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Technical Bulletin

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Organic Trace Minerals in Animal Nutrition

Trace mineral supplementation in animals is a subject that continues to garner a lot of interest and attention of animal nutritionists. Although trace minerals comprise less than 0.01 percent of the total mass of an organism, they are essential for vital functions. Trace minerals play a variety of important roles in the body. Trace minerals are required in small amounts compared to other nutrients, but their deficiency causes poor health and lower performance. A trace mineral deficiency in the diet can reduce animal production by 20-30%. Trace mineral supplementation in animal diets has been used as an approach to ensure rapid development, improved reproductive health, and improved immune response (Overton and Yasui., 2014).

Trace minerals are needed for several reasons such as immune system functioning, enzyme formation, vitamin synthesis, normal reproductive function, hormone, blood synthesis and more. A deficiency in any trace mineral can result in the impaired function of any of the physiological processes listed above. However, these deficiencies can be corrected through proper trace mineral supplementation, thus preventing further impairment. Trace minerals have been supplemented in animal feeds as inorganic salts such as sulphates and chlorides. However, the bioavailability of trace minerals from inorganic sources is relatively lower to that of minerals from feed and fodder sources (Spears., 2003). Recent advances in mineral research indicate that absorption and utilization of trace minerals is higher if they are supplemented in organic forms.

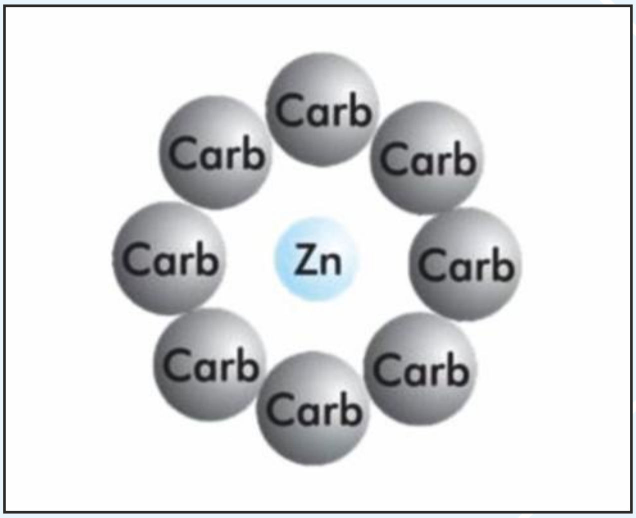
Different Forms of Organic Trace Minerals

According to Association of American Feed Control Officials (AAFCO, 1998), organic minerals are metal ions chemically linked to an organic molecule (amino acids) forming highly stable chemical structures with high mineral bioavailability.

The categories of organic trace minerals as defined by Association of American Feed Control Officials (AAFCO, 1998) include:

Metal polysaccharide complexes:

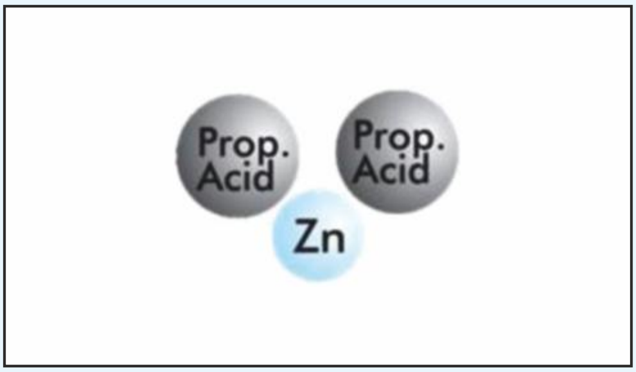
Metal polysaccharide complexes are formed by



complexing a soluble salt with a polysaccharide solution, e.g., Zn or Mn-polysaccharide complex.

These complexes are developed by coating the metal with polysaccharide molecules. These are bigger molecules made up of simple sugar chains that are known to be extremely soluble in the gastrointestinal tract. Case and Carlson (2002) and Buff et al. (2005) found similar growth performance in pigs on using reduced levels (500 mg/kg) of Zn-polysaccharide complex (Zn-PS) as compared with pharmacological level (3000 mg/kg) of ZnO. Sandoval et al. (1998) did not find improved Zn bioavailability using either Zn-gluconate or Zn-acetate. The utilization of Cobalt by sheep fed dietary levels of 40 to 60 mg/kg was equal from cobalt-sulphate and cobalt-glucoheptonate (Henry et al., 1997; Kawashim et al., 1997). Similarly, the utilization of Fe from Fe-citrate, Fe-fumarate and Fe-gluconate are essentially equal to that of Ferrous sulphate (Ammerman et al., 1995).

