WIN²ME
Western Integrated Nutrition and Nutrient Management
Feed Management Education for the Agri-Professional

102 - PHOSPHORUS REQUIREMENTS OF DIFFERENT SPECIES, PHYTASE FEEDING, AND RATION FORMULATION

- by Ron Kincaid, Washington State University

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Introduction

As a nutritionally essential mineral, phosphorus (**P**) is required for the maintenance and growth of all plants and animals. Phosphorus is an integral component of DNA and RNA, accordingly, growth and reproduction of plants and animals require P. Capturing energy from our food is done by forming high-energy P bonds (ATP & ADP) that release energy as needed. Thus, synthesis of proteins and most other compounds necessary for life require P. However, we associate P with bone and about 85% of the P in the body is contained in our bones, about 14% in soft tissues and muscles, and only 1% in the blood.

“……..accordingly, growth and reproduction of plants and animals require phosphorus……..”.

Cattle also need P to support billions of bacteria and other micro-organisms that thrive within the rumen. These bacteria are needed for pregastric digestion of fiber in cattle. Replication and growth of the bacteria are dependent upon a P supply. Ruminants (cattle, sheep and goats) are unique in that they recycle P back to the rumen via salivary secretions instead of excreting the endogenous P via urine. Salivary P is a major P source for ruminal microbes. The total P content of rumen micro-organisms ranges from 2 to 6% of dry mass (Durand and Kawashima, 1980).

Fortunately, these micro-organisms eventually enter the small intestinal tract where their DNA and RNA are degraded, releasing much of the P to be absorbed across the intestinal tract to supply P to the body of the cow. However, P of microbial origin accounts for roughly two-thirds of P that is inevitably lost in the feces of ruminants (Rodehutscord et al., 2000).

Consequences of inadequate phosphorus intake by animals

Because P is required for many functions, there are many signs of P deficiency in animals. The most frequently observed signs include osteomalacia (deficient calcification of bones; rickets), anorexia, reduced performance (growth, milk yield or egg production) and pica (an appetite for substances not fit as food). Additional signs include lethary, muscle weakness, seizures, erythrocyte deformity, and hemolysis. In addition, animals severely deficient in P have more broken bones and increased death losses due to consuming bones (an example of pica) contaminated with *Clostridium botulinun* (Patterson, 2002)

Variation in phosphorus requirement as a function of the life cycle

Phosphorus constantly is lost from the body (endogenous losses) during normal metabolism and must be replaced. Additional P is needed to support functions associated with growth, gestation, and lactation. Accordingly, P requirements are greatest for those animals that are growing rapidly, lactating, or laying eggs. For growth, 3.9 g of P is needed for each 100 g of protein gain (NRC, 1996). Milk contains about 0.09% P (i.e., a gallon of milk contains 3.43 g of P), and an egg contains about 86 milligrams of P. Therefore, the greater the performance of animals, the higher is the dietary P requirement.

Factors affecting phosphorus requirement

Poultry and pigs cannot absorb 60 to 70% of the P in feed grains because the P is present as phytate (hexa-inositol-phosphate; and animals do not secrete sufficient intestinal phytases (the enzymes that breakdown phytates) that are needed to free the P bound to inositol. Thus, much of the feed phosphates used in the U.S. has been to supply inorganic P to poultry and swine. In recent years, phytases have become available commercially and their addition to diets reduces the need for inorganic P supplements because more of the phytate-P in grains is made available for absorption. In general, the addition of 600 phytase units/kg of diet supplies about 0.09% available P in dry matter. Whereas this may seem small, it represents over 25% of the P needs for most animals. Hence, phytases added to diets of pigs and chicks allow P intakes to be reduced about 25% with corresponding decreases in P excretion.

