Defining The Interactions Between Calcium (Ca) And Zinc (Zn) And Dietary Strategies For Improving Their Availabilities In The Nourishment Of The Growing Swine - A Review

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Abstract: Calcium level in swine diet is above 1g/kg of diet and hence is a macro-mineral whereas Zn is less than 1g/kg of diet and hence is a micro-mineral. Ca is naturally antagonistic to Zn and as such causes Zn deficiency when their dietary concentrations are not balanced. This stresses the need to understand the nature of ionic interactions existing between these two important minerals as well as other important dietary factors affecting their solubilities and assimilations in the nourishment of the growing pig as to better understand their dietary inclusion levels; to ensure their availabilities to the animal. Therefore, it is important to also note that the interactions between dietary Ca and Zn ions are very dynamic, complex and concentration dependent. Defining some of these essential interactions between their soluble ions would help better guard the nutrition and management of these minerals in the nourishment of the growing pig. Here, the possible interactions between Ca and Zn soluble ions are defined and expanded, including other dietary factors that help in maintaining their homeostasis.

Key words: Antagonism, Calcium, Interactions, Nourishment, Swine and Zinc

1 Introduction

Calcium and Zn are essential nutrients involved in the nourishment of growing swine. While Ca is a macro-mineral Zn is a micro-mineral. Both nutrients are very important in the structural (skeletal) soundness of the growing pig as it has been shown that 99% and 30% of dietary Ca and Zn reside in the skeletal system of the pig, respectively [2] while their remaining 1% and 70% components respectively are used for other essential physiological functions. Ca is naturally antagonistic to Zn in their availabilities when dietary Zn is below the animal requirements. Furthermore, Ca and Zn are known to interact physiologically with huge effect on the nourishment of the growing pig. These interactions may be beneficial (no antagonism) or detrimental (antagonistic) to the animal [2]. More importantly, the major concern is that if the interaction is of antagonistic nature, deficiency of the mineral whose dietary concentration is marginal or at borderline, such as that of Zn being a micro-mineral may be induced by the other mineral as found in Zn and Ca interactions [3]. This means that Ca is antagonistic to Zn (Figure 1) and therefore becomes an important nutritional key in dealing with the nutrition of the two minerals in the nourishment of the growing pig in their mineral-ion interactions as expatriated below.

2 Mineral-ion interactions

From nutritional assessment viewpoint, there are various interrelationships in mineral metabolisms. To this point therefore, an ion may be important for the absorption, utilization and assimilation of another and by vice versa. Accordingly, there are two main types of interactions; namely positive (synergistic) and negative (antagonistic) effects. Additionally, ions can also be mutually antagonistic involving multiple ions interactions [3]. Growing swine is always fed conventional corn-soybean meal diets with inorganic source of dietary Ca such as calcium carbonate that is highly soluble [2] while Zn is poorly utilized by the growing pig [2]. Thus, dietary requirement for Zn is often three to four folds higher in growing pigs fed these conventional diets compared with those fed phytate-free diets [2]. Therefore, in this review the physiologic responses of Ca to Zn will be used to define the possible interactions between Ca and Zn in the nourishment of growing swine based on dietary factors involving mineral interactions as depicted in Figure 1 [3], including organic chelating agents and other dietary components, such as fibre.

Figure 1: Antagonistic and mutually antagonistic interrelationships among minerals
At present, our knowledge in swine nutrition has increased tremendously. This has resulted in better understanding of dietary nutrient requirements, including Ca and Zn, and the negative impact animal agriculture especially that of swine has on the ecosystem as a result of high levels of mineral nutrients in the pig manure, such as eutrophication [4]. Although nutrient release into the environment is inevitable [5] the potential exists for significant reduction in the amount of nutrients released via manure into the environment by first recognizing the metal-ion interactions between Ca and Zn. This is strictly possible by feeding the animal based on the interrelationships existing between dietary ingredients, form and level of nutrient intake and the capacity of the animal to digest and absorb the digested nutrients. As stated earlier, Ca and Zn are implicated in the skeletal system of the growing pig. Therefore, for Ca and Zn to be effectively incorporated into bone for bone and animal health/welfare, both minerals should be dietary supplied in the concentration and form that is reading available to the animal in their soluble ionic forms. This is important because the effectiveness of Ca metabolism for bone health is also dependent on Zn availability in the required physiological concentration as Ca is antagonistic to Zn [6]. This in fact may be related to the activity of Zn on vitamin D and calcitonin. Normal vitamin D production cum physiological modulation and calcitonin activity are required for Ca homeostasis, including that of phosphorous (P) metabolism [8]. This is further supported by a recent finding that Zn can negatively impact the action of osteoclasts differentiation and function [7], thereby impeding normal bone functions that also affects the growth of the pig. Additionally, Ca and P are mutually antagonistic and P in turn is mutually antagonistic to Zn [3]. These antagonistic and mutually antagonistic interrelationships existing between Ca, Zn and P further emphasize that the ratio or concentration in which they are provided in the diet to the pig should be dietary balanced to avoid the formation of insoluble Ca-P-Zn complexes in the gastrointestinal tract and therefore render them available to the animal. To this point, EcoCare feeds such as that of Land O’ Lakes Purina Feed LLC, Shoreview, MN [9] with the potential to better support pig growth and health based on true mineral digestibility values and also to influence the environment positively have evolved [9] especially in the presence of phytase [11]. This will be discussed briefly in more detail under organic chelating agents. In conclusion therefore, one of the possible interactions between Ca and Zn is metal-ion interaction involving other ions, such as P and iron (Fe).

