Strategies to Modify Phosphorus (P) in Poultry Manure and Litter

Dietary strategies

Meet but do not exceed bird P requirements. Dietary P originates primarily from plant and animal feedstuffs and from inorganic P supplements. Formulating nutritionists can make considerable impact when they provide enough available P to meet bird requirements yet control the urge to add significant amounts as an extra margin of safety. For example, the National Research Council (NRC) (1994) recommends 250 mg available nonphytate P (nPP) per hen per day, while Leghorn breeder guides advise producers to provide 450 to 460 mg per hen per day early in lay, and 288 to 390 mg late in the hen's cycle. While a small margin of safety is advisable for a commercial flock, the literature supports the NRC recommendation. An experiment evaluating two levels of available P (0.2% and 0.4%), two levels of calcium (Ca), and three levels of phytase for commercial White Leghorn hens was carried out in two phases from 18 to 55 weeks and 55 to 67 weeks (Scott et al. 1999). In the period before 55 weeks of age, the lower level of available P was adequate for maximum production regardless of Ca or phytase levels. Boling et al. (2000) reported similar findings indicating that 0.15% available P supported optimum egg production from 20 to 70 weeks on corn and soybean meal (CSM) diets, while 0.20% maintained body weight and tibia ash equal to higher NRC (0.25%) and breeder recommendations (0.45%). The opportunity to reduce fecal P is quickly realized when a large complex of hens is involved. In a four-week period, 1.2 million hens in a large complex consume 7.4 million lbs of feed (3,696 tons). If dietary available P were reduced from 450 to 250 mg per hen per day, it represents a $4.82 per ton cost savings in dietary dicalcium phosphate totaling $17,814 in feed costs. With such a formulation, fecal P_2O_5 is reduced approximately 35,000 lbs in one month.

Meet but do not exceed bird P requirements.

While a small margin of safety is advisable for a commercial flock, the literature supports the [lower] NRC recommendation [for P].

According to Angel (2000), NRC (1994) broiler recommendations for nPP from hatch to 3 weeks appears to be well supported both under controlled experimental conditions and commercial conditions. However, in the grower and finisher phases, NRC (1994) recommendations for nPP (0.35% and 0.30%) exceed those used successfully in the field and proven to be adequate under experimental conditions. Waldroup (1999) indicated that after 3 to 4 weeks of age the P needs of commercial broilers are greatly reduced and that when birds consume a significant amount of feed there is little need for supplemental P in a typical CSM broiler diet. Similarly, commercial dietary recommendations for finishing turkeys fall between 0.45% and 0.57% available P, while the NRC (1994) recommends 0.28% nPP.

...after 3 to 4 weeks of age the P needs of commercial broilers are greatly reduced... .

Select feed ingredients with readily available P. While strategies for minimizing P levels in manure are numerous, a major impact can be made by selecting ingredients with highly available P. Phytic acid or phytate P (Figure 11-4) found in many cereal grains and plant byproducts is in a form that birds do not absorb well. The P in corn and SBM, for example, has a biological value of only 30 and 25, respectively, and is only 19% and 20% available because of the large phytate P content (Table 11-5). Compared with the P in animal meals and fishmeal, which are almost 100% bioavailable, feeding cereals can contribute to manure P. However, feeding low-phytate grains offers opportunities to reduce fecal P. New highly available P (HAP) corn

Phytic acid or phytate P...found in many cereal grains and plant by-products is in a form that birds do not absorb well.

The P in corn and SBM, for example, has a biological value of only 30 and 25, respectively, and is only 19% and 20% available because of the large phytate P content... .

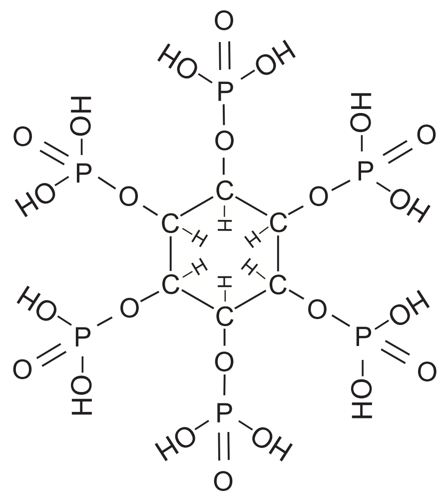

Figure 11-4. Phytic acid.

