Swine supplementation with zinc and copper: A review about Organic minerals as a solution for environmental contamination

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Abstract
This review critically analyzes the problematic of contamination of soils and food chains by two trace minerals, copper and zinc, usually present in inadequate levels in pig manure. Applications of copper and zinc for pigs need to be reviewed due to genetic advances in swine breeding and the emergence of the technology of organic minerals, which is a technology that in some studies has demonstrated a significant effect in reducing excretion of copper and zinc by pigs and other species. Some experiments have shown that organic trace minerals may be added to the diet of pigs at levels considerably lower compared to inorganic sources of trace minerals.

Key words: animal nutrition, trace minerals, copper, zinc, environment, organic minerals

Introduction
Copper and zinc are two trace minerals involved in key metabolic reactions and are vital components of many enzymes and molecules in the organism. Saline sources are forms of supplementation of zinc and copper being often used, but with low absorption and bioavailability, as well as the presence of contaminants are important considerations when supplementing trace minerals. Sources commonly used in animal feeding as source of are zinc oxide and copper sulphate but as they are often derived from residues of steel industry, they can potentially carry high levels of contaminants as cadmium and fluorine, for example. Market regulations have added new concerns into the meat production business with extended limitations in terms of heavy metals and other contaminants in animal feed. The purpose of this review is by a deep analysis of the literature comparing the accumulated knowledge so far about trace minerals, especially zinc and copper, and through this confrontation of ideas to discuss about a sustainable solution, for reducing the environmental contamination by microminerals.

Absorption and bioavailability of trace minerals (Cu and Zn)
Absorption of copper and zinc has been often an important limitation of their utilization. Frequently, availability is dependent of the absorption because a trace mineral must be absorbed before it can be utilized. Nevertheless, copper and zinc can be absorbed but not be utilized making its bioavailability low. The ions of copper and zinc are liberated from their inorganic sources during digestion, and may re-combine with other digestive components in the intestine forming insoluble complexes and so excreted, decreasing their uptake across the small intestine. Mineral uptake can happen in any region of the intestines, but metals are usually absorbed in the duodenum provided ions are still soluble after gastric treatment (Ashmead, 1993).

Antagonisms among minerals
The absorption of some minerals, such as microminerals, can suffer mutual antagonisms, where significantly decrease absorption and metabolism rates of these and other minerals. The competition between organic and inorganic ligands can form insoluble precipitates. Zinc absorption is reduced by phytate and calcium prejudice the uptake of zinc and copper Molybdenum and copper are highly antagonics.
Competition among minerals

Copper and iron normally compete for the same carriers because these trace minerals share at least two membrane proteins, transferring and metalotionein. The presence of copper in excessive levels linked to those proteins may occasion deficiency of iron in the organism. According to Ashmead (1993), after being absorbed by the enterocyte, some metals come back to the intestinal lumen by excretion or mucosal sloughing and resume the competition for carrier proteins. The decreasing of absorption of one specific metal originated from a series of reactions involved in the absorption of other minerals is an example of interference and competition among minerals, that impact significantly in the copper and zinc swine absorption.

Excretion

The gastrointestinal tract (GIT) is a main route of excretion for copper and zinc, and apparent uptake is always considered to be limiting. Mohanna and Nys (1998) made one report where was calculated the whole body concentrations of copper and zinc, to obtain retention values of 6% for each of them, in diets containing 20 and 180 mg/kg, respectively, of these two minerals. In another report Mohanna and Nys (1999) have also shown that the quantity of zinc excreted from the feces increased linearly with dietary zinc supplementation. Taking into account the quantity of zinc and copper in the excretion of swine, where is included endogenous trace minerals that significantly influence its excrement, perhaps calculating the whole body levels of zinc and copper would be a more accurate way to estimate the retention of these trace minerals. According to Underwood and Suttle (1999b) and their general model of mineral depletion, during depletion, the storage pools of the minerals are firstly decreased. Under any circumstances it is reported that a marked reduction in dietary zinc is constantly accompanied, by a reduction in feed intake and zinc deficiency is not known, but the decreasing in growth associated with zinc deficiency is due essentially to the reduction in feed intake.

