Phosphorus, Phytase, and Poultry Litter

MISSISSIPPI STATE UNIVERSITY EXTENSION

Accumulation of excessive nutrients from poultry litter applied to Mississippi farms may result in a nutrient imbalance that can cause pollution. Using efficient feedstuffs and feeding techniques can significantly reduce the nutrient content of excreted manure and help reduce odors and other gaseous emissions from manure (Sutton and Lander, 2003). Properly managed poultry diets help balance nutrient flows and reduce the potential negative impacts some nutrients may have on the environment. Managing poultry litter and diets will become increasingly important in the future because many states have chosen to address the nutrient flow issue by placing restrictions on land-application of poultry litter to soils considered high in phosphorus.

Phosphorus and Poultry Litter: The Issue

Plant growth depends on an adequate supply of both phosphorus (P) and nitrogen (N) in the soil. However, many crops require only one-third to one-fourth as much P as they do N for optimum yields (Hansen et al., 2005). Because poultry litter contains similar amounts of N and P, the potential to overapply P existed in the past if litter application rates were based on crop N needs. Unfortunately, limiting litter applications to crop P rates means there is a lot of extra poultry litter generated in Mississippi today. In addition, current P restrictions are forcing many producers who had previously used poultry litter for its N to have to purchase additional commercial N fertilizer to meet crop N needs, thereby increasing production costs. Soil type (sand vs. silt vs. clay) may have an impact on nutrient retention properties of soils and, thereby, application rates of poultry litter and commercial fertilizer.

Poultry diets are made up primarily of plant seeds (usually corn and soybeans). Corn and soybean meal comprise as much as 80 percent of poultry diets. However, much of the P is bound in the phytate-phosphorus form and unavailable to the bird. Phytate-phosphorus within a given feedstuff is variable but typically averages 72 percent of the total seed P in corn and 60 percent in soybean meal (Ravindran et al., 1995). Because poultry digestive systems lack the phytase enzyme that breaks down and releases P, **only 10–30 percent of the P in corn and soybean meal is available to poultry** (Sims and Vadas, 1997). Therefore, forms of inorganic P, such as defluorinated phosphate, monocalcium phosphate, and dicalcium phosphate, are often added to the feed to meet dietary requirements. The combination of unavailable P from grain sources and added inorganic P means that much of the total P passes through the birds and ends up in the litter, increasing litter P concentrations (Hansen et al., 2005). As a result, land application of litter over a number of years may contribute to the buildup of P in some Mississippi soils.

Mississippi's poultry industry is vital to the state's economy and to many local agricultural communities across the state. Virtually all of the litter produced by the poultry industry in the state is land-applied as a nutrient source for forage or row crops. However, there is increasing concern that soils with excess P accumulation may lose P via runoff, erosion, and subsurface drainage. If this runoff enters surface waters, it can contribute to eutrophication and associated water quality problems such as algal blooms, fish kills, odors, scums, turbidity, and sedimentation (Sharpley et al., 1994). As a result, there is now considerable interest in developing agricultural management practices to prevent P accumulation in soils and P transport from soil to surface waters in the state.

Enzyme Use in Poultry Nutrition

The primary way to reduce the amount of nutrients excreted is to decrease the amount consumed and improve nutrient absorption (Sutton and Lander, 2003). The quantity of nutrients excreted by animals is affected by three main factors:

1. Amount of dietary nutrients consumed
2. Efficiency with which these nutrients are used by the animal for growth and other functions
3. Amount of normal metabolic losses (endogenous)

In other words, the amount of excreted nutrients can be expressed as:

(nutrients excreted - nutrient intake - nutrients used + endogenous nutrients)

There is increasing interest today in using enzymes, genetically modified feed ingredients, and feed processing technologies to enhance the availability of nutrients so as to meet the specific needs of the bird and reduce nutrient excretion. Enzymes are proteins or protein-based substances that speed up or catalyze chemical reactions (Applegate and Angel, 2004). Phytase enzymes convert phytate-P to inorganic P so that it is more readily available to poultry. Therefore, when diets are formulated with phytases, a certain amount of inorganic P can be removed from the diet (Applegate et al., 2008). Otherwise, the soluble portion of the P in the diet will actually increase as a result of the additional inorganic P not needed by the animal. The amount of inorganic P to be removed from the diet formulation will depend on how much P is being fed over and above the animal's requirement (Applegate et al., 2008).

