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Consistent Requirements for Precision Nutrient Feeding of Broilers

Environmental stewardship concepts and new regulations are steering current research to learn more about phosphorus (P) nutrition in broilers. Published research to date is inconsistent and varying methodologies do not allow for establishing P requirement concentrations for each of the different growth phases for different breeds and for different management systems. Dr. C. Roselina Angel from the University of Maryland presented a summary of current research and suggestions for establishing consistent requirements. Research has focused on phytase use and the actual requirements for calcium (Ca) and P has not been clearly determined in those recent studies. The phosphorus requirements are not clear for females or straight run birds, and even with males, data is inconclusive. This lack of data in publications is because data is missing or inconsistently reported between the studies.

Definition of Terms

Total P (P) encompasses all forms of phosphorus.

Available P (aP) is P that is absorbed from the diet into the animal (i.e., feed P minus P in the distal ileum). Determining aP is done in animal trials, is time consuming and costly. It is also influenced by many different factors. Most ingredient P availabilities used in most formulation systems or in tables are averages and based on limited numbers of availability values. Errors associated with availability values are present because biological availability is not a static value. The value changes depending on dietary factors. This includes concentration of other nutrients in the diet; physiological, health and management factors; choice of dietary ingredients and the availability of nutrients in those ingredients, the ratio between the concentration of other nutrients and P; and the type and concentration P in the diet.

Digestible P is feed P minus ileal content P, as established by a marker determination system.

Relative available P (Relative aP) sets a standard of 100 in a P containing product and then compares other P products in relation to the determined standard. Relative aP is often used interchangeably with aP. This standard compares specific products, but does not determine absolute P values that are digestible and absorbed by animals.

Retained P (rP) is P that stays in the body, (i.e., feed P minus excreta P).

Inorganic P (iP) is any phosphorus not bound to an organic molecule.

Continued on p. 2

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Phytate, is the anion form for *phytic acid* (IP6) and is found in this form in all plants. The acid is *myo*-inositol 1,2,3,4,5,6-hexakis dihydrogen phosphate and is an organic phosphate, phosphorylated cyclic sugar alcohol. Phytate is present as a complex salt of Ca, Mg, and K. In some instances, phytate is bound to proteins and starches. In this form the chelated (bound) molecule is known as phytin (O'Dell and de Boland, 1976; Cheryan, 1980; Lott, 1985; Graf, 1986).

Phytate P (PP) is organic P, specifically it's P that is part of a six carbon ring structure (phytic acid), found primarily in seeds in its chelated form.

Non-phytate P (nPP) is total P minus PP or the P in the feed or ingredient that is not bound in the phytic acid molecule. Non-PP is chemically determined by subtracting analyzed PP from analyzed P. Readers should note not all nPP is available. Non-PP excludes potentially available PP and includes any potentially unavailable iP. For reference, aP includes absorbed inorganic and organic P (including PP).

Developing an appropriate methodology to be consistently used across labs will be time consuming for determining digestible Ca and P values for ingredients. It will have to include enough samples to provide an average availability, as well as provide the minimum and maximum values and a coefficient of variability or a standard deviation by each ingredient. The recent efforts to reduce P concentrations in animal diets (due to environmental concerns) and more common use of phytase in diets has resulted in the ability to formulate diets closer to nutrient requirements. However, these diets are still based on the concept of total Ca to either aP or nPP. Going forward, Ca and P requirements and formulation matrixes will need to consider digestible Ca and P values. The matrix values to be used will assume available P and Ca are the same for broilers, laying hens and turkeys. To support the assumption between stages, more research is needed. The additional research will validate the assumption that digestibility matrixes can be used interchangeably.

In looking at the NRC ingredient P concentrations and P recommendations, there is an interesting comparison between the 1994 and 1984 edition. The 1994 NRC concentrations and recommendations are similar to those published in the 1984 NRC, and the references used to determine these values overlap. The 1994 values are based mostly on research done utilizing book values of aP for different feed ingredients. The 1984 NRC give the P values as aP and the 1994 NRC lists the values as nPP. This makes it apparent that NRC (1994) used aP and nPP interchangeably. As defined earlier, aP and nPP are not equal, yet from a practical standpoint, aP and nPP concentrations are the most commonly used with ingredients in the US today.

