watersheds: constructed wetlands system averts agricultural nonpoint source pollution. Environmental Protection Agency, 2007. www.epa.gov/owow/nps/Section319III/IN.htm Downloaded 06/28/2007.
2. Selle PH., Ravindran V. 2007. Microbial phytase in poultry nutrition. *Anim Feed Sci Technol.* 135:1-41.
3. Smith TN, Pesti GM, Bakalli RI, Kilburn J, Edwards, HM. 1998. The use of near-infrared spectroscopy to predict the moisture, nitrogen, total phosphorus, gross energy, and phytate phosphorus content of broiler excreta. *Poult Sci.* 80:314-319.
4. Baxter, CA., Joern, BC., Ragland, D., Sands, JS. and Adeola, O. 2003. *J Environ Qual.* 32:1481-1489.
5. Veum, TL, Bollinger, DW, Buff, CE, and Bedford, MR. 2006. A genetically engineered Escherichia coli phytase improves nutrient utilization, growth performance, and bone strength of young swine fed diets deficient in available phosphorus. *J Anim Sci.* 84:1147–1158.

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