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Benefits of supplementation organically complexed trace minerals (Zn, Cu, Mn and Fe) in poultry and swine: A mini-review

Benefícios da suplementação de minerais traço organicamente complexados (Zn, Cu, Mn e Fe) em aves e suínos: Uma mini-revisão

Beneficios de la suplementación con oligoelementos complejos orgánicos (Zn, Cu, Mn y Fe) en aves y cerdos: Una mini-revisión

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Abstract
The aim of this review is to provide a concise update on the benefits observed from supplementing organic trace minerals such as zinc, copper, manganese and iron in poultry and pig industry, with a focus on minerals complexed with non-specific amino acids and oligopeptides. A qualitative research of the narrative literature review type was conducted. Microminerals perform several essential functions in farm animals. Supplementation with microminerals in the form of complexed amino acids or small peptides can improve eggshell thickness and color in layer hens, prevent meat quality problems in broilers and maintain antioxidant capacity in pigs. In addition to improving production and health aspects, the use of organic minerals is associated with lower fecal excretion of these nutrients, which contributes to reducing negative environmental impacts, such as damage to plant growth, soil microbiota and ecological imbalance in general. It can be concluded that the use of organic minerals is a nutritional alternative with the potential to promote efficiency and reduce negative environmental impacts in the poultry and pig industry.
Keywords: Layer hens; Broiler; Pigs; Organic Mineral; Sustainability.

Resumo
O objetivo desta revisão é fornecer uma atualização concisa sobre os benefícios observados ao suplementar minerais orgânicos como zinco, cobre, manganês e ferro na indústria avícola e suinícola, com foco em minerais complexados com aminoácidos não específicos e oligopeptídeos. Foi realizada uma pesquisa qualitativa do tipo revisão narrativa da literatura. Os microminerais desempenham várias funções essenciais nos animais de produção. A suplementação com microminerais complexados a aminoácidos não específicos ou pequenos peptídeos pode melhorar a espessura e a cor da casca dos ovos em galinhas poedeiras, prevenir problemas de qualidade da carne em frangos de corte e manter a capacidade antioxidante em suínos. Além de melhorar os aspectos produtivos e sanitários, o uso de minerais orgânicos está associado a uma menor excreção fecal desses nutrientes, o que contribui para reduzir os impactos ambientais negativos, como prejuízos para o crescimento das plantas, à microbiota do solo e ao equilíbrio ecológico em geral. Pode-se concluir que o uso de minerais orgânicos é uma alternativa nutricional com potencial para promover a eficiência e reduzir os impactos ambientais negativos na indústria avícola e suinícola.
Palavras-chave: Poedeiras; Frangos de corte; Suínos; Minerais Orgânicos; Sustentabilidade.

Resumen
El objetivo de esta revisión es proporcionar una actualización concisa sobre los beneficios observados al suplementar minerales traza orgánicos como el zinc, el cobre, el manganeso y el hierro en la industria avícola y porcina, centrándose en los minerales complejos con aminoácidos no específicos y oligopéptidos. Se realizó una investigación cualitativa del tipo revisión narrativa de la literatura. Los microminerales desempeñan varias funciones esenciales en los animales de granja. La suplementación con microminerales en forma de aminoácidos complejos o péptidos pequeños puede mejorar el grosor y el color de la cáscara de los huevos en las gallinas ponedoras, prevenir problemas de calidad de la carne en los pollos de engorde y mantener la capacidad antioxidante en los cerdos. Además de mejorar los aspectos productivos y sanitarios, el uso de minerales orgánicos se asocia con una menor excreción fecal de estos nutrientes, lo que contribuye a reducir los impactos ambientales negativos, como el daño al crecimiento de las plantas, la microbiota del suelo y el desequilibrio ecológico en general. Se puede concluir que el uso de minerales

orgánicos es una alternativa nutricional con potencial para promover la eficiencia y reducir los impactos ambientales negativos en la industria avícola y porcina.
Palabras clave: Gallinas ponedoras; Pollos de engorde; Cerdos; Minerales Orgánicos; Sostenibilidad.

1. Introduction

Microminerals perform several essential functions in farm animals, for example in poultry and pigs. Some of the main microminerals supplemented in these species are zinc, copper, manganese and iron. Among the important processes that these minerals act on is wound healing, which contributes to the prevention of foot problems in broilers (Chen et al., 2017). For layer hens, zinc is used to maintain egg quality due to its role as a cofactor for carbonic anhydrase (Elnesr et al., 2024). This enzyme is responsible for catalyzing the reaction that forms calcium carbonate, the constituent of eggshells (Bernstein et al., 1968).