Table 11-5. Comparative ratings of phosphate supplements and other feedstuffs.

Compound	**Biological Value**
Reference standard:	
Beta-tricalcium phosphate	100
Reagent-grade chemicals:	
Monocalcium phosphate	120-135
Mono-disodium phosphates	115-125
Phosphoric acid	115-125
Dicalcium phosphate	95-100
Phytate P	2-10
Feed-grade phosphates:	
Phosphoric acid	115-125
Mono-diammonium phosphates	115-125
Dicalcium-monocalcium phosphates	105-115
Defluorinated phosphate	95-100
Sodium tripolyphosphate	95-102
Bone meal	90-100
Low-fluorine rock phosphate	55-75
Soft rock phosphate	25-35
Feedstuffs:	
Fishmeal	100
Meat and bone scraps	100
Poultry byproduct meal	100
Dehydrated alfalfa meal	80
Corn gluten meal	35
Yellow corn	30
Soybean oil meal	25

contains the same level of total P as normal varieties, although the level of phytate P in HAP corn is only 35% versus 75% to 80% in other corn varieties (Stillborn 1998). Denbow et al. 1998 showed that SBM with transgenicly inserted phytase enzyme was effective in improving phytate P utilization in poultry.

Calcium added to broiler and laying hen diets as well as Ca bound in dicalcium monocalicum and monocalicum dicalcium phosphates can reduce P utilization and allow passage through bird digestive systems undigested. For example, the P in monocalcium phosphate has a biological value of 120 to 135, while dicalcium phosphate is only 95 to 100 bioavailable when beta tricalcium phosphate was used as the reference standard (Anonymous 1982).

High Ca levels in a layer diet can contribute to poorer phytate breakdown and P absorption by the hen. In a study by Van der Klis et al. (1996), phytate breakdown decreased from 34% on the basal diet with 30g Ca/kg to only 10% on a diet with 40g Ca/kg.

Differences in literature values for P bioavailability can be explained by differences in the response criteria and experimental conditions used for evaluation. However, Waibel et al. (1984) using bone ash in turkey poults found average P availability of 97.1% for seven mon/dicalcium phosphate sources and 90.6% for 20 dicalcium phosphates using a commercial mono/dical as the reference standard. Others have reported improved P availability when higher proportions of moncalcium phosphate are added to the diet (Gillis et al. 1962, Sullivan et al. 1994, and Potshanakorn and Potter 1987).

Use effective vitamin D levels and compounds. Birds with a dietary deficiency of vitamin D do not use P well, and a study from the University of Georgia suggests the active form of vitamin D (found in bird bodies) is even more effective than the precursor form of vitamin D normally supplied in poultry diets (cholecalciferol). Addition of 1,25-dihydroxy vitamin D_3 to the feed reduced broiler phytate P excretion by 35% and improved total P retention by more than 20% (Edwards 1993).

A study reported by Angel (2001) with broilers determined the sparing effect of another vitamin D compound, 25-hydroxy-D_3, and other feed additives on dietary nPP. Dietary phytase, citric acid, and 25-hydroxy-D_3 each independently improved the percentage of tibial ash. However, the sparing effect on tibial ash, body weight gain, and feed-to-gain ratio was highest when all three additives were simultaneously included in the diets.

Use feed additives/enzymes to enhance P availability and retention. Cereal-based diets for poultry can contain a high proportion of P in cereal grains as phytate P. Phytate chelates other minerals, proteins, and starches, making them unavailable to the bird. To improve utilization, phytase enzyme can also be added to the poultry diets of birds that contain high levels of phytate. Workers in the Netherlands demonstrated how phytase enzyme supplementation of layer diets deficient in P could improve hen performance (egg production, body weight, shell weight, and bone strength) equal to that of the supplemented positive control. While the birds on the basal diet and positive control with supplemented P excreted similar levels of phytate P (0.54%-0.62%), the hens fed the phytase enzyme excreted 30% less (0.18%) phytate P. Similar studies have demonstrated that adding dietary phytase improved apparent ileal digestibility of phytate P as well and amino acids in turkey poults when dietary phytase is added (Yi et al. 1996a and b).