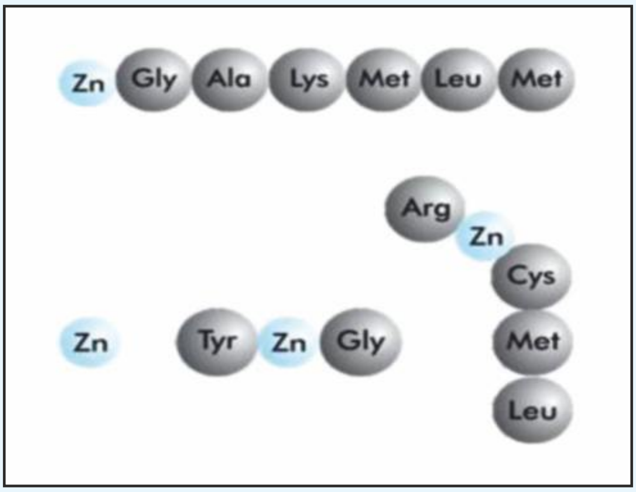
Metal propionates:



When soluble metals and propionic acid are combined, metal propionates are formed. Metal propionates are highly soluble and generally disassociate in solution.

Metal proteinates:

Metal proteinates result from the chelation of a soluble mineral salt with amino acids and /or partially hydrolysed protein. e.g., Cu, Co and Mn proteinates.



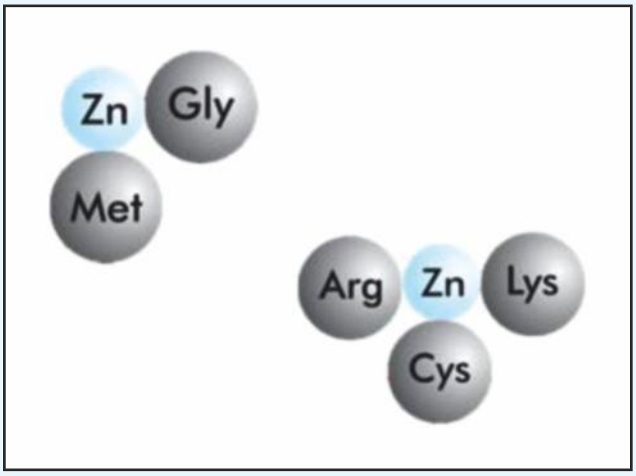
The final product may contain single amino acids, dipeptides, tripeptides or other protein derivatives. As a result, the molecular size of metal proteinates sometimes varies which influences bioavailability of minerals. Additionally, due to the size of its ligand, metal proteinate has a structure with a low stability constant. Metal proteinates are easily broken apart, especially when the pH changes, causing loss of heterocyclic chelate ring structure.

Yeast Based Complexes:

Yeast has the ability incorporate trace minerals within its cells. Selenium-enriched yeast, for instance, represents an important source of organic selenium used in animal nutrition. Presently the most common form is selenium yeast with selenium complexed with a methionine molecule (selenomethionine). Chromium enriched yeast also has gained popularity for improving animal production (Rao et al., 2012).

Metal amino acid chelates:

Metal amino acid chelates are produced when a metal ion from a soluble salt reacts with amino acids in a mole ratio of one mole of metal to one to three (ideally two) moles of amino acids, through coordinate-covalent bonds. In the process a specific mineral is bound to two or more nonspecific amino acids. The molecular size of such chelates is upto 800 Dalton.

