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Effect of Phytase on Production Parameters and Nutrient Availability in Broilers and Laying Hens: A Review

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Primary Audience: Poultry Farm Managers, Poultry Service Personnel, County Extension Agents, Poultry Scientists, Nutritionists

Summary

An increase in poultry production in recent years has led to greater use of poultry manure as fertilizer, which has, in turn, increased the amount of phosphorus runoff from fields fertilized with poultry manure. Phosphorus excretion in poultry manure can lead to water pollution when the manure is used as fertilizer. The need to maintain sufficient dietary phosphorus levels while reducing phosphorus excretion in poultry manure has led to an increase in the application of phytase to poultry feed in recent years. The use of phytase reduces phosphorus excretion in poultry manure by allowing the birds to utilize more of the phytate phosphorus. Phytate phosphorus has the ability to complex with cations such as calcium, magnesium, zinc, copper, and nitrogen and certain gastrointestinal proteases, thus reducing the availability of these cations and of amino acids. The use of phytase may free these cations and proteases bound in phytate phosphorus complexes and improve many production parameters and body structure characteristics in broilers and laying hens, such as body weight, bone ash content, feed consumption, egg weight, and eggshell quality. An excellent review article on phytase and its various effects on poultry was written by Sebastian et al. [1]. Herein, we examine more recent findings on the effects of phytase on body structure, production parameters, and nutrient digestibility and utilization in broilers and laying hens.

Key words: Body parameters, broilers, layers, phytase, production parameters
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Description of Problem

NUTRITIONAL SIGNIFICANCE OF PHOSPHOROUS IN POULTRY

Phosphorus is an essential mineral in the growth and development of poultry. It plays an important role in metabolism, being a part of many important organic compounds involved in metabolic processes, such as phosphates used for energy, and the synthesis of DNA and RNA [2].

Deficiency in phosphorus can hinder growth in birds and cause the onset of rickets. If the deficiency is severe, birds will lose their appe-

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tites, rapidly become weak, and die [2, 3, 4]. Excess phosphorus in the diet may cause precipitation of calcium in the gut, thus inhibiting its absorption [2, 4, 5].

IMPORTANCE OF THE REDUCTION OF PHOSPHOROUS EXCRETION BY POULTRY

Recently there has been a great deal of emphasis placed on reducing phosphorous in poultry manure. The reason for this emphasis is that runoff from fields fertilized by phosphorus containing poultry manure can cause environmental damage. Approximately two-thirds of the phosphorus found in the feedstuffs of poultry is bound in the form of phytate phosphorous that cannot be fully digested by birds due to the inability of the bird to produce sufficient amounts of phytase [4, 6]. Phytase is an enzyme that cleaves phosphorus from the phytate phosphorus complex, making it available for metabolic use [7, 8, 9]. Because birds are unable to use phytate phosphorus, additional phosphorus must be added to the feed to provide sufficient phosphorus in the diet, which often leads to excess phosphorus excretion in the manure. When poultry manure is used as fertilizer, excess phosphorus may be washed from the fertilized soil and into surface waters causing eutrophication [9, 10, 11, 12, 13]. Eutrophication has been called the primary reason for surface waters to be of poor quality in the United States [14]. The high levels of phosphorus in surface waters increase the growth of algae and bacteria that in turn consume a greater proportion of the oxygen in the water, resulting in the death of many aquatic species through hypoxia of anoxia [15, 16, 17, 18]. Thus, it is extremely desirable to find a method of reducing phosphorus in the manure of poultry without reducing the amount of phosphorus available to the birds.

