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INTAS ANIMAL HEALTH

Face2Vet
A Clinical Update

Wishing you a Happy New Year

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Mineral Chelates and Their Role in Animal Nutrition

Chelation - The Key to Better Absorption

Dear Vets,

Mineral nutrition is vital for livestock health and productivity. In India's dairy and poultry systems, mineral deficiencies often compromise growth, reproduction, immunity and milk yield. Traditional inorganic salts have limited bioavailability due to interactions with dietary components like phytates and oxalates, leading to poor absorption and wastage.

Chelated minerals, where minerals are bound to organic ligands like amino acids offer a superior solution. These complexes ensure better stability in digestive tract, improved absorption *via* amino acid pathways and reduced antagonism. Research shows chelated minerals enhance milk yield, reproductive efficiency, udder health and immunity while lowering somatic cell counts.

This issue of Face2Vet focuses on the role of chelated minerals in animal nutrition and their impact on production, reproduction and sustainability.

We invite you to read this issue and share your valuable feedback by scanning the QR code below or writing to us at face2vet@intaspharma.com.

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Introduction

Mineral nutrition plays a vital role in maintaining productivity, reproductive efficiency and overall health in dairy animals. Minerals act as co-factors for numerous enzymatic reactions involved in metabolism, immunity and hormone synthesis. They are essential components of cells and tissues, including blood, muscles, bones, teeth and soft tissue and participate in biochemical processes such as energy production, nerve impulse transmission, muscle contraction and cell permeability.

Minerals are classified into macro elements (calcium, phosphorus, magnesium, sodium, chlorine, potassium and sulphur) and trace elements (copper, cobalt, selenium, manganese, iodine, zinc, iron, molybdenum, chromium and fluorine). Although trace minerals are required in small amounts, they are indispensable for enzyme activity and metabolic functions. Requirements vary with age, physiological stage (lactating vs. non-lactating), production level, breed and mineral bioavailability from diet. Traditionally, minerals are supplied as inorganic salts such as sulfates, oxides or carbonates. However, their bioavailability is often limited due to interactions with dietary antagonists like phytates, oxalates and fiber components, which form insoluble complexes in digestive tract and reduce absorption efficiency.

To overcome these limitations, chelated or organic mineral sources have been developed. In chelated minerals, metal ion is bound to an organic ligand such as an amino acid or a peptide, forming a stable complex that resists antagonistic interactions and improves absorption. Chelated minerals offer higher bio-availability, lower inclusion rates and reduced environmental impact compared to inorganic salts. Studies have demonstrated improved milk yield, composition and reproductive performance in dairy animals supplemented with chelated minerals. In Indian dairy systems, where feed resources are often deficient in trace minerals, chelated mineral mixtures provide a practical solution for enhancing animal health and productivity.

Chelated Minerals

The term chelate originates from Greek word chel, meaning "claw," representing how the ligand tightly holds metal ion. Morgan and Drew coined term "chelate" and defined it as "a chemical compound in form of a heterocyclic ring, containing a metal ion attached by coordinate bonds to at least two non-metal ions." The phenomenon is known as chelation. A mineral complex is a mixture of a mineral and an organic compound, such as a protein or polysaccharide; thus, a chelate is a type of mineral complex.

Chelates are generated by reacting mineral salts with an enzymatically prepared mixture of amino acids and small peptides under controlled conditions. The ligand binds metal at several points so that metal atom becomes part of a ring. Amino acids and protein digestion products are ideal ligands because they have at least two functional groups (amino and hydroxyl) that can form a ring structure with mineral. In animal feed, primary chelated minerals used are trace elements such as zinc, copper, cobalt, iron and manganese. These elements form coordinate covalent bonds, giving them distinctive stability and biological activity.