Phosphorus absorption across the intestinal wall is greater for inorganic sources of P (such as dicalcium phosphate and sodium tripolyphosphate) than for P contained in grains and forages. Therefore, P contents in feeds and dietary P requirements of animals are expressed as both total P and available P. Available P represents the amount of dietary P that can be absorbed across the intestinal wall whereas total P is all the P in the diet, regardless of the chemical form. Although available P

most accurately expresses the P needs of the animal, total consumed P is highly correlated to the amount of P that is excreted by the animal.

Phosphorus excretion by livestock

About 160 million tons of animal manures are produced annually in the United States (Council for Agricultural Science and Technology, 1995). This represents a tremendous amount of nutrients available to plants. However, without proper handling, this quantity of nutrients is a potential pollutant. The nutrients in manure include nutrients that were not absorbed, nutrients that were absorbed but not used, and endogenous nutrient losses associated with normal metabolism. Waste feed and discarded bedding materials also enter lagoons and manure solids piles.

The amount of nutrients present in animal excreta can be expressed as pounds/year/animal or as a concentration of the total excreta. Both expressions have particular applications. In addition, the concentrations can be given on an *as-is* basis or a *DM* basis. When given on an *as-is* basis, the water content is a major factor influencing the concentration. In addition, the amount of bedding and waste feed that are included with the excreta affect the concentration of a nutrient. Listed below are tables that provide comparative differences in concentrations of P in various animal manures and lagoons. In some cases, the effect of animal age is included.

A. Poultry

In addition to waste feed, poultry manure includes feathers and urine, which is voided with the feces.

Concentrations of phosphorus and nitrogen in poultry litter obtained from a Washington poultry operation

Animal Description	% P, *DM Basis*	% N, *DM Basis*
Starter chicks	2.3	6.37
Pullets, growers	2.6	7.74
Pullets, 17-40 wk	3.4	2.93
Post-Molt	3.2	3.31

B. Swine

An estimated 3.3 lb of P is excreted in the manure of a pig from farrow through finish. The % P in the manure and lagoons varies with the age of the pigs, and the amount of bedding material and waste feed that also enters the lagoon.

Concentrations of phosphorus and nitrogen in swine manure

Animal Description	%P, *DM Basis*	%N, *DM Basis*
Nursery pigs[1]	1.5	4.02
Growers[1]	2.45	4.26
Finishers[1]	1.6	3.90
Hoop barn manure[2,3]	0.76	0.87

[1]Fecal samples collected at the WSU Swine Center

[2]The manure samples contained straw as the bedding source. Samples were taken from manure piles stored outside.

[3]DeRouchey et al., 2002.

*Significant effect of season; least in December (1.64% P) and greatest in June (2.39% P).

Concentrations of phosphorus in swine lagoons

Animal Description	% P*, *DM Basis*	% P*, *As-Is Basis*
Nursery pigs[3]	1.86	0.0223
Wean-to-finish[3]	2.32	0.0302
Finish[3]	1.89	0.0246
Farrow-to-finish[3]	1.76	0.0106
Sow[3]	2.82	0.0141

[1]Fecal samples collected at the WSU Swine Center
[2]The manure samples contained straw as the bedding source. Samples were taken from manure piles stored outside.
[3]DeRouchey et al., 2002.
*Significant effect of season; least in December (1.64% P) and greatest in June (2.39% P).

C. Horses

Apparent absorption (intake *minus* fecal loss) of P in mature horses fed at maintenance is only 10% or less (Crozier et al., 1997) because at maintenance, the horse only needs to replace lost endogenous P. Phosphorus need and absorption are much higher in young growing horses and lactating mares. Although P in manure is about 0.6% P or less (DM basis), P concentrations in manure piles are lower because of discarded bedding materials.

