Feed Management

A Key Ingredient in Livestock and Poultry Nutrient Management

Phosphorus Requirements for Poultry

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Disclaimer
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USDA United States Department of Agriculture

NRCS Natural Resources Conservation Service

Introduction

This fact sheet has been developed to support the implementation of the Natural Resources Conservation Service Feed Management 592 Practice Standard. The Feed Management 592 Practice Standard was adopted by NRCS in 2003 as another tool to assist with addressing resource concerns on livestock and poultry operations. Feed management can assist with reducing the import of nutrients to the farm and reduce the excretion of nutrients in manure.

Phosphorus (P) is one of the essential minerals for all animals. It plays a critical role in cellular metabolism, as a part of the energy currency of the cell, in cellular regulatory mechanisms, and in bone. Bone is the main storage organ for P containing 85% of the body's total P. Through its involvement in these metabolic and structural processes, P is essential for animals to attain their optimum genetic potential in growth and feed efficiency as well as skeletal development. Because of the key role of P in bone development and mineralization, the requirements of the animal for this mineral are highest during the time the animal is growing.

In diets of non-ruminant animals, such as broilers, the challenge in P nutrition is how to best make available to the animal, the P that is present in the diet. Most poultry diets are primarily composed of plant-based ingredients. In plants, P is present in different forms such as attached to organic molecules like phospholipids and proteins but most is present as part of the phytic acid molecule. Phytic acid P is variably available to poultry (0 to 50%), and in order to meet the meet the P needs of the bird, inorganic P must be added to the diet. The enzyme, phytase, can liberate much of this P. (For further information on phytase and other P reduction strategies, please refer to *Phytase and Other Phosphorus Reducing Feed Ingredients* Factsheet.)

Overfeeding of dietary P is common commercially, with excesses of 20 to 100 % over published requirements commonly observed. Part of this overfeeding is due to the lack of a centralized, up-to-date publication on poultry P requirements. Currently, the last National Research Council nutrient recommendation publication for poultry was published in 1994 and the recommendations for broilers, laying hens, and turkeys based on data published from 1952-1983, 1983-1987, and 1954-1986, respectively. Genetic progress has greatly changed performance of these poultry species since then, so industry nutritionists have limited resources to refer to requirements for their modern poultry strains. Further, variation in nutrient utilization due to health status, as well as nutrient variability within ingredients results in the need for feeding above the minimum P requirement of the bird (i.e. safety margins). (Please also see *Variation in Nutrient Utilization by Poultry and Ingredient Composition* Factsheet.)

When poultry are fed closer to requirements and strategies are implemented to improve phytate-P digestibility, reductions in the amount of P excreted by the bird can be 30 to 40% (Applegate and Angel, unpublished work) depending on how much P is currently being fed. Present commercial poultry strains are more efficient in utilizing nutrients and the present commercial feeds are better formulated to meet the requirements of the rapidly growing bird (Havenstein et al., 1994). For example, nitrogen (N) and P excretion per kg live weight produced was 55 and 69% less, respectively in a 1991 commercial broiler strain versus a 1957 commercial broiler strain when fed the same diet. Considerable variation exists within the literature, however, for utilization of different nutrients. Much of the variation can be attributable to feeding of different ingredients, ages, strains, rearing environment, and/or health status.

Definition of Terms

There exists a great deal of confusion related to the terms used for the different forms of P. Total P (tP) is generally referred to as P and encompasses any and all forms of P. Available P (aP) refers to the P that is absorbed from the diet into the animal (i.e. feed P minus P within the distal ileum). Retained P refers to the P that stays in the body (i.e., feed P minus excreta P).

Available P values have to be determined by conducting animal availability trials that are time consuming and costly. Nutrient requirements of poultry are averages and can have large error factors associated with them. These errors are present, in part, because biological availability is not a static number. Biological availability of P can vary depending on dietary factors such as the level of other nutrients (calcium, vitamin D, micro-minerals, etc.) in the diet, the relationship between the level of other nutrients and P in the diet as well as the type and level of P in the diet. Other factors affecting availability are environment, management, and age as well as sex, strain, and health status of the animal.