Chemical Characteristics and Formation

Chelates are heterocyclic compounds where metal ion is bound to two or more atoms of spatially oriented functional groups on same ligand (Fig. 1). The most stable complexes have five or six membered rings and this enhanced stability compared to similar complexes is known as chelating effect. Sulphur-based ligands often form very strong bonds, but excessive stability can hinder mineral release and in rare cases, lead to tissue accumulation. Natural feed components such as proteins, amino acids, peptides, starch, cellulose and organic acids (citric, oxalic) possess chelating properties and help maintain mineral solubility in weakly alkaline environment of digestive tract. This prevents precipitation and improves absorption. Chelates are electrically neutral, which protects minerals from chemical reactions during digestion that would otherwise render them unavailable.

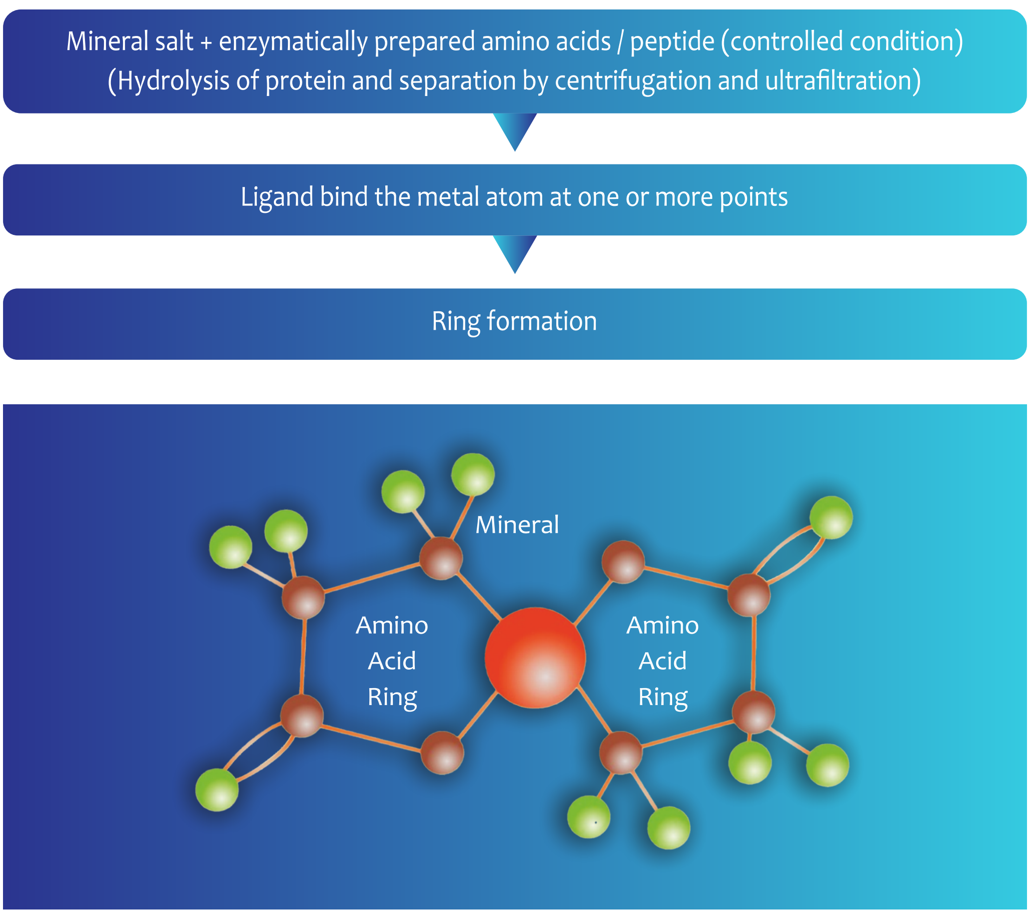

Fig. 1: Chelated Mineral Preparation Technique
(Source: Sheoran, 2017)

Biological Role and Advantages

Chelated minerals significantly enhance biological activity of metals by several orders of magnitude compared to their ionic state due to improved stability and absorption. They reduce antagonistic interactions with other minerals and dietary inhibitors like phytates and oxalates. Chelates also provide greater physical stability, reducing oxidation and separation of microelements and vitamins in feed.

