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Organic Minerals in Poultry

Vinus, Nancy Sheoran[1*]

[1]Department of Animal Nutrition, College of Veterinary Sciences, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar 125004, Haryana, India.

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Poultry is one of the most important source of animal protein for humans and now a days poultry production system is highly advanced and in context of nutritional advances a number of feed additives are now used to improve the efficiency of birds e.g. prebiotics, probiotics, organic acids etc. But in addition to these, chelated minerals/organic minerals has gained very much popularity. The word chelate derives from the Greek “chele”, which means tweezers or claw. They are the result of electron sharing between a metal and a ligand. A ligand is usually an anion or a molecule, which has an atom or a pair of electrons with available valences. Common ligands contain oxygen, nitrogen, sulfur, halogens, or a combination of these due to their electronic structure. Chelated minerals have non-metallic ligands, and are therefore organic. Proteins and carbohydrates are the most frequent candidates in organic mineral combinations. After absorption, organic minerals may present physiological effects, which improve specific metabolic responses, such as the immune response.

Keywords: Organic minerals; bioavailability; preparation; poultry.

**Corresponding author: E-mail: ranavenus8@gmail.com;*

1. INTRODUCTION

In commercial poultry diets, mostly trace minerals are supplemented as inorganic forms (sulphate or oxide salts). But, inorganic trace minerals can suffer from high rates of loss due to presence of interfering substances in the diet. Usually inorganic trace minerals are supplemented upto two to ten times more than the amounts recommended by National Research Council (NRC) [1] for poultry diets [2], because of the wide safety margins of ITM (inorganic trace minerals) and their low retention rates [3], excess of which sometimes leads to waste and environmental contamination from excessive excretion [4]. So use of organically complexed/ chelated trace minerals can help to prevent these losses, due to increased stability in the upper gastrointestinal tract of the animal and have greater bioavailability of organically complexed trace minerals, which in turn would allow for lower inclusion rates and reduced excretion [5,6].

Organic minerals include any mineral bound to organic compounds, regardless of the type of existing bond between mineral and organic molecules. Proteins and carbohydrates are the most frequent candidates in organic mineral combinations. Atoms, which are able to donate their electrons, are called donor atoms. Ligands with only one donor atom are called monodented, whereas those with two or more are called polydents. Organic fraction size and bond type are not limitations in organic mineral definition; however, essential metals (Cu, Fe, Zn, and Mn) can form coordinated bonds, which are stable in intestinal lumen. Metals bound to organic ligands by coordinated bonds can dissociate within animal during metabolism whereas real covalent bonds cannot. Chelated minerals are molecules that have a metal bound to an organic ligand through coordinated bonds; but many organic minerals are not chelates or are not even bound through coordinated bonds.

Utilization of organic minerals is largely dependent on the ligand; therefore, amino acids and other small molecules with facilitated access to the enterocyte are supposed to be better utilized by animals. Organic minerals with ligands presenting long chains may require digestion prior to absorption. Mineral utilization by animals primarily depends of their absorption from the ingested feed. After absorption, organic minerals may present physiological effects, which improve specific metabolic responses, such as the immune response. Chelation is very important in the biological systems. Most enzymes require a chelated metal in their structures to become effective. Vitamins, such as vitamin B12 (cyanocobalamin), have a metal (Co) complexed to a tetradent porphyrin group, nitrogen, and a pseudonucleotide. Porphyrin is also important for the chelation of iron on hemoglobin.

The presence of trace minerals (TM) in feed is vital for the birds's metabolic processes [7,8]. TM, such as zinc (Zn), manganese (Mn), and copper (Cu) are essential to maintain health and productivity in chickens. They are part of hundreds of proteins and organic molecules involved in intermediary metabolism, hormone secretion pathways, and immune defense systems [9]; they act as catalysts in many enzyme and hormone systems as a result, they influence growth, bone development, feathering, egg production, enzyme structure and function, and appetite of chickens [10].

Variable availability and presence of contaminants, are important considerations when we supplement trace minerals in poultry diet. For instance, zinc oxide and copper sulfate are sources commonly utilized in poultry feeding, but as they are often derived from residues of the steel industry, they can potentially carry high levels of contaminants, such as cadmium, fluorine, and lead to the feed. Also mineral absorption can suffer many interferences, such as mutual antagonisms, which potentially reduce absorption and metabolism rates of some minerals. But in case of metal amino acid chelates, these are chemically inert due to the covalent and ionic bonds between the mineral and the ligand, and therefore are not affected by factors that lead to precipitation, as it happens to minerals ionized after salt solubilization [11]. Due to their stability and small size, most chelated minerals are not altered during their passage through the digestive tract, and are completely absorbed with no break down of their amino acids.

