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# Efficiency Comparison of Organic and Inorganic Minerals in Poultry Nutrition: A Review

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**Abstract:**
Trend of using organic minerals over inorganic sources in poultry is increasing very rapidly as they are supposed to be more bioavailable and efficient, reducing feeding cost due to the reduction in dose rate without having negative influence on their performance. Moreover, environmental pollution is also reduced due to low excretion of mineral traces in birds' faeces. Most commonly used and evaluated organic forms in poultry are amino acid complexes, proteinates and chelates of zinc, copper and manganese. Most of the discussed studies have indicated the positive effects of organic minerals over inorganic in both broilers and layers. The main benefit is their lower inclusion rates due to their better absorption and low output in excreta.The objective of this review is to compare the bioavailability and efficacy of organic and inorganic minerals in poultry nutrition in the light of previous research findings.
**Keywords:** Minerals, poultry, proteinates, organic nutrition.

## INTRODUCTION

Trace minerals have been used as inorganic forms such as oxides and sulfates salts since long time in poultry diets. However, these inorganic minerals suffer a huge loss during their passage through GIT due to interfering substances present in the poultry diet. Inorganic forms are usually supplemented from two to almost ten times of the National Research Council (NRC) standards (Council, 1994) for poultry birds (Inal *et al.*, 2001). This is due to the consideration of low rate of retention and wide safety margins of inorganic trace minerals (Varun *et al.*, 2017). High inclusion then leads to the mineral wastage and environmental pollution due to excessive excretion by the birds (Leeson, 2003). There is one possible way to overcome this excretion by increasing stability in small intestine which ultimately improves the bioavailability and efficacy, also prevents the environmental pollution (Bao and Choct, 2009; Bao *et al.*, 2007). For example, 94% of total ingested zinc is added to the environment by excretion leading to phytotoxicity of soil.

Chelated complexes of minerals contains a central atom along with ligand (proteins, carbohydrates, lipids or amino acids) containing minimum of one ligand atom (sulfur, oxygen or nitrogen) with pair of free electrons (Swinkels *et al.*, 1994). Ligand atom is bound with metal atom via coordinate bond by donating electron pair from ligand to electron acceptor (Swinkels *et al.*, 1994). Inclusion of low levels of organic minerals has been widely observed due to their physiological and ecological contributions, however, data on response of the birds due to these are not enough because of reduction in their dietary levels (Saripinar-Aksu *et al.*, 2012)

While supplementing trace minerals in poultry ration, availability differences and contamination are of major concern. For instance, copper sulfate and zinc oxide are common inorganic sources of zinc for poultry feeding. These two sources are usually derived from steel industry containing large amount of contaminants like fluorine and cadmium that makes their way to the feed (Lopes *et al.*, 2017). Moreover, absorption of minerals can be disturbed due to the antagonism causing ultimate reduction in metabolism rates and absorption. While chelate complexes of metal with amino acids are inert because of ionic and covalent bonding between ligand and mineral. So, these forms remain unaffected from the factors that lead to precipitation reaction as it happen to inorganic minerals after solubilization of salt (Bao and Choct, 2009). Chelation causes the size reduction and stability improvement helping the complex to remain unaltered during their passage through GIT and absorbed in intact form without any degeneration of its amino acids (Bao *et al.*, 2007).

The purpose of this paper is to review the various research experiments conducted to investigate the role and influence of different minerals in chelated or organic form on performance of poultry birds in comparison with their inorganic form.

**Absorption of chelated minerals:**

After minerals intake in chelated form, absorption can occurs in any part of small intestine while inorganic metals are usually absorbed in duodenum. After reaching to intestinal lumen after hydrolysis in gastric region where ligand atoms covalently bonded with metal atoms work as transporter and also protect the mineral atom from various antagonists in their way like oxalic acid, gossypol, phytates etc. After that, these complexes get absorbed by enterocytes in intestine while inorganic forms only absorbed where they got transporter in the form of inorganic metal. Otherwise, they would be excreted (Świątkiewicz *et al.*, 2014).

**Use and efficacy of different organic minerals:**

**Zinc:**

Zinc is attributed as the 2nd most abundant among trace minerals and serve as an integral part of over 300 enzymes regarding their structure or metabolic and catalytic activity (Sahraei *et al.*, 2013). It has its share in many important functions such as an anti oxidant. Many hormones such as somatomedin, testosterone, osteocalcin, thyroid hormone, growth hormone, insulin require zinc for their proper secretion and functioning (Salim *et al.*, 2012). Being an important component of nucleic acids synthesis, cell division calcified matrix, it is also responsible to maintain integrity of epithelial tissues, keratin generation and bone metabolism. Moreover, it plays a key role in synthesis of proteins, catalytic and structural regulation of different enzymes, protein, fat and carbohydrate metabolism and some immune functions as well. Organically complexed zinc has higher bioavailability than its in organic form and proves to be more useful for birds (Salim *et al.*, 2011).