Chelated minerals are particularly beneficial during periods of high nutritional demand, such as pregnancy, lactation, weaning, rapid growth and environmental stress. They improve immunity, reproductive performance and overall herd health. Chelates can replace 25–40% of supplementary inorganic minerals while maintaining or improving performance and soluble forms are even used in drinking water for enhanced delivery.

Categories of Chelated Minerals

The Association of American Feed Control Officials (AAFCO) classifies chelated or organic minerals into several categories based on type of ligand and bonding mechanism. These categories differ in chemical structure, stability and bioavailability, which influence their effectiveness in animal nutrition.

1. Metal (Specific Amino Acid) Complexes

Obtained by complexing a soluble metal salt with a single, specific amino acid. These complexes form a well-defined chemical entity with strong coordinate bonds between metal and functional groups of amino acid, ensuring high stability and excellent absorption because metal remains tightly bound and protected during digestion. They often use amino acid transport systems for absorption, bypassing mineral antagonism and provide dual benefits-mineral and essential amino acid.

Examples: Zinc methionine, copper lysine, manganese methionine

Methionine Chelation

Methionine is a sulphur containing essential amino acid with a thioether group (-S-CH_3) that provides strong ligand properties for metal chelation. When methionine binds to minerals such as zinc, copper, manganese and iron, it forms coordinate covalent bonds through nitrogen and sulphur atoms, creating a stable chelate structure. This stability protects minerals from antagonistic interactions with phytates, oxalates and other dietary inhibitors in gut.

Mechanism and Benefits

- Exhibits medium-to-strong chelation strength, ensuring high resistance to dissociation in acidic gastric environment and maintaining integrity through small intestine.
- Mimics natural amino acid absorption pathways by using carrier mediated transport systems, which enhances mineral uptake.
- Provides dual nutritional benefits: supplying both mineral and methionine, which is critical for protein synthesis, methylation reactions and antioxidant defense (*via* glutathione synthesis).
- Results in higher mineral retention and reduced faecal excretion compared to inorganic salts.

Glycine Chelation

Glycine, the simplest amino acid, acts as an effective chelating ligand for minerals such as iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn). Its small size and single amino and carboxyl functional groups enable formation of stable bidentate chelate rings with metal ions. These complexes exhibit high solubility and stability, protecting minerals from antagonistic interactions with phytates, oxalates and other dietary inhibitors in gastrointestinal tract. Glycine chelates are absorbed through amino acid transport systems, bypassing competitive mineral absorption pathways.

Mechanism and Benefits

- Glycine forms bis-glycinate complexes with metals, creating a ring structure that enhances resistance to dissociation in acidic gastric conditions and maintains integrity through small intestine.
- Glycine chelates utilize carrier mediated amino acid transport systems, improving mineral uptake compared to inorganic salts.
- Studies show iron glycine chelate has significantly higher permeability and absorption in Caco-2 cell models than ferrous sulfate, indicating superior bioavailability.
- Glycine contributes to protein synthesis, neurotransmission and metabolic regulation, while the chelated mineral supports enzymatic and structural functions.

HMTBa Chelation

2-hydroxy-4-methylthiobutyric acid (HMTBa) is a hydroxy analogue of methionine that forms bis-chelated structures with trace minerals such as zinc, copper and manganese. Each mineral ion is bonded to two HMTBa molecules, creating a highly stable chelate that resists antagonistic interactions with phytates, oxalates and sulphates in gastrointestinal tract. Unlike methionine, HMTBa contains a hydroxyl group instead of an amine group, which gives it unique absorption and metabolic properties. After intestinal uptake *via* monocarboxylate transporters and passive diffusion, HMTBa is converted into L-methionine in liver and kidney, providing a dual nutritional role: methionine supply and mineral delivery.