Poultry feeds contain a range of different compounds that possess anti-oxidant activities, many of them being minerals or mineral–dependent. The most important step in balancing oxidative damage and anti-oxidant defence in the poultry is enhancing anti-oxidant capacity by optimizing the dietary intake of anti-oxidant compounds. The key minerals in anti-oxidation [10,12] are: Selenium - essential part of glutathione peroxidase (GSH-Px), thioredoxin reductase (TrxR), iodothironine deiodinase (ID), physiological requirement is low, but if not met, anti-oxidant system is compromised with detrimental consequences for bird's health. There are two major sources of Se: a natural source in the form of various selenoamino acids including selenomethionine and selenocysteine or inorganic selenium in the form of selenite or selenate. Organic selenium supplementation has physiological and biochemical benefits for poultry.

Zinc is the second most abundant trace element in birds and is a component of over 300 enzymes participating in their structure or in their catalytic and regulatory actions in most species. It takes part in anti-oxidant defence as an integral part of SOD, hormone secretion and function (somatomedin-c, osteocalcin, testosterone, thyroid hormones, insulin, growth hormone), keratin generation and epithelial tissue integrity, bone metabolism being an essential component of the calcified matrix, nucleic acid synthesis and cell division, protein synthesis, catalytic, structural and regulatory ion for enzymes, proteins and transcription factors and participates in the metabolism of carbohydrates, lipids and proteins, immune function. Organic Zn has higher availability in comparison to inorganic sources and is considered to be more beneficial for bird's health.

Copper is an essential component of metalloenzymes and takes part in anti-oxidant defence as an integral part of SOD, cellular respiration, bone formation, carbohydrate and lipid metabolism, immune function, connective tissue development, tissue keratinization, myelination of the spinal cord. Inorganic copper has a strong pro-oxidant effect and (if not bound to proteins) can stimulate lipid peroxidation in feed or the intestinal tract [13]. Organic copper does not possess pro-oxidant properties and can improve the copper status of birds. Manganese plays an important role in anti-oxidant protection as an integral part of SOD, bone growth and egg shell formation, carbohydrate and lipid metabolism, immune and nervous function, reproduction and Iron also has a vital role in many anti-oxidant defence as an essential component of catalase, energy and protein metabolism, heme respiratory carrier, oxidation/reduction reactions, electron transport system. Iron is a very strong pro-oxidant and if not bound to proteins can stimulate lipid peroxidation. This is especially relevant to the digestive tract where lipid peroxidation can be stimulated, causing enterocyte damages and decreased absorption of nutrients [14,15]. If iron is included in the premix in inorganic form, it can stimulate vitamin oxidation during storage. Therefore organic iron is a solution to avoid these problems and improve the iron status of animals.

NRC [1] specifies Zn:Cu:Mn requirements for broilers as 40:8:60 mg/kg. Many commercial nutritionists supply the trace minerals at twice this level in the diet for Zn and Mn. Although the physiological requirements of the bird are met by absorption of a fraction of this amount and in practice the majority of the trace mineral supply is excreted into the environment via the faeces and urine. Broiler and layer litter in England and Wales have been calculated to contain 217 mg/kg and 583 mg/kg Zn respectively. Zinc input rates into agricultural soils in England and Wales (2004) from layer litter was calculated as 2.5 g/ha/yr which was about 60% of the input rate from sewage sludge.

Organic minerals can be classified into two categories: natural and synthetic. Natural mineral complexes are formed during normal digestion, absorption, and metabolism in a living system. During digestion, a variety of natural mineral complexes are formed which either enhance or diminish the usefulness of the ingested minerals. Herrick [16] categorized natural organic minerals into three types based on their function in biological systems. These include complexes which: (1) transport and store metal ions, (2) are essential to physiological activity, and (3) interfere with metal ion utilization. Amino acids, EDTA (ethylene diamine tetra acetate) and other synthetic ligands are important as metal binding and transporting agents in the gastrointestinal tract, which enhance uptake of metal ions from the intestinal lumen into the mucosal cells. For instance, transferrin is essential for gut absorption, transport, and storage of iron. Additionally, metal complexes may form in biological systems to allow physiological activity of certain compounds. Hemoglobin contains iron and vitamin B12 contains a central cobalt atom.