Many experiments have been conducted to describe bioavailability of organic Zn sources. Birds performance was not always improved as an experiment was performed by (Star *et al.*, 2012) in which observed the bioavailability of Zn complexes with amino acid against zinc sulfate in broilers. Higher bioavailability was reported when organic form of Zn as zinc propionate (Brooks *et al.*, 2013). As a result of relative slope assay along with body weight gain, tibia zinc concentration, considering total tibia zinc as response parameters, observed relative Zn bioavailability of zinc propionate was observed to be was 119, 116 and 116 % respectively in comparison with zinc sulfates (feed grade) (Brooks *et al.*, 2013). Similarly, another organically complexed zinc form as Zn proteinate had shown some positive effects on feed intake, body weight gain and Zn concentration in tibia ash and plasma of broilers. However, no difference in bioavailability between Zn proteinate and zinc sulfate was reported in that study. It may be attributed to the low chelation bonding strength of Zn proteinate (Liu *et al.*, 2013).

Some studies have also been conducted to evaluate the different organic Zn sources in laying hens but less data is available compared with broilers. Results from a study on a post molt laying hen indicated the significant decrease in mortality, shell weight and egg albumin while significant increase in egg production was also observed. In contrary to these findings, no significant effect of organic Zn with amino acid was seen (Stanley *et al.*, 2012). However, positive effects were observed regarding quality of egg shell in older hens which was measured as egg shell breaking strength ultimately increase the negative impact of age on the shell (Swiatkiewicz and Koreleski, 2008). Supplementing with organic Zn upto 40 ppm in laying quails exerted some positive influences on weight, eggs hatchability and fertility. o 40 ppm of organic Zn positively affected the weight, fertility and hatchability of eggs (El-Samee *et al.*, 2012). Similarly, (Idowu *et al.*, 2011) reported in one of its study that Zn proteinate supplementation resulted in increased egg production, and retention of zinc in comparison with zinc sulfate while increases the climatic stress under tropical conditions.

**Manganese:**

Manganese is among the most important trace minerals for all living organisms and is an as a vital component of various enzymes involved in defense system against free redicals, metabolism of protein and bone formation in the form of superoxide dimutase, ligase, transferase and hydrolases (Keen *et al.*, 2000). Manganese propionate is widely used commercial source of organic form of manganese. Manganese propionate has been observed to increase the bioavailability when included in broiler feeds in comparison with inorganic manganese sulfate. However, on molecular level, in the same study non-significant differences were observed among inorganic and organic sources while considering activity of manganese superoxide dismutase activity as an indicator of Mn concentration (Wang *et al.*, 2012). Contrastingly, (Brooks *et al.*, 2012) had shown that bioavailability of Mn proteinate was 139% of the inorganic manganese sulfate when it was added in corn soyabean based diet along with increasing level of calcium and phosphorous, In that study, estimation of Mn concentration was done through slope assay using bones as response (Brooks *et al.*, 2012).

Two research trials were performed by (Bai *et al.*, 2012) to investigate the effect of various manganese sources on transport of manganese by the activation of divalent metal transporter through gene expression in small intestine of broilers. It was seen that chelated manganese with amino acids significantly increased the bioavailability and transport of the mineral atom. Moreover, increasing chelation strength increased the transport safety (Bai *et al.*, 2012). In the same way, Li at al 2011 also reported the positive effects of gene expression of superoxide dismutase on manganese chelated with amino acids at both transcription and translation levels in chicken heart (Li *et al.*, 2010).

Likewise in layer hens, birds supplemented with organic manganese chelated with proteinate gave better performance regarding egg weight, weight gain, egg shape, shell strength and tibial strength in comparison with inorganic sources (Yildiz *et al.*, 2011). This improvement in laying performance can be attributed to peculiar distribution of manganese to different tissues particularly in bones which is directly linked with its organic form (Yildiz *et al.*, 2011).

**Copper:**

Copper is a crucial constituent of metalloenzymes which actively participates in antioxidant defense, cellular respiration, lipid and carbohydrate metabolism, bone formation, immune functions, development of connective tissue, spinal cord myelination, keratinization of tissues and an integral component of super oxide dismutase as well (Shamsudeen and Shrivastava, 2013). Inorganic copper possesses strong oxidative effect in the absence of its chelation with protein and can ultimately leads to peroxidation of fats in intestinal tract and feed (Surai, 2005). However, organic form does not have this pro oxidant activity so has improves copper status in the birds.

Bioavailability of organic copper as copper proteinate against copper sulfate was compared by (Liu *et al.*, 2012). Results indicated that bioavailability of organic copper was decreased to 79.3% of inorganic copper sulfate (100%) estimating bile concentration n of copper with consideration of daily copper intake in broilers fed on corn soyabean based diet. However, the above differences had shown no statistical difference. In contrast to that, positive effects were observed while substituting the inorganic source of copper with organic form (Cu proteinate) on body weight gain, feed conversion ratio and better utilization of nutrients in broiler birds. Effective utilization of nutrients was linked with better digestibility of dry matter, organic matter, sugars and nitrogen free extracts (Das *et al.*, 2009).

