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A Review on Calcium to Phosphorus Ratio in Swine Nutrition

[1] Diri M, [2] Johnson NC, [3] David EU, [4] Amachree DD

[1, 2] Department of Animal Science, Rivers State University, Port Harcourt, Nigeria
[3, 4] Department of Agricultural Technology, Port Harcourt Polytechnic, Nigeria

Corresponding Author: **Diri M**

Abstract

The metabolisms of calcium (Ca) and phosphorus (P), including other minerals and nutrients are highly dependent on the dietary ratio of Ca to P. Wider ratios between Ca and P lead to antagonisms between Ca and P resulting in inefficiencies of nutrients absorptions and consequently results in high levels of dietary Ca, P and other nutrients in the pig manure that triggers eutrophication. One of the major reasons responsible for this is because dietary source of Ca is relatively cheaper compared to that of P. Later, due to the essential physiological functions of P, the concept of P insurance policy in the diet was introduced by adding more P in the diet as well as more Ca to avoid P deficiency. P insurance policy did not provide the expected results, again because further widening of the ratio of Ca to P. This stimulated about 151 independentstudies tailored to identifying the proper dietary Ca to Pratio as to enhance their metabolisms as well as other dietary nutrients. The Ca to P ratio in the bone is about 2: 1. It was thus recommended that Ca to P ratio in the diet should be 2: 1. Later reviews on the role of Ca and P revealed the fallacy of thinking that the ratio of Ca and P in bone is the ratio that should be used in feed formulation. The Ca to P ratio varies from 0.6 to 1.2: 1 in the sow's milk and was also thought to be the optimal ratio in the diet.This was later found to be fallacious. At present, it has been found that the dietary ratio of Ca to P for optimal performance as well as reduction in eutrophication is 1: 1.

Keywords: Nutrient Metabolism, Calcium, Phosphorus, Ratio and Swine

Introduction

The understanding of nutrient efficiencies is very essential in the effective management of the economics, health problems and environmental pollution emanating from the livestock industry, particularly the swine industry. From economic standpoint, dietary calcium (Ca) supplements in swine diets are achieved through the use of limestone; a well-known and relatively cheap ingredient. The consideration of Ca availability is therefore modest (Crenshaw, 2001) [2]. Consequently, producers will supplement Ca freely without paying much attention to the efficiency of it.

Conversely, phosphorus (P) is very expensive leading to P being deficient in the diet resulting to widening the ratio of Ca to P. This results in poor growth and overall productivity of the pig. However, for good productivity, there is the need for the producer to improve or maintain a realistic ratio of Ca to P in swine diets for production efficiencies. This involves the knowledge of improving their cost-benefit ratios via a better understanding of the kinetics of nutrient efficiencies as it concerns the levels of Ca and P in swine diets (NRC, 2012) [15]. It is known that Ca and P are involved in various essential physiological functions in the non-ruminants, particularly the pig (Shoback and Sellmeyer, 2010) [19]. For example, they are involved in the development and maintenance of the skeletal system. In fact, about 75% of the body P pool is located in the skeleton (Poulsen, 2000) [17]. Another structural function of P is that it is an important element of the phospholipids found in cell membranes. Additionally, is a constituent of adenosine triphosphate (ATP) and other phosphorylated intermediates and thus critically involved in energy metabolism (NRC, 2012) [15].

Due to the essential physiological roles of P, there is no doubt that its deficiency would lead to impaired metabolism, growth and abnormal bone mineralization. Phosphorus is a very economic nutrient in the nutrition of the pig. It is typically the third most expensive nutrient in the pig diet after energy and protein (NRC, 2012) [15]. Nevertheless, it is still a common practice to include a plentiful supply of P in swine diets, mainly to ensure that P deficiency does not occur. This common insurance policy approach to dietary P inclusion level for swine results in wider ratios between Ca and P leading to excessive P excretion in the

pig manure (Hu *et al*., 2010) [6]. This scenario is seriously linked to environmental pollution with huge negative consequences (Mallin, 2000) [13]. However, if the appropriate ratios of Ca to P are employed in swine diets these drawbacks can be significantly overcome.

An Overview of Calcium to Phosphorus Ratio in the Pig

The understanding of nutrient efficiencies is essential for significant breakthrough in the effective management of the economics, health problems and environmental pollution by the livestock industry, especially the swine industry. To these points, from the economic standpoint, dietary Ca supplements are achieved through the use of limestone; a relatively cheap ingredient (Crenshaw, 2001) [2]. Consequently, producers will supplement Ca freely without paying much attention to its efficiency. On the other hand, P is expensive and at the same time is of less benefit to the pig if it is deficient or in excess in the diet (*Hu et al*., 2010) [6]. Swine 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 and P in the diets of their animals (NRC, 2012) [15].