Mechanism and Benefits

- The bis-chelate structure of HMTBa-mineral complexes ensures strong resistance to dissociation in acidic gastric conditions and high ruminal bypass (up to 54%), protecting both ligand and mineral from degradation.
- HMTBa chelates utilize monocarboxylate transporters and passive diffusion, bypassing competitive mineral absorption routes. This mechanism enhances mineral bioavailability compared to inorganic salts.
- Supplies methionine precursor and trace minerals simultaneously, improving amino acid balance and supporting protein synthesis, methylation reactions and antioxidant defense.

2. Metal Amino Acid Complexes

A metal ion combined with several individual amino acids, but each molecule still contains one metal ion and one amino acid. These complexes improve solubility compared to inorganic salts, though their stability is lower than true chelates because they lack ring structures and have weaker bonding, making them more prone to dissociation in gut and resulting in moderate bioavailability.
Examples: Zinc lysine, zinc leucine, zinc cystine

3. Metal Amino Acid Chelates

True chelates are formed by reacting a metal ion with one to three amino acids (preferably two), creating coordinate covalent bonds and heterocyclic ring structures. For optimal absorption, molecular weight should not exceed 800 Daltons. Chelates provide superior protection against antagonistic interactions and exhibit high bioavailability due to structural stability, mimicking natural chelation in biological systems.
Examples: Copper bis-glycinate chelate, zinc bis-methionine chelate

4. Metal Proteinates

Produced by chelating a soluble metal salt with amino acids and/or hydrolyzed proteins. These complexes may include dipeptides and tripeptides. Their larger molecular size requires further digestion and variability in bonding strength can reduce bioavailability compared to amino acid chelates.

Examples: Iron proteinate, manganese proteinate

5. Metal Polysaccharide Complexes

Prepared by coating the metal with polysaccharide molecules. These complexes consist of larger molecules based on chains of simple sugars that are highly soluble in digestive tract. However, they lack strong chemical bonding and tend to dissociate easily, limiting their effectiveness.

Examples: Zinc polysaccharide complex

6. Metal Propionates

Formed by combining soluble metals with organic acids such as propionic acid. These complexes are highly soluble but generally dissociate in solution, offering limited protection against antagonists.

Examples: Calcium propionate, chromium propionate

7. Yeast-Derived Complexes

Mineral-enriched yeast products provide trace minerals in a biologically active form. These complexes are widely used for improving immunity, reproductive performance and stress tolerance in livestock. Yeast-based complexes often improve antioxidant status and immune response due to synergistic effects of yeast metabolites.

Examples: Selenium yeast (selenomethionine), chromium yeast

Mode of Action of Chelated Minerals

For chelated minerals to be effective, they must remain stable in rumen and abomasum and reach the small intestine intact. While some studies show modest improvements in apparent absorption compared to inorganic salts. Chelated minerals differ fundamentally from inorganic salts in their chemical behavior and potential biological roles. Inorganic minerals dissociate into reactive ions that readily form insoluble complexes with dietary antagonists such as phytates, oxalates and fiber components, reducing bioavailability. Chelation mitigates these interactions by binding mineral to an organic ligand (e.g., amino acids or peptides) through coordinate covalent bonds, creating a stable, ring-like structure. This configuration protects the mineral from precipitation and maintains solubility across varying pH conditions (Fig. 2).