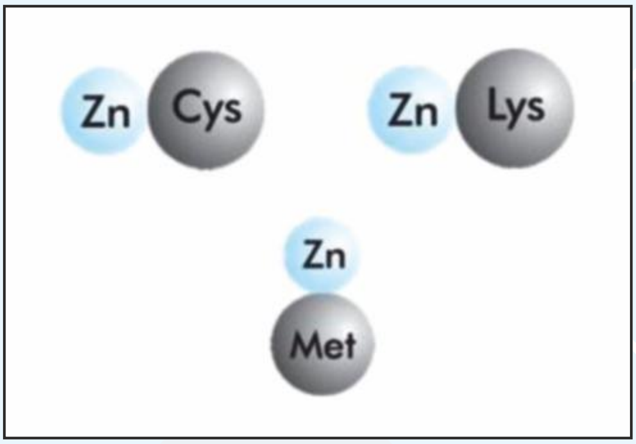


A chelate is formed only when a coordinate covalent bond exists between the metal and the amino acid.

Metal amino acid complexes:

These complexes result from complexing a soluble metal salt with an amino acid (s), e.g., Zn-Amino acid complex and Cu- Amino acid complex.

A metal atom is complexed with numerous single

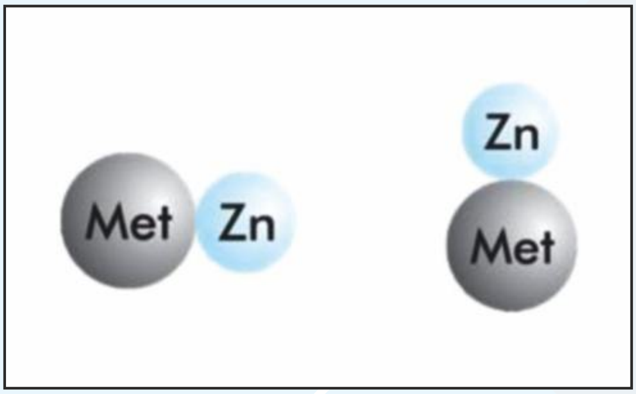


amino acids to form metal amino acid complexes.

In the blend, each individual molecule has one metal ion and one amino acid but from distinctly different amino acid groups. For instance, for a Zinc complex in this category, the blend may have Zinc methionine, Zinc lysine, Zinc leucine, Zinc cystine, etc.

Metal complexes (with some specific amino acid):

Metal complexes are formed when soluble metal salt combines with an amino acid. For instance, one of the most common metal complexes is Zinc methionine which is produced by combining Zinc sulphate and the amino acid methionine. Other such common complexes include Copper lysine and Manganese methionine.



Trace mineral glycinates with glycine as a ligand are popular as glycine is readily absorbable in the gut and is transported directly into the cells. Supplementation of Zinc with glycine chelate improves the growth performance of pigs (Wang et al., 2010) and broiler birds (Feng et al., 2010). These complexes are most efficiently absorbed in the gut amongst all the organic minerals.

Glycine is the smallest amino acid occurring in nature (i.e., < 75 Dalton size). As glycine is the smallest amino acid, any complex of the trace element with glycine is the smallest possible organic trace mineral entity. Glycine is naturally colourless, odourless and highly soluble.

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Glycinates are stable, highly bioavailable, electrically neutral and form stable trace element bonds. Monomeric glycinates have a unique chemical structure consisting of only one glycine and one metal, thus allowing a higher metal content relative to other organic trace minerals. The small size of glycinates enables better absorption.

Mechanism of Absorption of Organic Trace Minerals

Inorganic trace minerals commonly included in diets are solubilized by digestive fluids in the gut. They must first attach to ligands, which facilitate their passage from the lumen of the intestine into the cells of the intestinal wall. Two limitations, however, come into play (i) many free metal ions do not find a ligand and simply pass through the gut to be excreted and (ii) antagonists bind to the free metal ion, making it unavailable for absorption.

In the case of an organic trace mineral, the metal ion is pre-bound to a ligand. The organic trace mineral is thus theoretically not affected by the digestion process and moves directly to the gut lining for absorption. Thus, organic trace minerals allow more metal to be absorbed and increase the trace mineral status within the animal relative to inorganic trace minerals.