Phytase is present in microorganisms, plants, and certain animal tissues. Phytase present in the digestive tracts of poultry can potentially come from four sources:

1. Phytase native in digestive secretions
2. Phytase native in feed grains
3. Phytase from bacteria native in poultry or feed grains
4. Phytase produced by microorganisms and added to the feed

The first three phytase sources are negligible in poultry. Therefore, to increase phytate-P availability in poultry feed, the **phytase enzyme must be produced by microorganisms** and added to the feed as a supplement (Sims and Vadas, 1997). For example, inclusion of fungal phytase in poultry diets improved phosphorus retention by broilers from 50 to 60 percent (Kornegay, 1999; Simons et al., 1990). However, efficacy of phytase supplementation depends on numerous factors, including microbial source, form of the enzyme (coated, particle size, and so forth), temperature, pH of the enzyme, diet mineral concentration, ingredients used in the diet, diet manufacturing methodology, form of the diet (pelleted, mash, or liquid), location of addition of phytase (postpelleting or mixer), type and level of vitamin D metabolites, disease status of the animal, and other factors (Ravindran et al., 1995).

Enzymes are unique in that they are highly selective for the molecules they act upon (substrates) and for the end products they produce. For an enzyme to work, it must be in close proximity to the substrate, and the action site must not be blocked (Applegate and Angel, 2004). **Enzymes are proteins and therefore can be denatured or destroyed** by anything that can change their structure. For example, the inability of dietary phytase to survive pelleting and storage temperatures contributes to the low efficacy of phytase application (Slominski, 2011). To counteract these negative temperature effects, postpelleting applications, granulation, and enzyme coating have been proposed. Even then, phytase must maintain functionality in the digestive system of the bird (Loop et al., 2012). Phytase function may be affected by pH of the gastrointestinal tract and gut transit time. This means that the pH activity range of the phytase, relative to broiler physiology, should be an important factor in choosing a commercial phytase, as it will determine to a great extent how well the enzyme works under different physiological conditions and feed nutrient concentrations (Angel, 2006).

It is believed that phytate hydrolysis (decomposition of a chemical compound by reaction with water) takes place mainly in the crop, proventriculus, and gizzard, where the pH is more conducive to phytase action and the phytate is more water-soluble (Selle and Ravindran, 2007). However, in other areas of the gastrointestinal tract, the phytate molecule may actually bind zinc, copper, manganese, iron, magnesium, calcium, and cobalt, among others, in very stable complexes (Angel, 2006). The availability of any nutrient held in these complexes is greatly reduced. In addition, these phytate complexes tend to precipitate at the higher pHs found in the small intestine, and most enzymes have little to no effect on these precipitated complexes (Angel, 2006).

This will likely be an important consideration in the future as more states pay additional attention to the buildup of copper, zinc, and other elements in soils amended with poultry litter (Sims and Vadas, 1997). Fortunately, a reduction in litter P can be achieved without any adverse effects on poultry production, bird health, or carcass quality (Hansen et al., 2005). However, in assessing the efficacy of phytase, Slominski (2011) indicated consideration should be given to the large granule size of some phytase products, which may prevent the substrate phytate from being hydrolyzed effectively in a relatively short period of time in the critical compartments of the upper gut. This could be the result of uneven enzyme/substrate distribution within the feed matrix and subsequently in the digesta, which, in turn, could delay phytate-P release (Slominski, 2011).

Nutrient Balance

As mentioned earlier, without careful attention, one possible source of some "high P" soils could be surplus P applied to fields on poultry farms or other locations, where P inputs (feed, litter) have historically exceeded P outputs (birds, harvested crops and/or forage) (Hansen et al., 2005). Without proper management, the excess P in poultry litter that is land-applied over several years may eventually cause a buildup of soil P. **Nutrient "imbalances" are known to occur where animal production is geographically concentrated** (Beegle et al., 2002; Slaton et al., 2004). This makes achieving a nutrient balance a critically important goal for the long-term, sustainable management of poultry litter in Mississippi. It is important for all producers who use poultry litter on their farms to follow best management practices for litter application regardless of whether or not they raise poultry or where their farm is located within the state.

Better nutrient retention by the bird and continued advances in nutritional programs are important steps toward reaching nutrient balance on individual farms and in Mississippi as a whole. Sutton and Lander (2003) reported dietary considerations that offer the opportunity for reducing nutrient content of poultry litter have several advantages:

1. A smaller land base per animal unit is required for litter application.
2. A greater volume of litter can be applied per acre of land to meet agronomic crop production rates.
3. Reduced N and sulfur excretion may reduce the amount of odor associated with litter application.

As nutrient balances improve, challenges will still remain regarding "high P" soils and how best to manage them. However, use of phosphorus index equations and nutrient management plans can help identify fields with the greatest potential for P runoff. In addition, increased use of best management practices (improved litter application and storage practices, buffer strips, and so forth) will help lessen the threat of P runoff to surface waters.