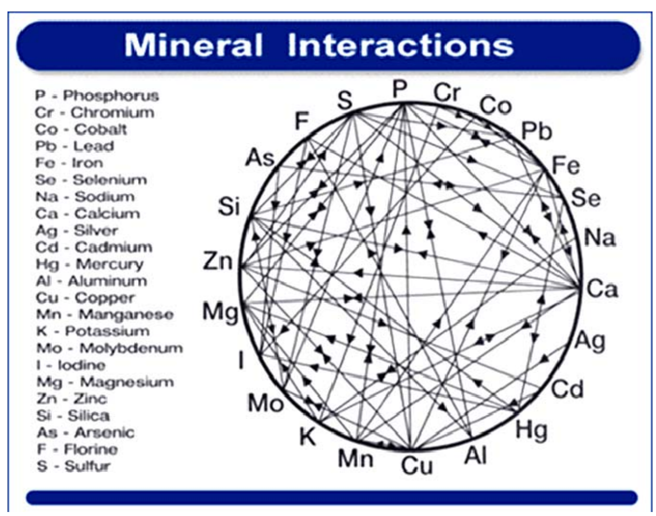
Given all these definitions for phosphorus, which term is the best option to use when determining the requirements or formulating diets? Is it aP, nPP, a new term such as retainable P, or digestible P (and Ca)? To be clear and for ease in comparing future studies, it is obvious agreeing on one term is essential. Which one is the "best" term to use is still debatable.

Challenges of each systems

Each system (aP, nPP and rP) has challenges when being used. The requirement values for digestable P (and Ca), aP and (available Ca) need to first be determined in vivo for ingredients being used in trials. This is cost prohibitive and time intensive. Digestible P and Ca values would be useful if good values (those having ranges and standard errors) are in existence or are generated accurately and quickly.

Non-PP can be measured chemically indirectly through laboratory procedures. Recommendations based on nPP are problematic because of the potential variable availability of PP between and within plant ingredients, as well as the variable availability of iP from inorganic and plant sources.

The challenges with using rP recommendations arise from the impact of the other dietary nutrients, particularly Ca and vitamin D. Dietary and growth rate impact is higher when rP is being determined for ingredients compared to the other systems.



Direction of arrows denotes interference
Arrows **aimed at each other** denote **mineral synergy**
Arrows **aimed away from each other** denote mutual **mineral interference** or antagonism

Figure 1

Continued on p. 3

Regardless of the system being utilized the mean, minimum and maximum values and standard errors for the mean values must be provided. Figure 1 demonstrates the interactions between the minerals and provides a visual explanation of how minerals work together in the diet or how they can work against each other if over- or under fed in the diets.

The many published studies used by the NRC (1994) to establish nPP recommendations used the book values for aP in research. Available P values are generally determined in experiments that use animal models. Further the availability of PP varies greatly between feed ingredients. The concentration of PP within the same ingredient can vary as well. This variance can depend on soil fertilization, time of harvest, maturity and variety. Based on these factors, only one single average book value that does not refer to the number of values being used to drive the average or give ranges and standard errors for nutrient concentrations and recommendations can only be applied in limited formulation systems.

Since the ingredient PP content and availability changes like this, aP values would also be expected to change between batches of the same feed ingredient. Solely basing P recommendations for broilers on aP would mean that the aP values would have to be determined every time a new batch of ingredients is used to formulate feed for each research project where aP requirements are being determined. For this standard to be applicable, use of aP requirement recommendations would have to be based on a large database that contains ingredient averages as well as range and standard deviations.

The nPP system is advantageous by being based on chemical analysis that is readily done on the different batches of ingredients. The limitation of this system is that the chemical analysis does not include information on the P availability of the ingredients or diets. This means any changes in PP and P availability of the ingredient would not be reflected in the nPP system.

What is the phosphorus requirement?

The recommendations for nPP for broilers (NRC, 1994) are based on peer-reviewed research as published between 1952 and 1983. It is clear that today's broilers are nothing like commercial birds prior to 1983. This is partly because of genetic selection and due to management practice and feed related changes. Genetic changes are clearly evident between 1991 and 1957 broilers. At d 42, a 1991 broiler fed a 1991 diet, the body weight was 4,497 g compared to the 1957 broiler fed the 1991 diet with a body weight of 680 g. The body weight of the 1991 broiler fed a 1957 diet was 3.4 times the weight of the 1957 birds on the 1957 diet (1,877 g vs. 538 g). This study by Havenstein et al. (1994) clearly indicates that the genetic changes more than dietary changes account for the differences between the birds over the years.