There are 151 references regarding P requirements (NRC, 1998) [14]. However, out of this figure only 37 were from the 1990s and more so only 5 of the 37 addressed the P requirements (Knowlton *et al*., 2004) [9]. Of more importance to this observation is the fact that only one of the 37 really addressed the bioavailability of P from feed ingredients (Knowlton *et al.,* 2004) [9]. With increase in knowledge, it is now known that bioavailability of P differs among feed ingredients resulting in a better estimate of P requirements on digestible or bioavailable P basis. Another important factor to consider in formulating precise diets for any of the physiological phases of the animal to meet P requirements for pigs is the availability of Ca. This requires that diets should be formulated based on P-available to Ca-available ratios. In these ways, environmental pollution due to P would be significantly reduced in addition to more economic gains to producers.

Calcium to Phosphorus Ratio in Poultry

In growing poultry, a total of Ca to a total P ratio of 1.1: 1 to 1.4: 1 has been recommended. Feeding diets with wider ratios between Ca and P has also been shown to reduce performance, P utilization and bone mineralization. These observations were confirmed by the data reports of Qian *et al.* (1996) [18]. In that study it was demonstrated in turkeys that 8.7, 10.8 and 6.6% reduction was calculated for body weight gain, P retention and total ash percentage, respectively, when Ca to P ratio was increased from 1.1: 1 to 2.0: 1.The findings of Qian *et al.* (1996) [18] therefore suggest that wider ratios between Ca and P would be detrimental to animal performance, P utilization and negatively affect the bone health of the animal. This situation may not be limited to poultry species alone as literature data depict.

Calcium to Phosphorus Ratio For Swine

Jongbloed (1987) [7] recommended that an optimal ratio range between total Ca and total P of about 1.2 – 1.4: 1 was adequate for pigs. Currently it is known that the ratio of Ca to P when expressed as digestible Ca to digestible P is more accurate for meeting animal requirements. This further requires that digestibility of the Ca source, intrinsic phytase activity of the feed, the concentration of digestible P and the type of production pig category be known to better guide the inclusion levels of Ca and P on digestible bases. Hall *et al.* (1991) [3] corroborated the findings of Jongbloed (1987) [7] that high intake of Ca together with low intake of P is detrimental to the health of the animal. Furthermore, Ketaren *et al.* (1993) [8] studied the metabolism of P in pigs based on the available P requirements of grower and grower/finisher pigs using four Ca to available ratios as: 1.7, 2.1, 2.5 and 2.9: 1. Significant linear depression effects were observed with increasing Ca to available P feed ratios on carcass gain and feed conversion ratios. The majority of these negative effects occurred when the ratio increased from 2.5: 1 to 2.9: 1. In reference to these findings, it was concluded that a Ca: available P ratio of between 1.7 and 2.5: 1 was suitable for grower and grower/finisher pigs.

Liu *et al.* (1998) [11] using growing-finishing pigs investigated the effect of three dietary Ca: total P (tP) ratios: 1.5: 1, 1.3: 1 and 1.0: 1.0 on P utilization in diets supplemented with microbial phytase at 500 phytase units/kg.It was observed that the lowering of Ca to tP ratio showed a significant linearly increase in average daily gain during the growing phase and overall; gain to feed ratio during the growing phase and P retention during the finishing phase. Furthermore, the lowering of the Ca to tP ratio significantly linearly increased body weight at slaughter, carcass weight, bone breaking strength and bone ash weight. These findings suggest that a wide Ca-to-P ratio lowers Ca and P retention whereas a narrow ratio is more correlated with increase in Ca and P retentions. This fact was supported by the data of Liu *et al.* (2000) [12]. Liu *et al.* (2000) [12] investigated three dietary Ca to P ratios as: 1.5: 1, 1.3: 1 and 1.0: 1, respectively. They found that the lowering of dietary Ca to tP ratio significantly linearly increased absorption of P in the small intestine. It was also found that the lowering of Ca to tP ratio to 1.0: 1 resulted in a significant amount of P being absorbed in the caecum in that study implying that the caecum-colon region of the digestive tract plays a role in maintaining Ca and P homeostasis in pigs, especially when the Ca to tP ratio is 1.0: 1.

Brady *et al.* (2002) evaluated the effect of phytase on Ca to P ratio on performance and nutrient retention in grower-finisher pigs using Ca to P ratio of 1.85: 1 and 1.15: 1. They found that phytase had no effect on Ca and P digestibility in the 1.85: 1 diet. Performance of the pigs were also very poor compared with the group of pigs fed the 1.15: 1 Ca to P diet. In the 1.15: 1 diet phytase significantly increased Ca and P digestibility that were evidently confirmed by the significantly reduced amounts of Ca and P in the pig manure. The findings of this study also suggest that imbalance in Ca to P ratio in the diet rendered phytase completely inefficient as evidenced by the significantly high levels of P and Ca in the pig manure and poor animal performance. Furthermore, some of the 'take home' messages from the findings of this study include:reduction of the ratio of Ca to P increased the digestible energy (DE) content of the diet, digestibility of protein, DE, Ca and P leading to significant improvement in feed conversion ratio and overall performance of the pigs. Additionally, wider ratio of Ca to P ratio have a diluting effect on the DE content of the diet due to the high levels of limestone (NRC, 2012) [15].