BROILERS

Use of Phytase: Effects on Body and Production Parameters. Currently, one of the most common methods of reducing phosphorus excretion in poultry is the supplementation of feed with microbial-derived phytase. Nelson et al. [19] first showed that supplementing broiler diets with phytase from *Aspergillus ficcuum* improved phytate phosphorus utilization based on bone ash content. More recently, Zyla et al. [20] found that supplementing broiler feed with phytase significantly increased bone ash content when using 600 and 1,000 phytase units (FTU)/kg and 0.15% nonphytate phosphorus when compared to no phytase supplementation and the same level of available phosphorus. Neither of these phytase levels improved bone ash content when compared to no phytase and 0.45% nonphytate phosphorus. Bone ash content, body weight gain, and tibia length have been shown to be improved by the supplementation of phytase in broiler diets [21, 22, 23, 24, 25]. Body weight gain and bone ash were increased by the supplementation of 600 FTU/kg diet with 0.45% total dietary phosphorus [21]. Bone ash content, body weight, and tibia length have also been found to increase with the addition of 400, 600, and 800 FTU/kg phytase to 0.34%, 0.27%, and 0.20% nonphytate phosphorus diets, respectively [22]. When 600 FTU/kg was supplemented to broiler diets with 0.31% nonphytate phosphorus, feed intake and body weight increased [23]. Azcona et al. also observed an increase in body weight when Natuphos 5000 was supplemented to broiler diets; however, nonphytate phosphorus levels were not reported in the abstract [24]. Qian et al. [25] observed that adding phytase at 300, 600, and 900 FTU/kg increased body weight gain and bone ash content linearly when diets contained 0.27% nonphytate phosphorus. Zanini and Sazzad [26] showed that adding phytase at 500 FTU/kg to broiler diets with 0.40% nonphytate phosphorus produced increased tibia ash. At low (0.225%), but not at high (0.325%), levels of nonphytate phosphorus in the diet, phytase supplementation significantly increased body weight, bone mineral content, bone density, and livability of broilers [27]. It can be concluded that phytase supplementation to broiler feeds tends to increase body weight gain and improve bone structure of birds.

Use of Phytase: Nutrient Retention and Digestibility. Phytate phosphorus has the ability to bind and form complexes with cations necessary in body functions and metabolism. Cations that are bound by phytate phosphorus cannot be properly used by the body. In broilers, the addition of phytase to the diet at 600 FTU/kg feed has been shown to increase retention phosphorus when nonphytate phosphorus is between 0.15

and 0.54% [23, 28, 29]. A study by Broz et al. [30] indicated that phytase supplementation to diets with 0.16% nonphytate phosphorus at the levels of 125, 250, or 500 FTU/kg significantly improved phosphorus utilization. Zanini and Sazzad [26] also found that adding 500 FTU/kg phytase to 0.40% nonphytate phosphorus diets improved phosphorus utilization and reduced phosphorus excretion, which is similar to the finding of Yi et al. [31] when 350, 700, and 1,050 FTU/kg were supplemented to diets with nonphytate phosphorus levels between 0.27 and 0.54%. Other necessary minerals, such as zinc, calcium, and nitrogen, have been shown to have improved retention and utilization with the supplementation of phytase, because they are freed from the complex that phytate phosphorus forms with them. Sebastian et al. [23] have shown that phytase added at 600 FTU/kg to diets with 0.31% nonphytate phosphorus improves calcium and nitrogen retention and phytase levels of 350, 700; and 1,050 FTU/kg indicated the same [31]. Phytase supplemented to broiler diets with 0.40% nonphytate phosphorus at the level of 500 FTU/kg also improves calcium, zinc, and nitrogen utilization [26].

The digestibility of proteins and amino acids may be affected by addition of phytase due to the purported ability of phytate phosphorus to bind certain gut proteases. The addition of 600 FTU/kg phytase to diets with 0.35% nonphytate phosphorus [32] and 1,200 FTU/kg phytase to diets with 0.13% nonphytate phosphorus [33] had no effect on amino acid digestibility. However, Namkung and Leeson [34] and Ravindran et al. [35] found that around 1,200 FTU/kg phytase added to diets with 0.35 and 0.25% nonphytate phosphorus improved amino acid utilization. Improvements in growth and feed conversion were observed by Henidl [36] when up to 750 FTU/kg were added to lysine-deficient broiler diets (nonphytate phosphorus levels of the diets were not given in this abstract). Ravindran et al. [35] also showed that the amount of digestibility of amino acids based on phytase supplementation varied widely depending on the feedstuff used and the amino acid being analyzed. This variation may be one reason for the lack of agreement between these studies.