Environmental concerns

The maximization of swine performance is a major goal of animal nutritionists and producers. This objective has been achieved, in part, by increasing the allowance of some minerals, particularly copper and zinc, or by including them at pharmacological levels aiding in the control of some enteric diseases or as growth promoters. NRC (1998) states that the common practice of using pharmacological levels of copper and zinc in swine diets has resulted, in excessive amounts of excretion of those minerals in feces, as the apparent absorption of copper and zinc does not exceed 30% of the intake. The National Research Council (NRC) publications include fairly good minimum requirement estimates for zinc and copper. Concerns about emissions are emerging from feeding animals high dietary concentrations of inorganic sources of zinc and copper to stimulate growth and health rather than supplying actual nutritional requirements. High levels of fecal excretion of copper and zinc may pose serious environmental problems in delicate areas, because of the high concentration of these minerals in swine slurry. Its subsequent accumulation in the soil can adversely affect soil microbial activity and its contribution via leaching and run-off can cause eutrophication of groundwater and freshwater sources and subsequently increase concentrations in flora and fauna. In addition, Underwood and Suttle (1999a) suggest that have been made reports of chronic copper poisoning in sheep grazing herbage treated with the liquid manure from swine fed with copper supplements, in both The Netherlands and in the USA. A study carried out in Spain showed a positive and considerable correlation between hepatic copper levels in calves and density of young pigs in the region. In areas with the highest swine densities, more than 20% of the cattle tested had the hepatic copper concentrations higher than the potentially toxic concentration of 150 mg/kg fresh weight. Hernandez (2006) affirms that there is a wide variation in inclusion levels, some 2 to 3 times higher than that recommended by NRC (1998) and BSAS (2003) in pig diets in several countries of the European Union. Spears (1996) suggest that this high copper and zinc supplementation is because that requirement are poorly defined, factors that impact mineral requirements are not well characterized, a safety margin is applied to prevent any likelihood of deficiencies and also because of the possibility of genetic differences in mineral requirements among pigs. The increasing environmental concerns about trace minerals such as copper and zinc has led to legislation in swine-dense countries like The Netherlands to limit the use indiscriminate of animal manure (Jongbloed and Henkens, 1996). Canada, Japan and Denmark are also making a cautious approach and restricted the concentration of
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these minerals allowed in pig diets. In this decade, the European Union (EU), under Commission Regulation 1334/2003, has established lower (non-pharmacological) concentrations of zinc and copper in swine diets. The dietary mineral levels allowed by the mentioned new legislation in the EU, may result in a decrease in performance, thus alternatives are being investigated to keep within the EU regulations.

The organically complexed trace minerals

The following descriptions of organic mineral complexes were given by the Association of American Feed Control Officials:

1) A metal amino acid chelate is a product resulting from the reaction of a soluble metal salt with amino acids with a molar ratio of one mole metal to one to three moles of amino acids to form coordinate bonds.

2) A metal amino acid complex is the product resulting from combining a soluble metal salt with an amino acid.

3) A metal proteinate is the product resulting from the chelation of a soluble salt with amino acids and/or partially hydrolyzed protein.

4) A metal polysaccharide complex is the product resulting from complexing a soluble salt with a polysaccharide solution declared as an ingredient as the specific metal complex. Mineral chelates have been the topic of interest of a growing number of scientists in the past few years. Results expose a better utilization and higher bioavailability for this kind of organic trace mineral supplementation in comparison to inorganic sources. Among the main objectives of improve the copper and zinc bioavailability for swine, is the possibility of decrease excretion of these trace minerals, reducing the soil contamination.

Organic trace minerals (Cu and Zn): A sustentable alternative

As mentioned, from an environmental and economic point of view, it would be necessary to decrease trace mineral levels in diets close to requirements to minimize waste contamination. In fact, feed manufacturers use higher concentrations of copper and zinc in pig diets than the values recommended by NRC (1998) to try reaching maximized performance. One alternative for replacing inorganic trace minerals sources would be the use of organic minerals. The organically chelated minerals are believed to have an improved absorption and bioavailability for the animals than their inorganic salts or oxides, providing a pathway to benefit the environment without affect negatively animals’ performance. Some studies have shown a higher retention of organic minerals, such as copper-lysine in weanling pigs (Appgar et al. 1995), zinc amino acid chelate in growing pigs (Susaki et al., 1999) and copper and zinc proteinate in weanling pigs (Schiavon et al., 2000), than inorganic forms. The replacement of 50% of the Cu, Zn, Fe and Mn sulphates in the premix by metal proteinate reduced significantly the concentration of zinc in feces in the nursery phase (506 and 1267 mg/kg DM for organic and inorganic forms, respectively) and that of copper in the growing phase (71 and 108 mg/kg DM for organic and inorganic forms, respectively) compared to the concentration of zinc and copper in feces from pigs fed sulphates at the same levels. Pigs fed the proteinate also gained weight more efficiently than pigs fed the trace minerals solely from inorganic sulphates in the nursery phase (Creech et al., 2004). Also a higher copper retention was observed when copper proteinate was added at 50 or 100 mg/kg instead of sulphate at 250 mg/kg in weaner diets (Veum et al., 2004). Other researches have successfully reduced significantly the concentrations included in the diets by using organic mineral sources only, without adversely affecting the growth performance of pigs and greatly reducing the excretion of these minerals into the environment. In nursery pigs, by including 50 mg/kg as proteinate copper, a reduction of 4.5 times in the amount of copper excreted was achieved compared to 250 mg/kg CuSO4 (Veum et al., 2004). In the case of zinc, the reduction in feces was 7 times lower when feeding 200 mg/kg proteinate zinc instead of 2000 mg/kg ZnO (Carlson et al., 2004).

Conclusions

In synthesis, high copper and zinc supplementation in diets for pigs are being targeted by growing criticism and pressure arising from recent environmental legislation in several countries due to high contaminant

Section 7 . Animal Husbandry
impact of these minerals in the environment. The scientific community must find a solution to determine the most accurate way to estimate nutritional requirements of pigs, taking into consideration various endogenous and exogenous variables and advances in animal science in the last years that may interfere with such demands. There is evidence that organic forms might be an option, however recommendations on their optimum use are yet to be well established.

References