In pig sows, manganese is essential for reproduction, as it has been shown to accumulate in the ovarian corpus luteum of mammals, which is associated with the maintenance of pregnancy and the secretion of progesterone (Studer et al., 2021; Studer et al., 2022). Also, of note in this category is copper's role as a cofactor of lysyl oxidase, an enzyme necessary for the formation of connective tissue and, therefore, to help prevent the causes of involuntary culling related to locomotor problems (Sampath et al., 2023; Wang et al., 2019). In general, zinc, copper, manganese and iron will be essential for a wide variety of biological processes for animals in the poultry and pig industry.

For these functions to be fulfilled properly, the mineral source used must be critically evaluated. Inorganic minerals show antagonism during the absorption process, which reduces utilization efficiency and increases the environmental excretion of these nutrients (Ashmead, 2012). Alternatively, biocomplexed minerals can be used, which have different classifications depending on the production process and constituent organic structure. In this regard, the aim of this review is to provide a concise update on the benefits observed from supplementing organic minerals such as zinc, copper, manganese and iron in poultry and pig industry, with a focus on minerals complexed with non-specific amino acids and oligopeptides.

2. Methodology

A qualitative research was conducted (Pereira et al., 2018) and of the specific type of narrative literature review. For the preparation of this article, works available in scientific research databases were selected, for example: Web of Science; PubMed, and Google Scholar. The evaluation of journals on the Scimago platform was used as a selection criterion, excluding articles belonging to the Q4 classification in the year preceding this publication (2024). Another criterion was that at least 50% of the references used had been published in the last five years. Words and expressions such as “chelated,” “organic mineral,” “poultry,” “swine,” and the application of Boolean operators guided the search for studies. For the specific topic about environmental benefits, the following examples can be added: “eutrophication”; “soil pollution”; and “plant growth.” Studies in which the organic minerals evaluated had organic ligands other than non-specific amino acids and/or small peptides were excluded, considering the objective of this narrative literature review.

3. Results and Discussion

3.1 Benefits for layer hens

In layer hens, the inclusion of organic minerals has been reported to improve various aspects of egg quality. For this category, especially at the end of the production cycle, alternatives are needed to maintain the product suitable for consumption and the economic potential of the activity. Using low doses of Zn, Cu, Mn and Fe complexed with non-specific amino acids, mineral deposition in egg yolks was found to be equivalent or superior to mineral supplementation in the form of sulphates, in addition to a better antioxidant response in the shell gland (Dong et al., 2022). In the same study, the supplementation of

organic minerals at 50% of the dose of inorganic minerals contributed positively to the gene expression of OC-116 and OCX-32, genes which together regulate the organization of calcite crystals, the elasticity and thickness of eggshells (Dong et al., 2022).

Similarly, Zhang et al., 2021, who also used biocomplexed minerals at 50% of the level of inorganic minerals, observed an improvement in eggshell thickness during the first four experimental weeks. This same treatment showed a darker shell color during the eighth week of the experiment, which is a relevant qualitative criterion for the consumer public. Also in this study, although not statistically significant, the mortality rate was the same (0.93%) for the treatments that received organic minerals at levels of 30% of the inorganic dose and 100% of the inorganic dose. The treatment that received only a basal diet, without the mineral sources tested, had a mortality rate of 2.32%, highlighting the importance of meeting the micromineral requirement regardless of the source used (Zhang et al., 2021).

In another study comparing different sources of organic minerals, higher egg production and better feed conversion were observed in response to the use of Zn, Cu and Mn in the form of metal-amino acid chelates (Santos et al., 2024a). The authors argue that this result was probably obtained due to the use of the same intestinal transport pathways for the different amino acids used for chelation, which resulted in greater absorption efficiency and a reduction in the antagonism process for the minerals. Corroborating these findings, Santos et al., 2024b found that replacing inorganic minerals with low levels of organic minerals improved production performance, egg quality and tibial characteristics, with the optimum level of supplementation corresponding to 40% of the level of inorganic minerals.

3.2 Benefits for broilers

In broilers, it is well established that the use of organic minerals can have a positive impact on health and performance. Nie et al., 2025a and Nie et al., 2025b carried out an extensive experiment with animals using a local and rustic genetic in China. Among the large volume of data analysed, meat quality parameters were assessed, and it was found that the use of low-dose organic minerals Zn, Cu, Mn and Fe significantly increased the pH of the breast cut in the first 45 minutes post-slaughter (Nie et al., 2025a). As discussed by the authors, this result is important for preventing the formation of PSE (Pale, Soft and Exudative) meat, one of the main causes of consumer rejection of the product.

The occurrence of PSE meat is also an economic indicator, since there is a reduction in shelf life (Gonzalez-Rivas et al., 2020). This effect is mainly caused by loss of liquids and proliferation of microorganisms (Chae et al., 2007.). Thus, the same treatments that showed an increase in pH in the first 45 minutes had less exudative loss (Nie et al., 2025a). The second part of this project investigated the effects on performance, with increased weight gain in animals given low and medium levels of the organic minerals tested (Nie et al., 2025b). Similarly, Vieira et al., 2020 using low and medium dosages of Zn, Cu, Mn and Fe reported ameliorate feed conversion and improve broiler viability.