LAYING HENS

Use of Phytase: Effects on Body and Production Parameters. It has been shown by Van der Klis [37] that body growth, tibia ash, and bone mineral density of laying hens can be positively affected by supplementing their feed with 100, 200, or 300 FTU/kg when the diets contain 0.12% nonphytate phosphorus. Body weight gain and tibia bone ash can be increased by the supplementation of 600 FTU/kg to feed containing 0.10% nonphytate phosphorus [38]. No differences were found when 0.18% nonphytate phosphorus diets with no phytase supplements were compared to 0% nonphytate phosphorus diets and 1,000 FTU/kg phytase [39]. A positive effect on bone mineral density was also observed by Punna and Roland [40] when phytase was added at the level of 300 FTU/kg to diets with 0.1% nonphytate phosphorus levels. No effects on egg weight or egg specific gravity were observed by Carols and Edwards [38] when 600 FTU/kg was added to a 0.1% nonphytate phosphorus layer diet. Urn et al. [41] observed no effect on eggshell strength, egg specific gravity, or eggshell thickness when 250 FTU/kg was added to diets with 0.26, 0.21, and 0.16% nonphytate phosphorus but did find these parameters to be lower when diets with 0.11% nonphytate phosphorus were used. Urn and Paik [42] showed that phytase supplementation could improve feed consumption when phytase was added at 500 FTU/kg to diets with 0.37 and 0.24% nonphytate phosphorus.

Use of Phytase. Nutrient Retention and Digestibility. A study by Leske and Coon [29], using 0.1% nonphytate phosphorus, has shown that the supplementation of layer feed with 300 FTU/kg improved total phosphorus retention. Absorption and retention of phytate phosphorus and calcium can be significantly improved with the addition of 250 FTU/kg of phytase to layer diets containing 0.12% nonphytate phosphorus [37]. Carlos and Edwards [38] found that phytate phosphorus retention was improved with the addition of 600 FTU/kg to layer diets with 0.10% nonphytate phosphorus levels. Retention of calcium, magnesium, and copper was observed to be greater, and excretion of these minerals to be lower, in birds supplemented with 250 FTU/kg phytase when the diets contained 0.16, 0.21, or

0.26% nonphytate phosphorus [41]. Five hundred FTU/kg was supplemented to 0.37 and 0.24% nonphytate phosphorus layer feed by Um and Paik [42] and was found to significantly improve retention of calcium, magnesium, iron, and zinc as well as reduce excretion of these elements. The amount of phosphorus excreted has also been reduced in laying hens with the supplementation of 250 FTU/kg [41] and 500 FTU/kg [42]. Thus, it appears that the supplementation of phytase to their diets has similar positive effects on broilers and layers.

Conclusions and Applications

1. Phytase supplementation reduces phosphorus excretion and improves many bone structure measurements in broilers when nonphytate phosphorus levels are between 0.15 and 0.45%.
2. Zinc, calcium, and nitrogen are better retained and utilized in broilers when phytase is added to the feed at 27 to 54% nonphytate phosphorus as a percentage of total phosphorus.
3. Calcium, magnesium, iron, zinc, and copper are better retained in layers when feed with 0.11 to 0.26% nonphytate phosphorus is supplemented with phytase.
4. Phosphorus excretion is decreased in broilers when phytase is supplemented to diets containing 0.27 to 0.54% nonphytate phosphorus.
5. More research is needed to determine the effects of phytase supplementation on amino acid digestibility.

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