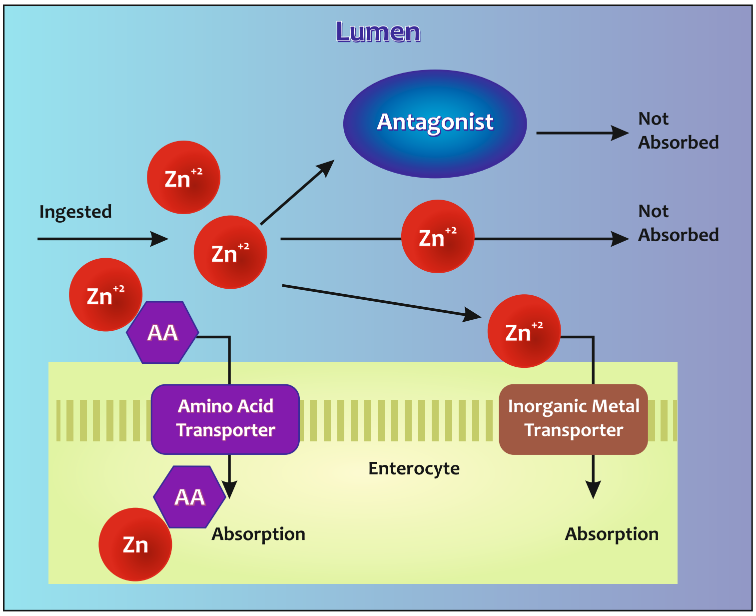

Fig. 2: Mechanism of Absorption of Chelated Minerals
(Source: Sheoran, 2017)

Chelated minerals often utilize amino acid transport systems rather than mineral-specific channels, reducing competitive absorption among minerals. Beyond absorption, evidence suggests that organic forms may enter different metabolic pools or stimulate specific biological processes compared to inorganic forms. Collectively, these properties contribute to improved mineral utilization, enhanced enzyme activity, better immune function and reduced environmental excretion.

Key Advantages

- Stability in Digestive Tract: Chelates resist precipitation and remain intact across a wide pH range.
- Enhanced Bioavailability: Chelated minerals mimic natural food-bound minerals, facilitating recognition and uptake by intestinal transport systems.
- Reduced Antagonism: Protection against interactions with other minerals and dietary inhibitors.
- Efficient Transport: Ability to use amino acid transport pathways for absorption.
- Lower Inclusion Rates: Higher absorption efficiency allows reduced supplementation levels, minimizing environmental contamination from excreted minerals.

Benefits of Chelated (Organic) Minerals

Effect on Production

Chelated (organic) minerals provide significant advantages over inorganic sources due to their superior bioavailability and absorption. Numerous studies across livestock species have shown that chelated minerals enhance growth, milk production, reproduction and overall health. Binding minerals such as copper, zinc, iron and manganese with amino acids and peptides improves their uptake and utilization, resulting in better performance and reduced mineral wastage.

Chelated zinc supplementation consistently outperforms inorganic forms in terms of average daily gain, feed intake and milk yield in cattle, goats and sheep, as well as growth performance in pigs and poultry. Glycine-based chelates, such as zinc glycinate are readily absorbed and transported into cells, ensuring efficient mineral delivery.

Chelated minerals also act as production enhancers in ruminants, improving milk yield and composition while supporting reproductive efficiency. Copper and zinc from methionine complexes exhibit significantly greater bioavailability compared to inorganic sulphates. Supplementing cows with chelated minerals has been associated with increased milk yield, higher milk fat and protein percentages and improved overall lactation performance even when mineral supplementation levels were reduced by up to 40%.

Chromium in its inorganic form has poor bioavailability, which led to the development of organic chromium sources such as chromium enriched yeast, chromium picolinate and chromium nicotinate. These forms improve chromium absorption and play a vital role during stress conditions like transit or early lactation, enhancing immune function and stress resistance. Similarly, organic (chelated) zinc sources such as zinc methionine, zinc proteinate and zinc glycinate provide higher ruminal soluble zinc concentrations compared to inorganic zinc. They positively influence rumen fermentation by increasing propionate proportions and reducing butyrate and valerate, which improves microbial efficiency in energy utilization. Chelated zinc also supports better rumen health and structural development of ruminal papillae, while inorganic zinc at high concentrations can negatively affect protozoa and cellulolytic bacteria, reducing fiber digestion. Supplementing chelated zinc at appropriate levels has been associated with improved immunity and overall health in sheep and goats. Other trace minerals, including cobalt and iron, show similar utilization patterns when provided in chelated forms, maintaining or improving absorption compared to inorganic salts.