A three-age-phase feeding program is recommended by the NRC (1994). The industry is using a four-age or five-age-phase feeding program. The nPP requirements of rapidly growing broilers decrease over the age of the bird. The increased number of phases matches dietary nutrient concentrations closer to the requirements of the birds. The higher number of phases during production also results in a reduction in the amount of nPP and P fed, and thus a decrease in feed costs. The lower amount of nPP and P fed means that less P is being excreted. On the flip side, the increased number of feeding phases means more feeds are mixed at the feed plant and thus costs are higher. Producers will have to balance the cost of producing (mixing and shipping) the feed more often against less P added to the diet and the economic importance (and significant environmental impact) of a lower litter P.

In the current literature on P requirements, it is extremely difficult to interpret the published results and compare the results between studies. In the research, certain factors are always included that have a large impact on results. These factors include breed/strain, age, starting and ending body weights, replication and birds/replicate, prior nutrition (specifically Ca, P and vitamin D), age of breeder flock at the eggs' source, feed consumption (as corrected for mortality), formulated and analyzed Ca and P, formulated vitamin D, protein, ME, fat and all vitamins and minerals, dietary ingredients, light and temperature schedule, possible light intensity, pen size/animal density, actual mortality and are data is adjusted for mortality, formulation and mixing technique, the use of feed additives, vaccination programs, and environmental factors.

The research on Ca and P requirements in growing birds is done based on the impact the concentration of the nutrients have on bone ash. By using bone ash to determine nutrient requirements, the result can be defined as the Ca and P requirement for maximal bone ash. On a practical note, this type of requirement has little application since bone ash is not a sellable product. While the bone ash method is the most sensitive method to determine Ca and P adequacy, the application is limited to the point where bone ash decreases start to impact performance and where it starts to impact processing plant downgrades that affect carcass yields and the incidence of bone chips in deboned meat. In theory, low concentrations of dietary nPP fed to birds could increase the processing losses. The compromised bone integrity is related to the breakage of femurs, broken drumsticks, cartilage separation at the rib cage, blood splash of meat and fractures. Published research has shown that the continuous feeding of low concentrations of dietary aP will also lead to the processing losses (Moran and Todd, 1994). However, there has been no current work completed that demonstrates any clear correlations between the lab results of bone mineralization (ash, breaking and density measures) and the performance changes or processing plant losses. These correlations, (how Ca and P requirements as determined by bone ash) will expand the practical application of bone ash measures. This type of research will also enable predictions of losses based on nPP consumption or mineralization measures will allow the industry to better decide what P levels to feed as determined by market conditions, environmental regulations and desired outcomes.

Since most Ca and P requirements are given on the basis of percent dietary inclusion in most published works, the research has tended to study the percent concentration or to compare the percent requirement concentrations between studies without giving enough credence to other influencing factors. These factors include feed consumption, actual nutrient intake and other related nutrients, dietary sources of macrominerals and the availability of the macrominerals from those sources, the growth rate of the animals, the animal strain and its impact on requirements, the Ca to P ratios, and concentration of key nutrients (i.e. vitamin D and microminerals). It would be ideal if Ca and P requirement are given as a weight unity of the mineral actually consumed within a defined growth range (not age) and always specifically compared within the context of different trials.

The relevance to the industry

It is obvious that calcium and phosphorus requirements need to be clarified. Determinations must consider the influence of genetics and management systems in use. Researchers and other industry professionals will have to come to an agreement on the definition of true P nutrition and other related terms (i.e., aP, rP, nPP).

To come to this agreement, researchers will have to develop a streamlined experimental design for consistency in studies. This will increase the integrity of the data. The data from improved experiments will enable the development of reliable standards of calcium and phosphorus in ingredients. Standardized P values will be reflective of balance between in vivo (in the animal) and in vitro (in the lab) studies of ingredients.

The newly developed standards, consistent terminology and even more reliable research across the industry will also require an update to the NRC to reflect the nutrient requirements of birds by more than the current three growth-phase system the manual uses. These changes as they occur will also provide guidance in addressing environmental concerns related to feeding phosphorus and further understanding of the interactions of other nutrients in the diet.

Information for this article taken from:

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