European Journal of Science, Innovation and Technology

ISSN 2786-4936

Vol. 1 No. 6 (2021)

Calcium (Ca) to Phosphorus (P) Ratio: Key to Positive Ecosystem in Animal Production

James T. Mbachiantim[1], Ntinya C. Johnson[2] and Victor M. Ogbamgba[2]

[1]Federal University of Agriculture, Makurdi, Department of Nutrition and Dietetics, Nigeria

[2]Rivers State University, Port Harcourt, Department of Animal Science, Nigeria

Abstract. P is the most limiting nutrient for plants' growth and development. Thus to avoid its deficiency, plants at maturity normally conserve P (known as phytate-P) for their next growing phase. However, the conserved phytate-P is tightly bonded to phytate which confers on them their indigestible characteristics as they are unavailable to the animal. This has resulted in the over-supply of P via inorganic sources to avoid P deficiency leading to wide dietary ratios between Ca and P or over-supplying of Ca in the diet because of phytate-P; this also results in wider ratios between Ca and P. Ca and P are very critical nutrients for bone health and development. Ca and P unlike other nutrients are not digested but must be solubilized into their ionic forms for absorption, utilization and retention. Their solubility is tightly dependent on their dietary ratio. Furthermore, their homeostasis is hormonally modulated which further stresses the usefulness of an agreeable ratio between Ca and P for their optimal retentions. This paper highlights some of the insights relating to the ratios of Ca to P in farm animal diets that can be adopted to better manage the nutrition of dietary ratio of Ca to P to improve animal performance, Ca and P retentions and therefore significantly reduce nutrient levels particularly those of Ca and P in the animal manure and urine. This aids to making animal production to influence environmental factors positively. The ratio that should be adopted to achieve these is Ca to P ratio of 1: 1, since they are mutually metabolized and also mutually antagonistic when their dietary ratios are in disagreement.

Key words: Ca to P Ratio, Performance, Ca and P retentions and Environment

Introduction

The understanding of nutrient efficiencies is essential for a significant breakthrough in the effective management of the economics, health problems and environmental pollution by the livestock industry, particularly those of swine and poultry industries. To this extent, from the economic standpoint, dietary Ca supplements in swine and poultry diets are achieved through the use of limestone; a well-known and relatively cheap ingredient. Therefore, the consideration of Ca availability is modest (Crenshaw, 2001). Consequently, producers will supplement Ca freely without paying much attention to the efficiency of the use of Ca in the diet. Conversely, the problem with P is that it is very expensive and at the same time is of less benefit to the animal if it is deficient or in excess in the diet. Additionally, most of dietary P comes from plant sources meaning that animal ability to utilize plant P is very limited. Non-ruminant producers are prone to improving their cost-benefit ratios by having a better understanding of the kinetics of nutrient efficiencies, especially as it concerns the levels of Ca to P ratios in animal diets.

Animal health problems, such as osteoporosis can be prevented by fortifying animal diets with adequate levels of Ca in combination with P (NRC, 2012). When background information regarding nutrient efficiencies and requirements are lacking or not available, it becomes difficult to prevent such bone disease leading to poor animal performance. It is very important to have nutritional information or knowledge about combination of nutrients and nutrient availability with respect to diet ingredients in order to formulate diets that match animal needs depending on their genotypes and physiological states.

At present, there is considerable concern regarding environmental pollution emanating from excess P excretion in the pig manure and poultry droppings (Mallin, 2000). The excess P in the manure is as a result of dietary P not utilized by the animal and consequently is excreted resulting in the undesirable incidence of P pollution. The potentials exist to significantly reduce P inefficiencies of P retention by optimum diet formulation regarding the ratio of Ca to P. Minimizing over-formulation is the cheapest and surest means to reduce P excretion and waste by farm animals, such as pigs and poultry. This is where the ratio of available Ca to available P in animal diets becomes handy. Therefore, the objective of this communication is to provide available ratios of Ca to P that can be used in diet formulations to improve animal performance, Ca and P retentions, reduce urine volumes and Ca and P in animal manure thereby aiding in animal production that positively supports our ecosystems for sustain productivity.