As mentioned earlier, most of the P in seed-based plant ingredients is present in the phytin molecule and is referred to as PP. The P that is not bound to the phytin molecule is referred to as non-phytin P (nPP). This nPP can be chemically determined by subtracting analyzed PP from analyzed tP. Typically total P is determined via inductively coupled spectroscopy (ICP) or colormetrically. Diet concentration of PP is much more difficult and can determined through different chromatographic methods. Notably, PP can not be analyzed via NIR. A key difference between aP and nPP is that the term aP includes absorbed inorganic as well as organic P (including PP), whereas the nPP excludes any available PP.

Phosphorus availability for utilization from inorganic and organic sources

Inorganic sources Before going any further, it is important to clarify terms related to P levels and availability in inorganic feed ingredients. Most reports published on the availability of P in inorganic sources use the concept/method of "biological value". Biological value of inorganic sources refers to the relative P availability, relative to a "standardized" P source (typically monosodium phosphate), which is usually given a 100% relative biological value. Often these trials are conducted utilizing a) slope response or b) in vitro solubility in water, acid, or ammonium citrate. "Biological value", however, is often confused with "digestibility" or "availability" of that source. Most of the literature typically utilizes the "biological value" approach for determining the relative "value" of an ingredient, but often does not measure the digestibility of the P source. The few reports that have measured digestibility of P from inorganic sources have noted that they can range from 87% for mono-calcium phosphate to 76% for defluorinated phosphate (Table 1).

Notably, when most of these studies determined apparent retention of P from each of the inorganic sources noted above, the majority of studies were within the deficiency range. As such, Leske and Coon noted dramatic reductions in retention from monocalcium phosphate as the phosphorus concentration approached the requirement (98% at half of the requirement to 59% retention at requirement). Waldroup (2002) noted that nearly 50% of excreted P, therefore, is likely of inorganic origin.

Generally, P must be in the phosphate form to be absorbed by poultry and swine. As phosphates are heated, pyro- and meta- complexes are formed which greatly reduce the availability of inorganic sources. Other factors which substantially affect inorganic P source availability include: hydration of source, particle size (larger size typically increases availability), and contaminants (complexing with elements such as aluminum can reduce availability).

Table 1. Apparent utilization of phosphorus from inorganic sources by broiler chickens as determined under deficiency conditions.

Reference	Inorganic phosphorus source	Apparent phosphorus retention, %
Van der Klis et al., 1994	Mono-calcium phosphate	87
Van der Klis and Versteegh, 1996	Mono-calcium phosphate	84
Van der Klis and Versteegh, 1996	Mono- / dicalcium phosphate	79
Leske and Coon, 2002	Mono- / dicalcium phosphate	77
Leske and Coon, 2002	Mono- / dicalcium phosphate	80
Leske and Coon, 2002	Mono- / dicalcium phosphate	81
Coon et al., 2007[1]	Dicalcium phosphate	83
Coon et al., 2007[1]	Defluorinated phosphate	86
Coon et al., 2007[1]	Defluorinated phosphate	76

[1]Retainable P determined through broken line slope response.

Organic Sources

Phytin-P content in grains can be highly variable (Table 2). Factors influencing this variability are still unknown, but soil and environmental factors may affect this content (Cossa *et al*., 1997, Raboy and Dickinson, 1993). Raboy and Dickinson (1993) reported that the magnitude of the effect of soil P on soybean seed phytic acid was variety specific. Regardless of variety they found that phytic acid content increased as soil P availability increased. Non-phytic acid P levels in the seed, however, did not change. There is also limited information on potential variability in the availability of PP within an ingredient and on how diet manufacturing process may affect this availability. Variability in PP content in grains and relative bioavailability and digestibility from inorganic P sources has led to substantial safety margins in commercial diet formulation. For all practical purposes, these over-formulations may have the greatest influence on total and soluble P content of in excreta and litter.