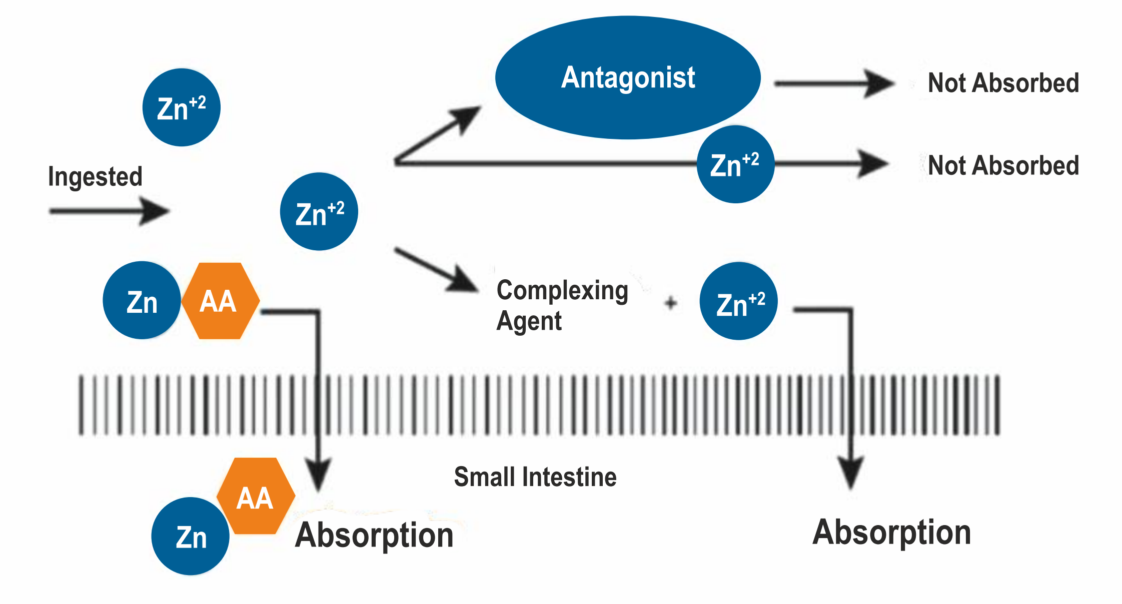
Characteristics of an Ideal Ligand

- The ligand should not separate while the mineral travels through the GI tract.
- The ligand prevents the mineral from being tied up by an antagonist.
- The ligand with high stability implies the mineral arrives intact at site of absorption.
- The ligand's molecular weight along with the molecular weight of the mineral are critical for organic trace mineral absorption.

Factors Affecting Absorption of Organic Trace Minerals

Molecular Size:

Molecular size of an organic trace mineral is a major factor in determining its bioavailability. The molecular size of organic trace minerals depends on the size of the ligand and the molecular ratio of ligand to the metal. The variations in the molecular size of organic trace minerals affect



Metal absorption in the gut

their bioavailability and, ultimately, their ability to influence animal performance. It is generally accepted that a smaller size of an organic mineral is advantageous for absorption.

Solubility:

High water solubility is a key indicator of high bioavailability of an organic trace mineral. Highly soluble organic trace minerals are homogenously distributed in the intestinal content. Insoluble materials will not be absorbed in sufficient concentrations and will pass through the digestive tract of the animal. The solubility of an organic trace minerals generally decreases as the size of the ligand increases from a single amino acid to a dipeptide, tripeptide, and so on. If the size of the ligand exceeds a tetra or pentapeptide, the ligand is almost insoluble in the intestine.

Stability:

The effectiveness of an organic trace mineral is attributed to the association of the metal with the ligand. It is important for the metal-ligand complex to remain stable in the digestive tract. The pH in the digestive tract varies between 2 and 7. This means, that when ingested by an animal, organic trace minerals face the challenge of an acidic to a neutral environment. This change in pH levels affects the stability of the organic trace minerals complex as a reduction in pH could lead to an increase in the dissociation of the mineral and ligand.