Ca to P Ratio on Animal Performance, Ca and P Retentions and Diets' Efficiencies

As previously alluded to, Ca and P are critical nutrients in the proper growth and development of the animal skeletal system (NRC, 2012). The ratio of Ca to P in the bone is 2: 1 (NRC, 2012). Thus formulators thought that by using the ratio of 2 to 1 for Ca and P, respectively, animal growth and performance would be enhanced. However, the big fallacy in it had been discovered and done away with. Secondly, the ratio of Ca to P in sow's milk ranges from 0.6 to 1.2 of Ca to 1 of P, respectively (NRC, 2012). To this end also, some formulators thought that sometimes Ca can be lower or higher in the diet than P; this is also fallacious. The truth is that the metabolism of Ca and P are mutual and thus when their dietary provisions are imbalanced they become mutually antagonistic as their metabolisms involves a well-orchestrated interplay of physiological cascades involving many hormones, including parathyroid hormone, calcitonin and vitamin D (Shoback & Sellmeyer, 2010) supporting the fact that their metabolism and interaction for absorption are concentration dependent. As a result of these phenomenon their ratios should be narrow or close and dependent on animal genotypes and physiological classes. In this way animal performance, Ca and P retentions are enhanced, leading to minimized endogenous losses of the minerals resulting in their minimized levels, particularly that of P in the manure (Pettey et al., 2006; Shoback & Sellmeyer, 2010).

To these points, Qian, Kornegay and Denbow (1996) who investigated the effects of Ca to P ratio in turkeys with Ca to P ratio of 1.1 to 1 and 2.0 to 1 found that animal performance was most optimized with the 1.1 to 1 of Ca to P ratio diet compared with diets of more dietary Ca than P. The 1.1 to 1 ratio diet also resulted in improved Ca and P retentions and better bone mineralization. These findings therefore support the fact that wider ratios between Ca and P are detrimental to animal performance, P utilization and negatively affect bone health of the animal and thus contributed to poor animal performance. The findings of Qian, Kornegay and Denbow (1996) were corroborated by the studies of Brady et al. (2002) and Hu et al. (2010). Thus wider ratios of dietary Ca to P leads to poor feed efficiency with the environment paying huge economic price due to high dietary P in the animal manure.

It is imperative to note that amongst all nutrients it is only the minerals that are not digested compared to the rest of other dietary nutrients. Therefore, although excess minerals do not exhibit any known anti-nutritional effect *per se*, nevertheless are considered undesirable as they can potentially cause the dilution of nutrients in the diet (a negative impact that mimics the negative effect of fibre in the diet) and causing diarrhea, especially in the young animals, such as chicks and piglets (Smith et al., 1999). This is important and also explains in part why wider ratio of Ca to P suppresses animal performance. Amongst feed effects energy concentration of diets is one of the major nutritional factors causing variation in feed intake. Consequently, it has been reported that the regulation of feed intake depends on the energy densities of diets. Thus at low energy densities, energy intake is reduced and subsequently growth performances of the animals are similarly reduced. This also results in poor feed efficiency (Smith et al., 1999).

These effects of Ca to P ratios are of major concerns in non-ruminants whose diets are always formulated for feed effectiveness and efficiency. The absorption of both dietary Ca and P is usually influenced by the concentration of dietary P. The absorption of P therefore is reduced with increasing levels of dietary Ca. A wide Ca-to-P ratio lowers Ca and P absorption whereas a narrow ratio is more correlated with increase in Ca and P retention (Liu et al., 2000). Achieving proper balance between Ca and P will invariably favour reductions in dietary P and P excretions with no detrimental effect on skeletal growth and development as well as bone soundness; P endogenous losses are also significantly reduced (Han, & Thacker, 2006; Hanni et al., 2005). Lowering Ca to P to 1: 1 increased the digestible energy (DE) content of the diet, digestibility of protein, DE, Ca, P and resulted in a significant improvement in feed conversion ratio in pigs. These findings were also confirmed by the studies of Stein et al. (2011) and Johnson et al. (2012).