Broilers - Phosphorus requirement

The NRC (1994) nPP recommendations for broilers are based on peer-reviewed research published between 1952 and 1983 (Table 3). But, the present commercial bird is very different from commercial birds available prior to 1983, due in part to genetic selection as well as management practice changes and feed related changes (Havenstein *et al*., Numerous studies have recently been conducted to determine P requirement for young broilers up to three-wk of age when phytase was added to the diet. Limited research has been done to determine the P requirement in the finisher and withdrawal phases either with or without phytase. The most recent information on the P requirement of broilers is presented in Table 4.
1994; Williams *et al*., 2000)

Table 2. Phytin-phosphorus (PP) content of feed ingredients as a percent of total phosphorus (TP) (data per Nelson et al., 1968; Cossa et al., 1997, and Barrier-Guillot et al., 1996a).

Ingredient		Number of Samples	PP, % (SD)	PP (% of TP)
Soy beans	*G max*	24	0.41 (0.22)	69.5
	G soja	24	0.56 (0.18)	72.7
SBM (50% protein)		20	0.37 (0.03)	71
SBM (44% protein)		3	0.38	58
Corn		10	0.17 (0.02)	66
Corn		54	0.27 (0.24)	86
Corn Gluten Meal		1	0.36	62
Milo		11	0.21 (0.03)	68
Wheat		56	0.218 (.035)	60
Wheat		2	0.18	67
Wheat Middlings		1	0.35	74

One of the important factors to be kept in mind while determining requirements for different phases is the carry-over effect of previous nutrition. When the bird is fed a sufficient amount of P and Ca during the starter, grower and finisher phases, the removal of any added nPP and Ca in the withdrawal phase, will not affect the performance of the bird (Skinner *et al*., 1992a and b; Angel *et al*., 2000a), but can have effects on bone integrity and well-being of the bird. When the bird is fed sufficient P during earlier phases and less than the P required, in the later phases, then P from bone will be used to meet the other P needs of the body.

The degree and length of mineral deficiency is important as both of these determine the structural integrity of bone. The question remains to be answered as to what level of bone integrity is needed such that no changes in processing plant downgrades versus current levels are observed. If bone integrity is compromised by feeding low levels of dietary nPP, then processing losses related to breakage of femurs, broken drumsticks, cartilage separation associated with the rib cage, blood splash of meats and fractures could increase (Moran and Todd, 1994; Chen and Moran, 1995).

Table 3. NRC (1994) requirement for non-phytate phosphorus (nPP) for broilers.