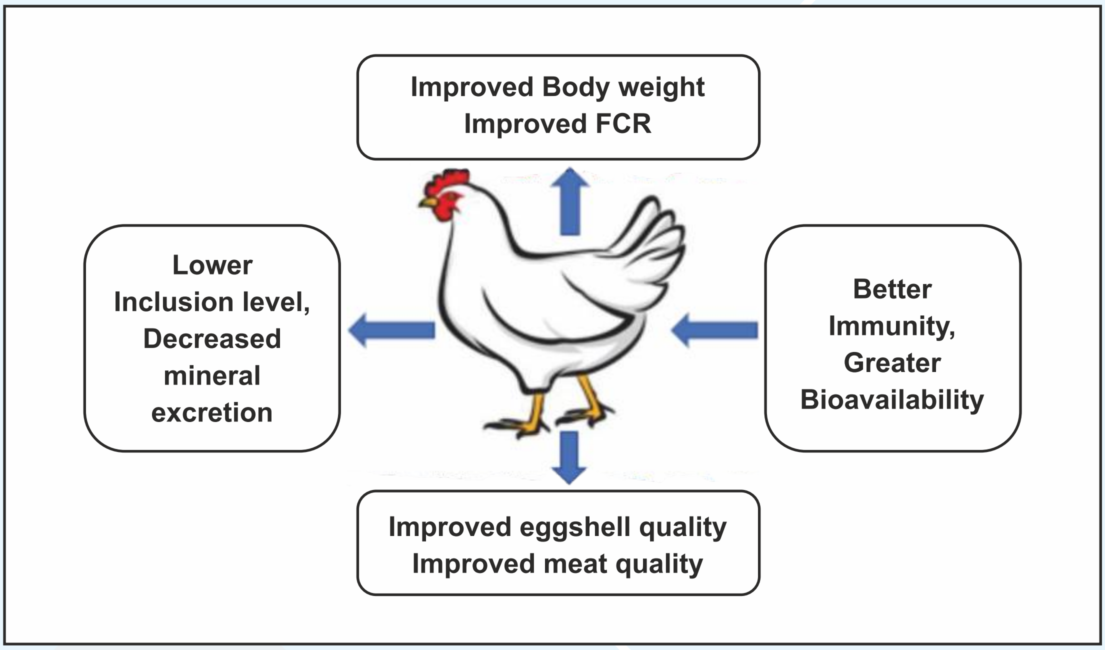
High-quality organic trace minerals should remain stable throughout the digestion process and should not interact with phytates, fibres, clays and minerals already in the digestive tract, minimizing the risk of antagonism.

Importance of Using Organic Trace Minerals in Animal Nutrition

Organic trace minerals enjoy enhanced bioavailability that is corroborated by their superior efficacy on animal performance. Studies suggest that binding Cu, Zn, Fe and Mn with amino acids and peptides can enhance the bioavailability of these trace minerals, thereby leading to improved milk & egg production, growth, reproduction, and general health status in animals.

Poultry:

Organic trace minerals are essential to optimal chicken development as they are involved in physiological functions that are essential to the



maintenance of life, including reproduction, growth, immune system, bone formation and energy metabolism.

In broiler nutrition, Organic trace minerals have been used in broiler feeds as they enhance live performance, bird health and meat quality characteristics. The most used organically complexed minerals include Zinc, Manganese, Selenium, Copper and Iron.

In layer nutrition, trace minerals play a very important role as the entire process of egg production is dependant on trace minerals. In breeders, optimum trace mineral absorption supports shell strength, the internal structure of the egg and tissue integrity of the unhatched chick. At the laying period, organic trace mineral nutrition plays an increasingly important role, ensuring the continued production of high quality eggs and the overall well-being of the bird. Eggshell quality and strength declines when zinc, copper, and manganese are not absorbed sufficiently. Supplementing a diet with organic trace minerals helps the bird lay higher-quality eggs as it grows older whilst minimising breakage losses that are prevalent among older layers.

Moreover, organic trace minerals appear to provide a pathway to minimise trace mineral levels in the excreta and meet the broiler chicken requirements for optimal growth and health (Leeson 2003).