**Phytate interaction and the use of phytase**

Also related to dietary consequence in defining interactions between Ca and Zn in the nourishment of growing pig is phytate. Phytate is not digestible by pigs, especially the young growing pig. Moreover, it chelates and thus makes unabsorbable certain important micro-minerals such as zinc and iron and to a lesser extent some macro-minerals such as Ca and Mg. figure 2 [2; 10] and therefore is another source of Ca and Zn interaction in swine nutrition.

Phytase hydrolysis by phytase into inositol, phosphate, and other divalent elements. Phytate is myo-inositol-1,2,3,4,5,6-hexakis dihydrogen phosphate that contains approx. 14 to 28% phosphorus and 12-20% calcium. Phytase also chelates trace-minerals of iron and zinc (1 to 2%) between phosphate groups within a single phytate molecule or between two phytate molecules. Phytase is the only known enzyme that can initiate the phosphate hydrolysis at carbon 1, 3 or 6 in the inositol ring of phytate. The removal of phosphate group by phytase results in releasing of calcium, iron, zinc, and other metals. As previously stated phytate is a common component of plant seeds and is particularly high in oilseeds and cereals that form the bulk of dietary ingredients in the nourishment of growing swine. Phytate decreases the absorption and utilization of zinc in the pig. This effect of phytate on zinc is exacerbated by excess dietary calcium [10] as zinc availability from diets containing phytate depends on both phytate and Ca concentrations. These complex interactions can result in the formation of insoluble calcium-zinc-phytate complexes thereby impeding Ca and Zn availability in the small intestine for absorption [12]. Overall, because of the hindrance of Ca on Zn availability for absorption, animal growth is usually significantly impaired. From physiological standpoint, the effect of these interactions is beyond the simple ratio of phytate to Zn but could better be predicted from the ratio of the relationship: [Ca x (phytate)/Zn]; where the constituents are expressed as moles per kilogram diet [12]. When this ratio is in excess of 3.5 growth rate of the pig is significantly reduced. To this end, the phytase nutritional technology has been employed in fortifying growing pig diets with commensurate phytase activity to aid in the solubility of phytate and hence the availability of Ca and Zn, including that of P to pigs [10]. Phytase activity is defined as one unit of the enzyme (FTU) that liberates 1 μmol of ortho-phosphate per minute from 5.1 mM sodium phytate at 37°C and at pH 5.5.

**Chelation interaction**

The uses of some organic chelators have been employed to better supply Zn to the growing animal. For instance, ethylenediaminetetraacetic acid (EDTA) that competes with phytate in the binding of Zn and forming a soluble complex.
has been used to enhance Zn availability and thus improve pig performance [1]. Furthermore, this nutritional strategy has been used recently involving dietary Zn glycine chelate to enhance Zn availability to weanling pigs and subsequently improved growth and serum enzyme activities as well as reducing zinc excretion in manure compared to pharmacological levels of zinc oxide (ZnO) [13].

**Dietary fibre interaction**

Another possible source of interactions between Ca and Zn would be through dietary fibre components of swine diets. This factor also has the capability to decrease Zn bioavailability and can further be exacerbated by phytate [14] – [15]. This has resulted in the processing of dietary ingredients such as pelleting and extrusion to modify nutrient and fibre structures with the sole objective of making nutrients more bioavailable to the pig. This has recently been demonstrated in a study with the pig model [16] - [17]. The mechanisms by which fibre induce interactions between Ca and Zn leading to Zn unavailability may be related to physical movement of minerals more rapidly through the gastrointestinal tract [18]. It may also involve physical or chemical adsorption of minerals on fibre components [18].

**3 Conclusion:**

Calcium and Zn are essential macro- and micro-nutrients, respectively for pigs. Ca has a huge impact in the bioavailability of Zn therefore these minerals have very profound interactions in the nutrition of the growing pig. This paper defined the major important physiological and metabolic interactions existing between the soluble ions of Ca and Zn, including other dietary factors in the well-being of the pig.

**4 References**