	Weeks of age		
	0-3	3-6	6-8
nPP req., %	0.45	0.35	0.30

Table 4. Recent research on phosphorus requirements in broilers

Reference	Age (wk)	Ca[1], %	P[2], %	nPP[3], %	aP[4],%	Criteria	Strain	Sex
Skinner *et al*., 1992b	42-56 d	0.80	0.50	0.12-0.24	NS[a]	Tibia breaking strength	Cobb 500	Male
Moran and Todd, 1994	0-3 3-6 6-7	1.00 0.90 0.80	0.68 0.62 0.56	NS	0.45 0.40 0.35	Growth, bone ash, processing losses	Ross x Arbor acres	Male
Chen and Moran, 1995	0-3 3-6 6-7	1.05 0.87 0.71	0.68 0.63 0.57	NS	NS	Growth, bone ash, processing losses	Ross	Male
Rao *et al*., 1999	3-30 d	1	NS	0.44	NS	Growth	- - -	Male
Waldroup *et al*., 2000	0-3	1	0.57 0.43 0.64	0.32 0.18 0.39	NS	Body weight Feed efficiency Percent tibia ash	Cobb 500	Male
Angel et al., 2000a	18-32 d 32-42 d 42-49 d	0.80 0.70 0.61	0.37	0.32-0.28 0.24-0.19 0.11	NS	Body weight and femur/tibia ash and breaking strength	Ross 308	Male
Angel et al., 2000b	0-17 d 17-31 d	0.91 0.81		0.45-.037 0.31-0.26	NS	Tibia/femur ash/strength Growth, tibia/femur ash	Ross 308	Male
Ling *et al*., 2000	18-29 d 29-39 d 39-47 d	0.80 0.71 0.61	0.59	0.32 0.26-0.18 0.19-0.14	NS	Body weight and Femur/tibia ash and breaking strength	Ross 308	Male
Dhandu and Angel, 2003	32-42 d 42-49 d	0.69 0.72	0.48 0.43	0.21 0.166	NS	Tibia ash	Ross 308	Male
Yan *et al*., 2001	3-6	0.90	0.43 0.40 0.33	0.19 0.16 0.09	NS	Weight gain Feed efficiency Percent tibia ash	Cobb 500	Male

[1] Calcium, [2] Phosphorus (P), [3] Non-phytate P, [4] Available P [5] Phytate P. [*] Weight in grams at the end of the age phase. [a] Not specified

Laying Hen Phosphorus requriements

Of all the poultry species, the laying hen industry feeds typically much more P relative to the requirement, largely because of concerns of inadequate mineralization of egg shells and skeletal abnormalities resulting in poor egg production, morbidity, and mortality. Due to previous selection of certain laying hens strains for early maturation and increased egg size, hens are, therefore, typically fed 350 to 450 mg of nPP/hen/day what recent research considers to be nearly twice what is required (Table 5).

As mentioned previously, valid industry concerns are variation in diet intake and variation in ingredient P content exist. Assuming the cost of dicalcium phosphate of $370 a ton, producers could save $1489 per year per 100,000 hens on dicalcium phosphate for every 100 mg/hen/day reduction in hen nPP intake.

Table 5. Recent research on non-phytate phosphorus (nPP) requirements in laying hens

Reference	Without phytase (mg/hen/day)	With phytase (mg/bird/day)
NRC, 1994	250	- - -
Van der Klis et al., 1997	165	130
Gordon and Roland, 1997	164	83
Boling et al., 2000a	159	108
Boling et al., 2000b	155	104
Keshavarz, 2003	- - -	204

Turkey Phosphorus Requirements

Despite the NRC (1994) recommendations being based on turkey experiments from 1954 to 1986. They appear to be consistent with the current needs of the turkey (Roberson et al., 2000; Roberson and Fulton, 2000; Thompson et al. 2002). The current NRC (1994) recommendations for turkeys are listed in Table 6.

As mentioned with the other specie, valid concerns of the industry for variation in diet intake, intestinal health affecting nutrient digestibility and absorption, and variation in ingredient P content exist. The turkey industry also has long standing problems with skeletal integrity. Currently, this issue is at the forefront as femur breakage is occurring during the latter phases of turkey tom production (15 + weeks of age).

Table 6. NRC (1994) requirement for non-phytate phosphorus (nPP) for turkeys.

	Weeks of age					
	0-3	3-6	6-9	9-12	12-15	15-18
nPP req., %	0.6	0.5	0.42	0.38	0.32	0.28

Summary

When poultry are fed closer to requirements and strategies are implemented to improve phytate-P digestibility, reductions in the amount of P excreted by the bird can be 30 to 40% depending on how much P is currently being fed. The poultry industry, however, currently utilizes substantial safety margins for formulation of P, due largely in part to uncertainty of nutrient requirements and ingredient P variability. Dietary mass reduction of P eaten and improvement in phytate-P utilization, therefore, can have dramatic impacts on the amount of P excreted.

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Project Information

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