Effect on Reproduction

Chelated trace minerals have demonstrated significant benefits in improving reproductive performance in dairy animals. Supplementation with these minerals has been associated with increased pregnancy rates, reduced open days, fewer services per conception and shorter intervals to first postpartum estrus. Amino acid chelated minerals are particularly effective because they enhance mineral concentration in uterine tissue, supporting better ovarian function and uterine health. Feeding these chelates can reduce open days by up to 42 days and decrease services per conception by approximately 42% compared to inorganic mineral sources.

Effect on Udder Health

Chelated zinc plays an important role in udder health and mastitis resistance due to its involvement in maintaining skin integrity and keratin lining of teat canal. Supplementing chelated mineral sources can reduce somatic cell counts in milk, improving milk quality and reducing mastitis incidence. Feeding zinc methionine has resulted in substantial reductions in somatic cell counts-up to 22% at lower supplementation levels and as much as 50% at higher levels-compared to inorganic zinc sources.

Pig and Poultry

In pig and poultry production, inorganic mineral sources are commonly added to diets to prevent trace mineral deficiencies. However, these diets often include minerals at levels exceeding physiological requirements, which can lead to poor bioavailability due to interactions with other dietary components. Excess inorganic minerals are largely excreted in faeces, contributing to soil and water contamination. A practical solution to reduce mineral concentrations in diets without compromising animal performance is the inclusion of organic (chelated) mineral sources, which offer higher bioavailability and greater body retention.

Studies have shown that supplementing chelated minerals in pig and poultry diets enhances growth performance, feed efficiency and overall health. In broilers, organically complexed minerals such as zinc, manganese, selenium, copper and iron improve live performance, bird health and meat quality. Layers fed copper methionine exhibit better egg shell quality compared to those fed copper sulphate. Chicks receiving diets with chelated minerals demonstrate higher body weight gain, improved tissue mineral deposition, better feed conversion ratios and enhanced immunity compared to those fed inorganic minerals.

Chelated mineral supplementation reduces metabolic disorders and mortality. Importantly, research indicates that levels of organically complexed minerals can be reduced in broiler diets without negative effects on growth, immunity or meat quality. Even at 20–25% of recommended inorganic mineral levels, organic (chelated) minerals maintain performance while reducing environmental contamination through lower mineral excretion.

In pigs, organic mineral sources such as proteinates and amino acid chelates improve growth performance and mineral retention compared to inorganic sulphates. Weaning and growing pigs fed copper proteinate or zinc methionine perform as well or better than those fed higher levels of inorganic copper or zinc. Chelated mineral supplementation allows for reduced inclusion rates without compromising growth or feed efficiency. Even when chelated minerals are included at 30% of normal levels, pigs exhibit faster growth compared to those fed full inorganic mineral levels. This demonstrates that chelated minerals not only improve performance but also support sustainable feeding practices by reducing mineral excretion and environmental impact.

Conclusion

Mineral chelates represent an advanced approach to improving trace mineral delivery and utilization in animal nutrition. Chelation offers clear advantages over inorganic salts by enhancing stability, reducing antagonistic interactions and facilitating absorption through amino acid transport pathways. Beyond absorption, chelated minerals may influence metabolic processes and enzyme activity, contributing to improved growth, immune function and reproductive performance. They also support higher milk yield, better feed efficiency and improved udder health by reducing somatic cell counts and maintaining tissue integrity. Additionally, their ability to reduce mineral excretion supports environmental sustainability, making chelated minerals an effective strategy for enhancing production and reproductive outcomes in farm animals.

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