High Ca levels in a layer diet can contribute to poorer phytate breakdown and P absorption by the hen.

...improved P availability [is possible] when higher proportions of moncalcium phosphate are added to the diet... .

...Boling et al. (2000) demonstrated a 50% reduction in fecal P in laying hens consuming a low P...diet plus phytase...compared to a normal commercial P level diet.

...Zyla et al. (1996) demonstrated an advantage of enzymatic "cocktails" over phytase alone for...enhanced performance, bone mineralization, and retention of P and Ca in growing turkeys.

Minimizing bird stress is an inclusive goal to reduce P excretions.

More recently, Boling et al. (2000) demonstrated a 50% reduction in fecal P in laying hens consuming a low P (0.10% avP) diet plus phytase (300 U/kg) compared to a normal commercial P level diet (0.45% avP). The authors indicated that the CSM diet with added phytase supported optimal egg production from 20 to 70 weeks of age. Similar studies have demonstrated that adding dietary phytase improves phytate P utilization in broiler chickens (Simmons et al. 1990, Broz et al. 1994). Compared to the NRC (1994) recommended nPP level of 0.45%, Yi et al. (1996b) showed that adding 350, 700, and 1,050 U phytase/kg to a CSM diet with 0.27% nPP reduced fecal P excretions by 30%, 37%, and 41%, respectively.

Studies by Zyla et al. (1996) demonstrated an advantage of enzymatic "cocktails" over phytase alone for dephosphorylating CSM-based feeds for growing turkeys. Dietary treatments included

- NRC (1994) recommended levels of 0.6% avP and 1.2% Ca
- 1,000 U phytase/kg diet with 0.16% avP, 0.84% Ca
- An enzymatic cocktail with 1,000 U phytase/kg, 100 U/g acid phosphatase, 42 U/g acid protease, 2.94% pectinase with 0.16% avP, 0.84% Ca
- 5% fungal mycelium (*Aspergillus niger*) with 0.16% avP and 0.84% Ca
- A positive control diet with 0.42% avP and 0.84% Ca.

One hundred turkey poults were assigned to the dietary treatments from 7 to 21 days of age. Turkey poults fed the enzymatic cocktail from 7 to 21 days of age performed as well as the NRC or positive control diet but retained more dietary P (77%) compared to the NRC or positive control (31% and 42.75%, respectively). Greater retention of Ca was also observed as a result of feeding the enzymatic cocktail (68.15% vs. 45.5% and 49%). Poults fed the mycelium-supplemented diet retained 79% P and 56% Ca, and gained more weight, more efficiently than any other treatment. Compared to the diet containing phytase as the sole supplemental enzyme, both the cocktail and fungal mycelium with phytase and other activities enhanced performance, bone mineralization, and retention of P and Ca in growing turkeys.

Angel (2001) determined the nPP sparing effect of dietary phytase and citric acid on nPP in feed for commercial turkeys in a factorial design. Poults were fed a starter diet that met NRC (1994) recommendations until 8 days of age. Then the birds were fed three levels of phytase (0, 300, and 600 FTU/kg) and four levels of citric acid (0%, 1%, 2%, and 3,%) with a diet low in nPP (0.44%) and Ca (1.20%) Ca. Phytase and citric acid significantly affected gain, feed conversion, feed/gain ratio, and toe and tibia ash. The sparing effect of 600 FTU phytase/kg was 0.0898% nPP. Citric acid was effective only at the 3% level sparing 0.031% nPP. When 600 FTU phytase and 3% citric acid were used together, 0.130% nPP was made available to the poults.

Management strategies

Minimize poultry stress. Minimizing bird stress is an inclusive goal to reduce P excretions. It includes everything from proper brooding and ventilation to the use of vaccines and other medication to improve body weight gain, feed efficiency, and bird uniformity. With greater production on less feed, ultimately less P is excreted into the environment per pound of meat or eggs.