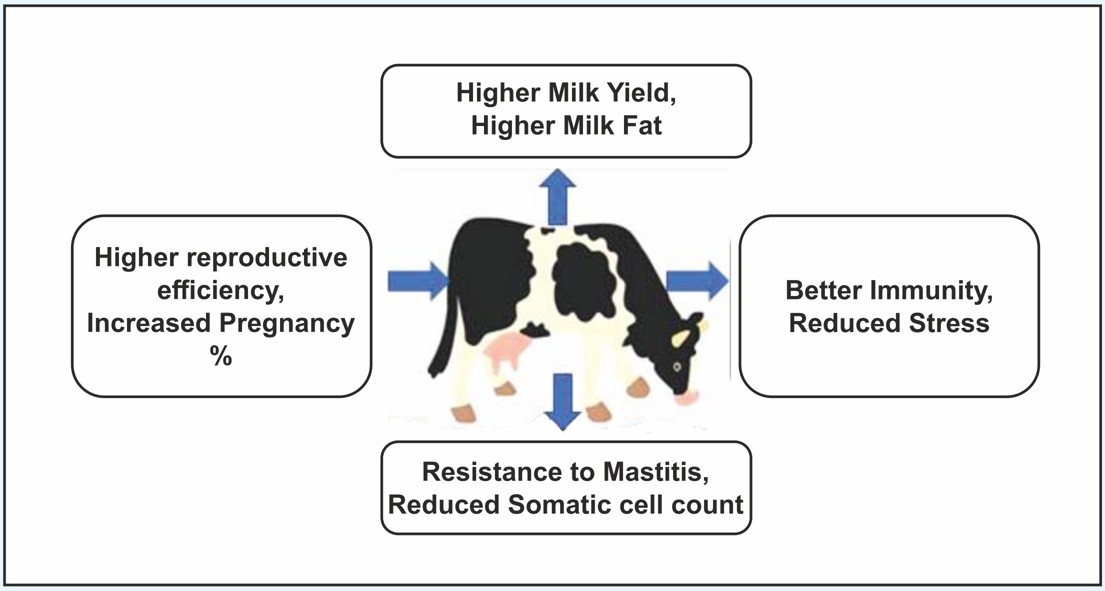
Dairy:

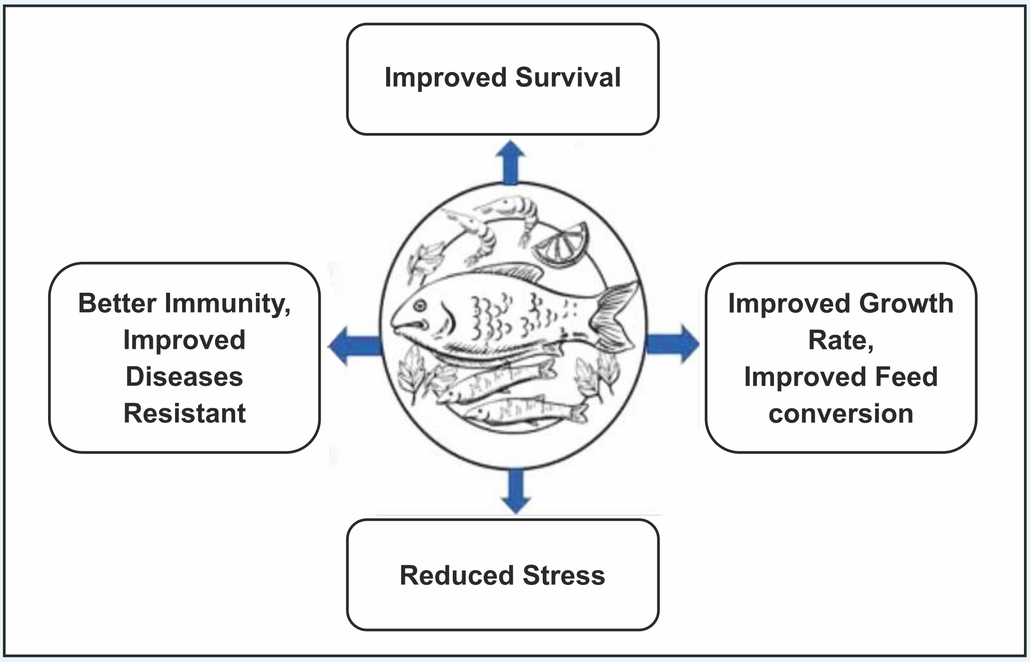
The quantity and quality of milk are critical parameters in dairy production. Studies (Griffiths et al., 2007; Siciliano-Jones et al., 2008; Hackbart et al., 2010) have shown a positive effect on milk yield by supplementing ration with organic trace minerals in a feeding trial.

Several studies have suggested that organic trace minerals improve various indices of reproduction in cows, including an increase in pregnancy percentage (Nocek et al., 2006; Defrain et al., 2009), a reduction in open days and services per conception (Kellogg et al., 2003), and a decrease in days to first postpartum oestrus (Campbell et al., 1999). Therefore, supplementation of minerals through organic sources may be more effective in addressing reproductive issues in ruminants.

Organic Zinc is beneficial in enhancing resistance to mastitis because of the role of Zn in maintaining skin integrity and the keratin lining of the streak canal. Udder health can be improved through reduction in somatic cell counts in the herd by supplementation of the organic mineral sources.