Again, Hanni *et al.* (2005) [5] studied the effects of increasing Ca-to-P ratio in the diets for finishing pig growth

performance in two different experiments and came to the conclusion that a wide ratio of Ca to P in swine diets suppresses performance resulting in high levels of P excreted in the pig manure into the environment leading to eutrophication (Mallin, 2000) [13]. In the first study involving Ca to P ratios as: 1.0: 1, 1.25: 1, 1.5: 1 and 2.0: 1, respectively, in the diets fed to the pigs from 39kg to 113kg body weight found that increasing Ca: P significantly decreased average daily gain (ADG), average daily feed intake and carcass weight; with the greatest reduction observed when Ca: P increased from 1.5: 1 to 2.0: 1. Similarly, in their second study that evaluated the effect of Ca: P ratios: 0.75: 1, 1.0: 1, 1.25: 1, 1.5: 1 and 2.0: 1 found that increasing Ca to P ratio significantly decreased ADG and gain-to-feed ratio with the greatest decrease observed as Ca to P ratio increased from 1.5: 1 to 2.0: 1. They concluded that growing-finishing pig diets should not have a Ca to P ratio of more than 1.5: 1.

Han and Thacker (2006) [4] examined the effects of Ca to P ratio in high zinc diets on performance and nutrient digestibility in weanling pigs using four dietary Ca to P ratio levels formulated to contain 20.4% crude protein and 1.31: 1, 1.51: 1, 1.65: 1 and 1.91: 1 of Ca to P ratios, respectively. It was observed that feed-to-gain conversions were significantly affected as dietary Ca concentration increased throughout the duration of study whereas ADG and feed intake were only marginally affected by the dietary treatments. Digestibility of fat, Ca and P in the 1.91: 1 ratio diet were significantly lower than for the other diets. These results suggest that more Ca and P would have been released via pig dung into the environment. The feeding of higher levels of Ca decreased fat digestibility. These observations are potent factors that cause environmental pollution due to increased nutrient loads on the environment.Furthermore, for the fact that crude fat digestibility was reduced can potentially reduce the digestible energy of the diet and thus negatively impact performance. It should also be noted that higher dietary Ca levels causes Ca to complex with fatty acids in the lumen of the pig to form insoluble metallic soaps, thereby reducing both fat and Ca digestibility as established in the study.

The Ca to P ratio in the bone is about 2: 1. Therefore, it was recommended that Ca to P ratio in the diet should be 2: 1. However, later reviews (Kornegay, 2001) [10] on the role of Ca and P in swine nutrition revealed the fallacy of thinking that the ratio of Ca and P in bone is the ratio that should be used in feed formulation for swine. Again, it was thought that a more appropriate indicator probably is the composition of the ratio of Ca to P in sow's milk. The Ca to P ratio varies from 0.6 to 1.2: 1 (Peo, 1991) [16]. When one considers the purpose and importance of sow's milk to neonates for their rapid development and survival, it is quite reasonable to postulate that Ca to P ratio is near optimal. Again, recent findings (Stein *et al*., 2011) [20] confirmed that dietary Ca concentration affects P digestibility and P digestibility was optimized when the true dietary Ca to P ratio was around or slightly less that 1.1: 1. Currently, based on the findings of Stein *et al.* (2011) [20], NRC (2012) [15] recommends that the ratio of Ca to P in swine diets should be 1: 1.

Conclusion

The summing up of data relating to evaluation of Ca to P ratios in the pig diet generally agree with the fact that a wide ratio between Ca and P in the pig diet adversely affects the efficiencies of the utilization of Ca and P as well as other nutrients in the diet, such as protein and DE. The overall impact being poor animal performance and a huge price on the environment as a result of high nutrient levels, particularly P in the pig manure excreted into the environment resulting in eutrophication.

As a first step guide to using nutritional strategy involving the utilization of Ca and P to curb eutrophication and improve animal growth and health a suitable Ca to P ratio should be employed. When P as well as Ca levels in the pig diet are similar but meet the requirements of the animal the levels of Ca, P and other nutrients availability in the hindgut of the pig are significantly low resulting in minimal levels of the nutrients in the manure. To this end, the amounts of inorganic P and limestone used in diet formulation would be low. Economically, this results in increasing the net income for the producer. The ratio of Ca to P for optimal performance as well as reduction in eutrophication is 1: 1.

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