Summary

To ensure the long-term sustainability of poultry production and environmental quality in Mississippi, disposal of poultry litter must be accomplished in an environmentally sound manner. Phytase is a cost-effective enzyme that improves P use from phytate-P in feed grains and can help decrease P levels in litter. However, the bird consumes considerably more P than it uses, so there is plenty of opportunity for improvement in phytate-P release and increased P retention in poultry flocks. Options such as phytase use and low-phytate feed grain sources can help lessen the amount of P excreted in the litter and reduce the potential for poultry litter to contribute to surface runoff and non-point source pollution of Mississippi's surface water resources.

References

Angel, R. 2006. Broiler Production and the Environment: 2006. R. Angel and W. Powers, Eds. Bulletin EB 368. University of Maryland. Accessed: August 24, 2013.

Applegate, T. J., and R. Angel. 2004. Phytase: Basics of enzyme function. Fact Sheet AS-560-W. Purdue University Cooperative Extension Service, West Lafayette, IN.

Applegate, T. J., B. Richert, and R. Angel. 2008. Phytase and other phosphorus reducing feed ingredients. Fact Sheet AS-581-W. Purdue University Cooperative Extension Service, West Lafayette, IN.

Beegle, D., L. E. Lanyon, and J. T. Sims. 2002. Nutrient balance. p. 171-192. In P. Haygrath and S. Jarvis (ed.) Agriculture, hydrology, and water quality. CAB International, Oxon, UK.

Hansen, D., J. Nelson, G. Binford, T. Sims, and B. Saylor. 2005. Phosphorus in poultry litter: New guidelines from the University of Delaware. College of Agriculture and Natural Resources, University of Delaware, Newark.

Kornegay, E. T. 1999. Application of phytase for retention of nonphosphorus nutrients. Proc. MD Nutr. Conf. 46:83-103.

Loop, S. A., K. G. S. Lilly, L. K. Shires, C. K. Gehring, K. R. Beaman, M. E. Persia, and J. S. Moritz. 2012. The phytase analytical activity of pelleted diets may not adequately describe efficacy in the bird. J. Appl. Poult. Sci. 21:492-501.

Ravindran, V., W. L. Bryden, and E. T. Kornegay. 1995. Phytases: Occurrence, bioavailability, and implications in poultry nutrition. Poult. Avian Biol. Rev. 6:125-143.

Selle, P., and V. Ravindran. 2007. Microbial phytase in poultry nutrition. Anim. Feed Sci. Technol. 135:1-41.

Sharpley, A. N., J. T. Sims, T. C. Daniel., R. Wedepohl, and S. Chapra. 1994. Managing agricultural phosphorus for protection of surface waters: Issues and options. J. Environ. Qual. 23:437-541.

Simons, P. C. M., H. A. J. Versteegh, A. W. Jongbloed, P. A. Kemme, P. Slump, K. D. Bos, M. G. E. Wolters, R. F. Beudeker, and G. J. Verschoor. 1990. Improvement of phosphorus availability by microbial phytase in broilers. Brit. J. Nutr. 64:525-540.

Sims, J. T., and P. A. Vadas. 1997. Use of phytase and low-phytate corn to increase phosphorus availability in poultry feed. Soil Testing Program Fact Sheet ST-10. University of Delaware, Newark, DE. Available at: http://www.udel.edu/DSTP/FactSheets/sto10.htm. Accessed: June 19, 2013.

Slaton, N. A., K. R. Brye, M. B. Daniels, T. C. Daniel, R. J. Norman, and D. M. Miller. 2004. Nutrient input and removal trends for agricultural soils in nine geographic regions in Arkansas. J. Environ. Qual. 33:1601-1615.

Slominski, B. A. 2011. Recent advances in research on enzymes for poultry diets. Poult. Sci. 90:2013-2023.

Sutton, A., and C. H. Lander. 2003. Effects of diet and feeding management on nutrient content of manure. Nutrient Management Technical Note No. 1. USDA. NRCS. October.

Publication 2805 (POD-10-19)

By **Tom Tabler**, PhD, Extension Professor, Poultry Science, **Morgan Farnell**, PhD, former Associate Professor, Poultry Science, **Jessica Wells**, PhD, Associate Clinical/Extension Professor, Poultry Science, and **Haitham Yakout**, Visiting Research Professor, Poultry Science.

MISSISSIPPI STATE UNIVERSITY EXTENSION

Produced by Agricultural Communications.