D. Dairy Cattle

A dairy cow excretes from 40 to 69 pounds of P per year. Phosphorus excretion is largely a function of P intake and most P excreted by cattle is voided in the feces. Because P losses in urine are fairly negligible (< 1 gram/day/cow) the concentration of P in manure solids and lagoons is mostly affected by a combination of dietary P intake and the amount of bedding material and waste feedstuffs that have entered the manure stream. In a survey of dairy manure solids in WA, the concentration of P in manure of dairy cattle ranged from 0.5% to 1.5% *DM basis*. Approximately 90% of P is associated with the total solids portion of manure and 10% is dissolved in the liquid portion, however, manure separators only recover a portion of the total solids because most solids are suspended in the liquid. The dietary need for P increases with growth, pregnancy, and milk production, however, milk production is the largest single factor. Milk contains 0.09% P, thus, daily secretion of P in milk can be calculated (in grams per day) by multiplying total daily milk secretion (in kg) by 0.9.

E. Beef Cattle

On average, brood beef cows have a low % P in their manure because they typically are fed forage diets containing relatively low concentrations of P. We found the manure of cows at the WSU Beef Center contained 0.42% P, which is less than the normal values found for dairy cattle.

F. Feedlot Cattle

Because cattle typically are fed finishing rations in feedlots for varying lengths of time (perhaps 120 days) then marketed, P excretion can be expressed several ways. First, as the amount excreted by a particular finishing steer over the fattening period or extrapolated to a full year, assuming the steer is replaced by another steer. For example, a feedlot that keeps their finishing pens filled for 350 days per year would have P excretions between 22 and 30 lb of P per head. Feedlot cattle generally are overfed P because most feedstuffs, such

as corn, barley, and protein supplements, in their rations contain fairly high concentrations of P, and feedlot cattle often retain only 12 to 18% of P consumed. At the WSU feedlot, manure samples obtained contained 0.81% P

Ration formulation

Rations are formulated to first meet energy and protein requirements, then minerals and vitamins are added to meet or exceed minimum requirements of the animal. This makes economic sense because energy and protein are the most costly components of the diet. Feed additives, such as exogenous phytases, can be easily formulated into rations because they reduce the need for supplemental P. Thus, the savings from adding less P supplement help offset the costs of the enzymes. Because many byproducts are cheaply priced relative to their energy and protein contents, to reduce the % P in many ruminant diets will require at least partial replacement of some byproduct feeds with more expensive sources of energy and protein.

Reasons that phosphorus is often overfed

Many feeds, particularly byproduct feeds, contain fairly high concentrations of P. For example, the % P (DM basis) of some byproduct feedstuffs are: corn gluten feed, 0.82%; distillers' grains, 1.07%; wheat millrun, 1.13%; and canola meal, 1.22%. Thus, diets that include appreciable amounts of wheat byproducts, canola meal, or corn byproducts often exceed recommended requirements for P. At present there are economic challenges to formulating rations, especially for dairy and feedlot cattle, that minimize P intakes so that P excretion will be minimized.

Ways to reduce phosphorus content of diets

1. When possible, do not exceed NRC requirements for P. This means using several different rations within a production unit. In swine and poultry production, phase feeding is practiced whereby pigs and chicks are fed different diet formulations as they grow. The reason is primarily economic, i.e., the most economical feeding program is one that most closely matches the nutrient intakes and needs of the animals. Fortunately, this matching of dietary P provision to requirements also minimizes nutrient excretion. Grouping animals by age or productivity is routinely practiced on large livestock operations, and grouping reduces overfeeding of nutrients.
2. Utilize phytases appropriately in diets of nonruminants. A combination of reformulating diets and adding phytases can reduce excretion of P by 25 to 40% for pigs and poultry.

Conclusion

About 80% of the phosphate use worldwide is as agricultural fertilizer, about 12% as detergent, and about 5% in animal feeds (Patterson, 2002). However, livestock manures must be managed carefully to avoid surface water contamination. By use of exogenous phytases, refining our estimates of P requirements of animals, and reducing supplemental P to a minimum, progress has been made in reducing the amount of P in livestock excreta. Future work on P in livestock production may focus more on recovery of P from lagoon slurry and manure solids.

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