Utilize litter/manure amendments to stabilize soluble P. While manure management can have a significant impact on the N concentration of poultry manure because of the volatile nature of NH3-N, fecal P is relatively stable. However, fecal P can be concentrated with long-term storage because moisture evaporates and composting losses of CO_2 and NH_3 ultimately increase P levels. Fecal P can be stabilized in broiler litter by adding agriculture-grade alum (aluminum sulfate) as a litter amendment. Work by Moore et al. (1994) demonstrated how acid-forming compounds like alum and ferrous sulfate reduced ammonia volatilization and water-soluble P concentrations in litter. Further work by Shreve et al. (1994) showed how litter treated with alum or ferrous sulfate in turn decreases soluble P runoff from fields fertilized with treated litter. Results with alum added to litter are highly dependent on pH (if pH is less than 4.3, soluble P is increased). In another study, gypsum (calcium sulfate) at 50 to 200 g/kg litter had results equal to alum and reduced soluble reactive P to half that of control litter. Litter pH was little changed with gypsum additions, and no effect on NH_3 was reported according to Martin and Zimmerman (2000).

Utilize litter/manure amendments to stabilize soluble P.

Manage feeding equipment. Additional P can come from feed P contaminating the manure or litter. Feeders not properly adjusted for height permit birds to pull feed from the trough or pan. The rule of thumb for floor-reared birds is to adjust feeders to the height of their backs. Similarly, adjust the level of feed in the feeder to prevent wastage. Maintain the feeding system in good working order. Troughs, pans, or hoppers with holes allow feed P to contaminate the manure or litter. Any transfer point in the system that is not properly adjusted can contribute to feed wastage and contaminate the manure litter, e.g., feed tubes to hoppers, hoppers to troughs or pans, etc. Lubricate the system and keep foreign materials out of the feed to prevent jams in the system that spill feed into the litter, e.g., feathers, wood, etc. Lastly, provide enough feeder space per bird at all stages of growth or production. This is especially important when implementing feed restriction programs that result in crowding at the feeder and spilled feed.

[Manage birds and feeding equipment to prevent] feed P [from] contaminating the manure or litter.

Recycle fecal P into livestock feeding systems. In the future, recycling the P that poultry excrete may be a practice with greater acceptance. Workers at Auburn University have shown experimentally that the mineral components in layer manure, when allowed to settle in lagoons, can be reclaimed as a dietary Ca/P source (30% Ca, 0.9% P) and re-fed to hens or other poultry. Diets supplemented with 2.5%, 3.25%, and 4.0% of the reclaimed minerals resulted in egg production, feed consumption, and egg weight equal to hens fed traditional mineral sources (Rao et al. 1992).

In the future, recycling the P that poultry excrete may be a practice with greater acceptance.

Similarly Patterson et al. (1990) recycled a nutrient dense byproduct from the anaerobic digestion of livestock manure. The feed supplement contained 2,199 kcal/kg energy, 20.2% protein, 8.18% Ca, and 2.00% P. When fed to broiler chicks at both 1.5% and 3.0% of the diet, body weight was similar to the birds fed either a commercial or purified control diet.

Fibrowatt Ltd., a company that operates three power plants in the United Kingdom burning poultry litter to generate electricity, also generates a nutrient-rich ash. The ash is currently sold as a N-free fertilizer, although Fibrowatt and other similar litter incineration plants could recycle the K and P rich ash as a mineral supplement for poultry or livestock.

Export manure or litter when total P exceeds capacity. After all dietary and management efforts aimed at P reduction are exhausted, the total P remaining in the litter or manure may still exceed the P requirements of the

[If] the total P...still exceed[s] the P requirements of the crops on your land. ...[it] must be exported... .

crops on your land. At this point, fecal P must be exported from the farm. Hauling fresh manure or litter long distances is rarely practical because of the weight and unstable condition of the product. Rather, deep stack or compost the litter to a stable endpoint, allowing time for N mineralization and odor and moisture reduction. Drying and pelleting are other strategies that reduce litter moisture and modify bulk density to improve the economics of shipping the litter off site. Finally, anaerobic digestion, gasification, or incineration are other means to reduce or eliminate the organic constituents of the litter, leaving an ash composed primarily of Ca and P. The remaining ash can be marketed as a fertilizer or feed supplement for livestock, thereby recycling these nutrients to either plant or animal systems.