Ratio of Ca to P on Drinking Water, Energy Efficiency and Urine Volume

The animal requires water for its various biological needs. Water is required for the regulation of the animals' body temperature, nutrient digestion/absorption as well as for the elimination of waste products of digestion and metabolism (NRC, 2012). Water is also a major component of saliva and milk. From nutrition standpoint, it is difficult to truly quantified water requirements by the animal because of the many factors involved. Nevertheless, the amount of water required by animals is driven mainly by the amount required to maintain the body water pool. Body water pool appears to remain constant throughout the various physiological phases of growth (NRC, 2012). However, the main route of water elimination is by urination.

When the concentrations of minerals are beyond the recommended levels as it relates to the dietary ratio of Ca to P it exacerbates the inability of the acidic environment of the stomach to dissociate phytate-P inherent in cereal grains that constitute the bulk of the animal feed (Montminy et al., 2007). Non-dissociation of phytate-P in the stomach results in skewed ratio in favour of Ca against P. This often emanates from dietary origin when there is a wider ratio of Ca to P. This leads to the triggering of the formation of insoluble phytate-mineral-complexes that cannot be solubilized and thus passes through the gastrointestinal tract unabsorbed. This leads to high levels of minerals in the animal manure causing eutrophication (Mallin, 2000).

Wide ratio of Ca to P apart from compromising animal performance also causes mineral toxicities (Ammerman, 1995). This encourages the animal to drink excessive water as a physiological response to detoxify self (Mroz et al., 1995; Johnson et al., 2012). This also results in excessive urination and leads to difficulties of managing such slurries just because of the intake of excessive water. Disposal of such slurries are also very time-consuming resulting in delay in the time it takes for re-stocking in the commercial setting. Here, the emphasis is on the fact that wider ratio of Ca to P makes animals to have excessive water usage which in turn results to problems of slurry handling and management as a result of increased water volume of the slurries (Mroz et al., 1995). Additionally, it is a must that animals, such as pigs will eliminate excess water consumed from their system. This can negatively impact productivity as energy for growth and other useful purposes are sequestered to water elimination from their bodies. This also leads to feed inefficiencies because of the sequestration of energy away for more productive purposes. Furthermore, excessive water consumption results in difficulties in manure management principally due to increased slurry volume. In the overall therefore, diets of young animals should be fortified with a dietary Ca to P ratio of 1: 1 (5g/kg of diet, respectively) and as they enter the more active growing-finisher phase the ratio still maintains 1: 1 but with increased dietary concentration of 6g/kg of diet, respectively. The 6g/kg of diet, respectively should also be employed for the fast growing genotypes or breeds (Brady et al., 2002; Stein et al., 2011).

Conclusions

The summary of this communication is the fact that a wide ratio range between Ca and P in diets adversely affects animal performance, the efficiencies of the utilization of Ca and P as well as other nutrients in the diet. The overall impact being a huge negative price on the environment as a result of high contents of excreted manure P. The major step to better guide in using nutritional strategy to curb environmental pollution emanating from animal industry is a suitable range of Ca to P ratio in the diet. This is very critical and central to the success of using nutritional principles to significantly reduce P levels in the animal manure. It is not a gainsaying that low-Ca and low-P content diets based on the use of optimal digestible Ca to optimal digestible ratio in non-ruminant diets will not compromise animal health and performance but consequently reduce excess P in the diet leading to minimized P availability in the hindgut and ultimately reduce P level excreted in the manure and urine. Furthermore, it would reduce water intake with moderate urine volume for easy manure handling and management. Additionally, when Ca and P levels are low but meet the requirement of the animal lower amounts of inorganic P and limestone would be used in compounding the diet. Economically, this has a very high potential of increasing the net income for producers. This ratio is 1: 1 of Ca and P ranging from 5g to 6g/kg of diet depending on animal physiological status and genotype. In this way, animal production would be become eco-friendlier.

References

Ammerman, C. B. (1995). Methods for estimation of mineral bioavailability. In C. B. Ammerman, D. H. Baker, & A. J. Lewis (Eds.), *Bioavailability of Nutrients for Animals* (pp. 83-110). Academic Press, San Diego.