Synthetic mineral complexes (usually by dietary supplementation) conversely, are used to enhance mineral utilization efficiency. Synthetic organic minerals are produced in an attempt to increase the utilization of dietary minerals. By complexing metal ions with a variety of organic ligands, an effort is made to enhance mineral absorption across the intestinal mucosa.

2. ABSORPTION OF ORGANIC MINERALS

After intake of the organic minerals from the feed, mineral absorption can occur in any region of the intestine but metals are usually absorbed in the duodenum part of the digestive tract. After gastric hydrolysis these inert complexes of minerals reaches the intestinal lumen where ligand bounded to the minerals act as their transporter and protect them from interaction with the various antagonists present there from the diet like phytic acid, oxalic acid, gossypol etc. Then these ligand-mineral complexes get absorbed through the enterocytes while the inorganic minerals only get absorbed when there is any inorganic metal transporter otherwise they will be excreted in feaces.

Table 1. Nutritional requirements of the trace minerals for the poultry (NRC) [1]

Trace minerals (mg/kg diet)	White-Egg-Laying Strains				Broilers		
	0 to 6 Weeks	6 to 12 Weeks	12 to 18 Weeks	18 Weeks to First Egg	0 to 3 Weeks	3 to 6 weeks	6 to 8 weeks
Manganese (mg)	60	30	30	30	60	60	60
Zinc (mg)	40	35	35	35	40	40	40
Iron (mg)	80	60	60	60	80	80	80
Copper (mg)	5	4	4	4	8	8	8
Iodine (mg)	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Selenium (mg)	0.15	0.10	0.10	0.10	0.15	0.15	0.15

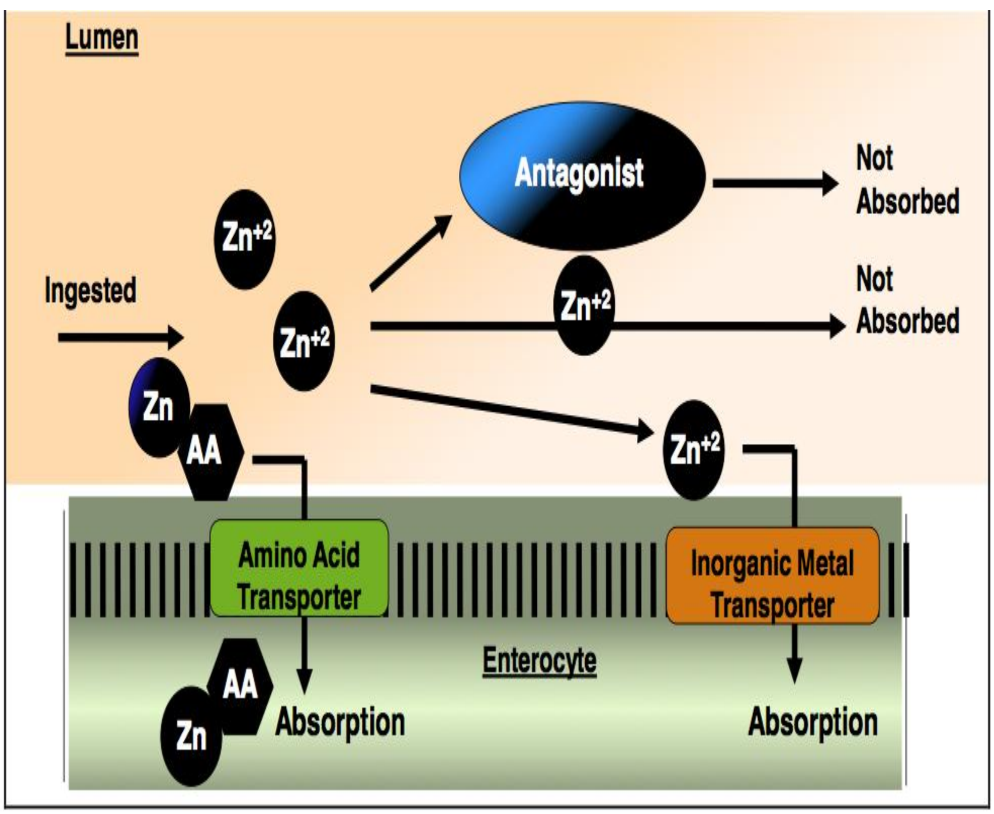


Fig. 1. Figure showing the absorption of organic minerals in digestive tract of poultry