Effects of aflatoxins were also studied during the supplementation of organic and inorganic sources by (Shamsudeen and Shrivastava, 2013) who reported the alleviation of these detrimental outcomes of aflatoxins by use of organic minerals that would ultimately improves the overall performance in broilers. Moreover, (Kim *et al.*, 2011) tested the efficacy of high doses of two different organic sources of copper (copper proteinate and copper methionine) against antibiotics in broilers and observed positive influence on different growth parameters and that improvement is more than tested antibiotic (avilamycin). Furthermore, increase in lactobacilli population and reduction in the number of E. coli in intestinal lumen. It can be concluded that organic minerals have the ability to successfully replace the antibiotics. In contrary to that, no significant differences were observed by (Kwiecień *et al.*, 2014) while comparing the efficacy of copper sulfate and organic copper chelate with glycinate in broilers, however, positive effects were observed regarding biochemical characteristics of femur (Kwiecień *et al.*, 2014). In growing pullets, different inclusion levels (50 ppm, 100 ppm and 150 ppm) were supplemented of both organic and inorganic copper sources to investigate their influence on growth parameters which shows non significant results. However, decrease in plasma cholesterol, triglycerides and low density lipids caused by the organic copper supplementation as compared with inorganic copper (Jegede *et al.*, 2012).

In laying hens, (Pekel and Alp, 2011) compared the efficiency of organic form of copper (Copper lysine) and inorganic (Copper sulfate) using their high inclusion levels and noted no beneficial effects, rather non significant results regarding egg mass, egg production, egg quality, feed conversion ratio, cholesterol level in egg yolk, total plasma cholesterol, triglycerides and activity of glutathione peroxidase activity. (Dobrzañski *et al.*, 2008) stated that yeast enriched copper increased the copper concentration in egg shell, feathers and blood more than the inorganic copper. The findings from a study conducted by (Witkowska *et al.*, 2014) indicated that soyabean based diet enriched with copper through biosorption has positive effect on egg shell quality.

**Relative comparison of bioavailability between organic and inorganic minerals:**

Inconsistency is found in bioavailability of different organic minerals. The possible reason can be the nature of ligand atom and strength of chelation but the confirmatory evidence is still incomplete. Table 1 is showing the bioavailability of different organic minerals taken from previous studies.

**Table 1. Relative comparison of bioavailability between organic and inorganic minerals**

| Organic minerals | Bioavailability | References |
|---|---|---|
| Zinc (chelated) | Greater metallothionine expression than inorganic in intestinal environment | (Varun *et al.*, 2017) |
| Zinc proteinate | Relatively higher bioavailability than inorganic sources based on zinc content of tibia | (Brooks *et al.*, 2013) |
| Manganese proteinate | Relatively higher bioavailability of almost 139% to that of manganese sulfate (100%) | (Brooks *et al.*, 2012) |
| Petides and amino acids chelates of zinc | Higher relative bioavailability almost 189% of inorganic | (Sahraei *et al.*, 2013) |
| Bio-plex (organic zinc 80 ppm) | Improvement in serum copper and iron levels | (Yalçinkaya *et al.*, 2012) |
| Organic and inorganic zinc | It has high relative bioavailability of 164% than inorganic zinc sulfate | (Star *et al.*, 2012) |
| Manganese (organic) | Causes higher gene expression for Mn containing superoxide dismutase | (Luo *et al.*, 2007) |
| Zinc sources in chickens | Relatively higher expression of mRNA for metallathioneine in small intestine tissues by PCR | (Richards *et al.*, 2007) |
| Organic zinc | More deposition of minerals in bone tissues as compared with inorganic sources | (Ao *et al.*, 2006) |
| Mineral proteinates and amino acid chelates | Improved bioavailability with reduced secretion | (Wedekind and Baker, 1990) |
| Lysine complexed zinc and copper | Their organic forms are 106% and 120% more bioavailable than inorganic | (Aoyagi and BAKER, 1993) |
| Manganese methionine complex | Bioavailability is almost 75% more than inorganic source (Manganese oxide) | (Fly *et al.*, 1989) |

## CONCLUSION

It can be concluded after review of various research experiments that organically complexed minerals have many advantages over inorganic sources like improved absorption and efficacy that make the nutrionists comfortable to meet the birds requirements with low dose rates along with pollution control caused by built up of trace minerals. Consequently, it can be recommended that low dietary levels of organic minerals can be used in poultry without any negative influence on growth performance in broilers and egg production in layers as replacement of inorganic forms of minerals.

## FUTURE DIRECTIONS

As organic minerals are more effective than inorganic minerals in terms of their absorption and efficacy, little data is available on response of the birds to these organic minerals. Moreover, chelation of macrominerals like calcium and phosphorous can also be a better consideration as they are more important than trace minerals regarding their role and requirements of the birds.

## CONFLICT OF INTEREST

The authors declare that no competing interests exist.

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