Organic chromium is beneficial in stressful situations like transit stress, late pregnancy, calving and early lactation in dairy cows.





Fish & Shrimp:

In aquaculture, a well functional immune system is critical for shrimp/fish survival and performance. Each trace mineral component has a unique role in the immunity of cultured animals. However, Zn, Mn, Cu, and Se are the most important trace minerals supporting immunity. The role trace minerals play in immunological defence and antioxidative protection is well established.

In intensive culture, fluctuating environmental and water quality conditions combined with practical husbandry practices can result in the development of stress situations that affect the physiology and micro mineral requirements of the species cultured. During stressful situations, the selenium status is effectively maintained by an organic form of selenium. Stress conditions can also affect the osmotic and ionic regulation in gills. The trace element is helpful in reducing stress and for disease resistance of shrimps/fishes in aquaculture.

A study to examine the effectiveness of organic trace minerals in shrimps was undertaken by Professor Orapint Jintasataporn (Department of Aquaculture, Faculty of Fisheries, Kasetsart University, Thailand). In this study, the effect of organic trace minerals on the growth performance and immune parameters of white shrimp (Litopenaeus vannamei) was observed. Professor Orapint concluded that glycine based organic trace minerals exhibited the fastest growth and best feed conversion ratio whilst displaying the highest survival rates in shrimps.

Balanced trace element nutrition neutralizes oxidative stress

Contamination in environment due to excess use of trace minerals in feeds

There are concerns that excess minerals released by farm animals into the environment are a source of pollution. Copper and Zinc are two minerals that are often used in excess in feed for land animals, as replacements for antibiotic growth promoters (AGPs). However, no such benefits have been shown in animals. Many are now concerned over excessive use of minerals as well as on use of mineral supplements with poor bioavailability. Excess or unabsorbed minerals in feed are often excreted directly into lakes, rivers and other waterways thereby contaminating them and posing health hazards to humans.

On the other hand, organic trace minerals improve metabolic utilisation by maximising trace mineral status and increasing uptake into critical tissues whilst decreasing excretion through faeces, urine and bile.

Characteristics of Organic Trace Minerals

The are four key characteristics of Organic Trace Minerals:

- Good solubility in water
- Good bioavailability
- Stable throughout the digestion process
- They should generate an economically beneficial response in the animal

Advantages of Organic Trace Minerals

1. **Enhanced bioavailability:**
   Organic trace minerals exhibit enhanced bioavailability. Certain minerals are recommended only in the organic form due to very low bioavailability in their inorganic forms e.g Chromium

2. **Superior metabolic activity:**
   Complexed trace minerals have been shown to exhibit superior metabolic activity and enhance animal performance.

3. **Environmental safety:**
   With growing awareness for a cleaner environment to decrease contaminants in the environment through the animal excreta, the use of organic trace minerals can be advantageous.

4. **Meeting the needs of high yielding animals:**
   It is opined that inorganic minerals have an absorption threshold beyond which the system is unable to uptake the mineral. Organic minerals allow for mineral availability and uptake beyond this threshold.

Commercially available forms of organic trace minerals

Sr. No.	Organic Trace Minerals	Molecular Size	Solubility	Digestive enzyme resistance	pH resistance	Stability
1	Metal specific Glycine complex	< 300 Dalton	Excellent	Strong	Excellent	High
2	Metal specific Methionine complex	> 300 Dalton	High	Strong	Low	Medium
3	Metal amino acid chelate	> 300 Dalton	Medium	Moderate	Low	Medium
4	Metal proteinate	> 1500 Dalton	Low to Medium	Weak	Low	Low
5	Metal Polysaccharide complex	> 1500 Dalton	Low	Weak	Low	Low

Conclusion

Organic trace minerals offer a desirable conjunct to inorganic trace minerals as inorganic trace minerals reach absorption constraints due to several factors as ligand availability, limited time, saturated absorption sites etc. All organic minerals are not the same; a smaller size, increased solubility, established stability are desirable traits whilst selecting an organic mineral. Organic minerals are a boon to the environment as they are readily absorbed and, therefore, do not contaminate the soil and ground water. The challenges of increased nutrient demand of high yielding animals may be addressed by using quality organic minerals.

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