3. PREPARATION OF ORGANIC MINERALS

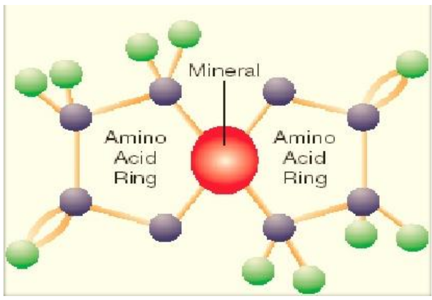
Mineral salt+ enzymatically prepared amino acid/peptide (Controlled conditions) (Hydrolysis of protein and separation by centrifugation and ultrafilteration)

↓

Ligand bind the metal atom at one or more point

↓

Form ring



Mineral proteinates are obtained by means of hydrolysis of a protein source which results into a mixture of amino acids and small peptides with chains of different lengths. In this way stable chelates are formed that protect trace elements against chemical reactions taking place in the course of digestion. This protection maintains the solubility of these substances during their passage through the gastrointestinal tract to the sites of absorption [17]. Such absorption would explain the apparent decrease in interaction between mineral forms shown in various reports as well as allowing inorganic and organic forms to be used together to advantage. Greater stability during digestion, along with absorption and transport via peptide and amino acid routes, results in higher biological availability [18,12] due to increased absorption of organic trace mineral source. Organic sources include mineral complex with methionine, polysaccharide complexes, lysine, glycine, proteinate, and amino acid complexes.

4. BIOAVAILABILITY OF ORGANIC MINERALS

Bioavailability of organic mineral in poultry are inconsistent. Table 2 shows the bioavailability of chelated minerals reported from different studies.

5. EFFECT OF ORGANIC MINERALS ON BIRD'S PERFORMANCE

Organic minerals can be utilized at a much lower concentration in the diet than inorganic minerals, without a negative impact on production performance. Inclusion of the metal specific amino acid complex had a significant effect on FCR (feed conversion ratio) over the 45 day growth period when compared to inorganic mineral but not on growth performance [33]. Incremental additions of a number of different organomineral sources of Zn were compared to the sulphate showed a significant improvement in weight gain with the organic versus the inorganic treatments and no impact on FCR [34]. Chicks fed diets containing 100% organic minerals (Zn, Cu, Mn and Fe) had significantly higher body weight and better feed conversion on comparision with those of inorganic minerals [35]. Significantly ($P<0.05$) lower serum cholesterol and higher SGPT and ALP levels were observed on feeding of organic Zn in broilers diet [36]. The trace elements Zn, Mn, and Cu influence the organic matrix of eggshells and therefore can influence the mechanical properties of the eggshell. Rodriguez-Navarro et al. [37] stated that membranes that compose the organic matrix may provide a network of fibrous reinforcement within the shell that can contribute to the resistance to breaking of the egg.

Table 2. Bioavailability of different minerals from organic and inorganic sources