Another aspect with the potential to economically harm poultry farming and which represents a criterion for assessing animal welfare is the presence of locomotor problems (Welfare Quality®, 2009; Mellor et al., 2020). One of the causes of these problems is bacterial chondronecrosis with osteomyelitis, for which the partial replacement of the minerals Zn, Cu and Mn in the form of sulphates by their chelated form with different amino acids has been evaluated, resulting in a reduction of lameness by 20 to 25%, depending on the type of flooring tested (Alrubaye et al., 2020).

3.3 Benefits for pigs

The advantages of including organic minerals in pig feed have been shown to extend to different categories. For example, in an experiment carried out with growing and finishing male pigs, a lower serum glutathione peroxidase activity and

a lower liver concentration of malondialdehyde were observed, both results referring to the treatment in which the dose of Zn, Cu, Mn and Fe used was 30% of the inorganic dose (XIONG et al., 2025). At the same time, no significant results were seen for the performance data, making it possible to infer that low dosages of organic minerals improved antioxidant capacity without altering performance (Xiong et al., 2025).

However, Thomaz et al., 2015 evaluated piglets in the nursery phase and found better feed conversion in animals that received low levels of organic minerals. On the other hand, Liu et al., 2016 did not report any improvement in performance parameters. Although they observed that supplementation with organic minerals in the form of proteinates could contribute to the prevention of oxidative stress, due to greater activity of the hepatic Cu/Zn-SOD enzyme. In fact, tissue levels of Cu and Zn were higher in the liver of supplemented animals (Liu et al., 2016).

In pig sows, hoof lesions and locomotor problems can reduce productivity and longevity, negatively impacting economic income in pig farming (Nalon et al., 2013). One of the strategies to mitigate this problem is the use of organic minerals; as explained in Varagka et al., 2016, in which the partial replacement of inorganic Zn, Cu and Mn with chelates was effective in improving the histology, morphometry and macroscopic appearance of the hooves of pregnant swine. Similar to what happens in poultry, the mechanism of action associated with this improvement is the ability of these minerals to promote greater resistance and tissue integrity in the region, as well as contributing to the synthesis of collagen and keratin (Rossi et al., 2007).

3.4 Benefits for the environment

The use of organic minerals is known to reduce the fecal excretion of these nutrients, due to a reduction in antagonism during the absorption stages and efficiency of utilization (Mellor et al., 2020; Nie et al. 2025b; Vieira et al., 2020). For this reason, negative impacts on the environment can be avoided, strengthening the practice of sustainability in poultry and pig production. An example of a process that can be mitigated by reducing minerals in the environment is eutrophication, which is defined as an imbalance in aquatic ecosystems due to the increase in organic matter generated by excess nutrients (Smith, 2009). Although minerals such as phosphorus are prominent in the prevalence of this environmental condition, metals such as copper and zinc also act as contaminants (Li et al., 2024).

Another consequence mitigated by supplementation with organic minerals is soil pollution, which can harm the development of different cultivars. According to Miotto et al, 2014, excess copper in the soil results in oxidative stress in productive vines, with an accumulation of this mineral in the leaves. Similarly, Wyszkowska et al., 2016, evaluating the inclusion of increasing doses of zinc chloride in oats and white mustard, found that growth was almost completely inhibited in both species in the treatments that received the two highest levels of contamination: 2,400 and 4,800 mg Zn^{2+} kg^{-1}. In the same study, damage to soil microbiology was observed, as the resistance of organotrophic bacteria and fungi was reduced as zinc concentrations were increased.

The accumulation of minerals can also hinder the effectiveness of waste treatment solutions. As explained by Aragão et al., 2024 analyzing plants that are part of the human diet (lettuce and onions), the presence of high concentrations of zinc, copper, manganese and iron in effluents can cause phytotoxicity by inhibiting the germination process and root growth. In addition, this study showed that effluents contaminated with excess minerals can have cytotoxic and genotoxic characteristics as a result of chromosomal and mitotic alterations in both cultivars evaluated.

4. Conclusion

In summary, the use of minerals chelated to organic compounds, including small peptides or amino acids, has been shown to be effective in improving the health, performance and well-being of poultry and pigs. In addition, harmful effects on

the environment are mitigated using this nutritional strategy, making it possible to strengthen sustainable practices in the poultry and pig industry. Therefore, biocomplexed minerals can be evaluated as part of a set of alternatives in animal nutrition capable of contributing to achieving production potential and maintaining food security in the agroindustry.

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