Brady, S. M., Callan, J. J., Cowan, D., McGrane, M. & O'Doherty, J. V. (2002). Effect of phytase inclusion and calcium/phosphorus ratio on the performance and nutrient retention of grower-finisher pigs fed barley/wheat/soybean meal-based diets. *J. Sci. Food Agric., 82*, 1780-1790.

Crenshaw, T. D. (2001). *Swine Nutrition* (2nd ed.). "Calcium, Phosphorus, Vitamin D and Vitamin K in Swine Nutrition." CRC Press, New York, pp. 187-212.

Han, Y. K. & Thacker, P. A. (2006). Effects of the calcium and phosphorus ratio in high zinc diets on performance and nutrient digestibility in weanling pigs. *J. Anim. Vet. Adv., 5*, 5-9.

Hanni, S. M., Tokach, M. D., Goodband, R. D., Dritz, S. S., & Derouchey, J. M. (2005). Effects of increasing calcium-to-phosphorus ratio in diets containing phytase on finishing pig growth performance. *The Professional Anim. Scientist, 21*, 59-65.

Hu, L. Yang, J., Fang, S. X., Wang, X. G., Shu, Z. Y., et al. (2010). Estimating an optimal ratio of true digestible Ca to P ratio in corn-rough-soybean meal-based diets for 20-50 kg growing pigs. *J. Food Agric. & Environ., 8*, 556-562.

Johnson, N. C., Atkinson, J., Finegan, E., & Cant, J. P. (2012). *Determination of Optimal True Digestible Calcium to True Digestible Phosphorus Ratio in Growing Pigs*. Ph.D. Thesis, Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada.

Liu, J., Bollinger, D. W., Ledoux, D. R., & Veum, T. L. (2000). Effects of dietary calcium: phosphorus ratios on apparent absorption of calcium and phosphorus in the small intestine, cecum and colon of pigs. *J. Anim. Sci., 78*, 106-109.

Mallin, M. A. (2000). Impacts of Industrial Animal Production on Rivers and Estuaries. *Am. Sci., 88*(1), 26-37.

Montminy, M. P., Jondreville, C., Lescoat, P., Meschy, F., Pomar, C., et al. (2007). First step of a model of calcium and phosphorus metabolism in growing pigs: Fate of ingested phosphorus in the stomach. *Livest. Sci., 109*, 63-65.

Mroz, Z., Jongbloed, A. W., Lenis, N. P., & Vreman, K. (1995). Water in pig nutrition: Physiology, allowances and environmental implications. *Nutr. Res. Rev., 8*, 137-164.

NRC. (2012). *Nutrient Requirements of Swine* (11th ed.). Natl. Acad. Press, Washington, D. C.

Pettey, L. A., Cromwell, G. L., & Lindemann, M. D. (2006). Estimation of endogenous phosphorus loss in growing and finishing pigs fed semi-purified diets. *J. Anim. Sci., 84,* 618-626.

Qian, H., Kornegay, E. T., & Denbow, D. M. (1996). Phosphorus equivalence of microbial phytase in turkey diets as influenced by calcium to phosphorus ratios and phosphorus levels. *Poult. Sci., 75*, 69-81.

Shoback, D. M. & Sellmeyer, D. E. (2010). Disorders of the Parathyroids and calcium and phosphorus metabolism. In S. J. McPhee & G. D. Hammer (Eds.), *Pathophysiology of Disease* (6th ed., pp. 465-496). McGraw-Hill Companies Inc.

Smith, J. W., Tokach, M. D., O'Quinn, P. R., Nelson, J. L., & Goodband, R. D. (1999). Effects of dietary energy density and lysine: calorie ratio on growth performance and carcass characteristics of growing-finishing pigs. *J. Anim. Sci., 77*, 3007-3015.

Stein, H. H., Adeola, O., Cromwell, G. L., Kim, S. W., Mahan, D. C., & Miller, P. S. (2011). Concentration of dietary calcium supplied by calcium carbonate does not affect the apparent total tract digestibility of calcium, but decreases digestibility of phosphorus by growing pigs. *J. Anim. Sci., 89*, 2139-2144.