Sr. no.	Organic minerals	Bioavailability	References
1.	Mn-methionine complex	74.4% more available than an inorganic source (MnO) using Mn concentration in bone	Fly et al.,1989 [19]
2.	Proteinates and aminoacid chelates of minerals	Had higher bioavailability and lowered excretion.	Wedekind and Baker, 1990; Wedekind et al., 1992 [20,21].
3.	Copper and zinc (complex with lysine)	Organic minerals were 120% and 106% more available than sulfate (inorganic) form(100%).	Aoyagi and Baker., 1993 [22]
4.	Organic Zinc	Higher bioavailability indicates more zinc was deposited in bone tissue from organic sources compared to inorganic sources.	Cao et al., 2000; Pierce et al.,2006 [23,24]
5.	Organic Zinc	Relative bioavailability (RB) of Zn from organic Zn was calculated at 121, 116 and 139% (versus ZnSO4/inorganic source at 100%)	Swiatkiewicz et al., 2001 [25]
6.	Organic Manganese	Higher expression of the gene encoding manganese-containing superoxide dismutase in broiler heart tissue than inorganic source.	Luo et al.,2007 [26]
7.	Organic Zinc	Higher expression of m-RNA for metallothionein in tissue from the small intestine exposed to organic Zn sources.	Richards et al., 2007 [27]
8.	Organic Zinc	Organic zinc had RB of 164% than zinc-sulfate (RB=100%) on the basis of tibia zinc content.	Star et al.,2012 [28]
9.	Mn proteinate	Higher relative bioavailability of Mn proteinate (139%), as compared to inorganic Mn sulphate (100%) in bone.	Brooks et al., 2012 [29]
10.	Organic Zn (80 ppm, Bio-Plex®	Addition of organic Zn and prebiotic (Mono Oligosaccharides) increased serum Cu and Fe levels.	Yalcinkaya et al., 2012 [30]
11.	Zn proteinate	Higher relative bioavailability of Zn on the basis of tibia zinc content.	Brooks et al., 2013 [31]
12.	Zinc amino acids and peptides chelates (Bio-Plex®)	High RB (147-200%) than inorganic Zn sulphate calculated from the regression of BWG by slope ratio methods.	Sahraei et al., 2013 [7]
13.	Chelated Zinc	Higher expression of the metallothionine (indicator of zinc status) in intestinal tissue than the inorganic salt.	Varun et al., 2017 [32]

Table 3. Effect of different organic minerals on bird's performance

Sr. no.	Organic minerals	Results	References
1.	Zinc/Manganese methionine	Reported that enhanced humoral and cell mediated immune function in turkeys, and improved feed efficiency.	Ferket and Qureshi.,1992 [38]
2.	Mineral specific amino acid complex	Had a significant effect on FCR over the 45 day growth period when compared to inorganic mineral but not on growth performance.	Burrell et al., 2004 [33]

Sr. no.	Organic minerals	Results	References
3.	Organic Zn or organic Cu	Reported that birds exhibited a significantly improvement in antibody immune response against coccidiosis.	Richards et al., 2006 [39]
4.	100% organic minerals (Zn, Cu, Mn and Fe)	Significantly higher body weight and better feed conversion than those with inorganic minerals.	Abdallah et al., 2009 [35]
5.	Zn glycine (90-120 ppm)	Had a beneficial effect on growth performance and immunological characteristics (Immunoglobulin A, Immunoglobulin G and Immunoglobulin M blood concentrations).	Feng et al., 2010 [40]
6.	Organic Zn	Reduced oxidative stress and improved immune responses indices.	Bun et al., 2011 [41]
7.	Zn-proteinate	The serum glucose and serum cholesterol levels were significantly ($p<0.05$) lower in organic Zn fed group than inorganic.	Idowu et al., 2011 [42]
8.	Zn glycine	Improvement in of Cu/Zn superoxide dismutase and glutathione peroxidase activity, a decrease in liver malondialdehyde content.	Ma et al., 2011 [43]
9.	Zn glycine	Increase in the height of intestinal villi, decrease in crypt depth and thickness of intestinal walls	Ma et al., 2011 [43]
10.	Mn proteinate	Better results (weight gain, egg weight, % undamaged eggs and tibia bone quality indices) than inorganic Mn sulphate.	Yildiz et al., 2011 [44]
11.	Cu proteinate (50, 100, and 150 ppm)	Decreased plasma cholesterol, low-density lipoprotein (LDL) and triglyceride in comparison to Cu sulphate.	Jegede et al., 2012 [45]
13.	Organic Zn	Significantly ($P<0.05$) lowered serum cholesterol and higher Serum Glutamate Pyruvate Transferase and Alkaline Phosphatase levels in broilers.	Mishra et al., 2013 [46]
14.	Cu proteinate	Alleviated the detrimental effect of aflatoxicosis, improved the growth performance of birds as compared to inorganic Cu sulphate.	Shamsudeen and Shrivastava,2013 [47]
15.	Organic minerals (Zn, Cu, Fe, Mn and Se)	During 2nd, 3rd and 4th weeks organic mineral supplementation showed better growth performance than inorganic.	Baloch et al., 2017 [48]

6. CONCLUSION

Thus the advent of organic sources of trace minerals with improved absorption characteristics provide an opportunity to meet bird's requirements and reduce trace mineral build up in the environment.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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