**S3.1**

## The Use of Organominerals in Poultry Production

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Mineral nutrition has suffered from a lack of research into the fundamental aspects of nutrient availability and animal requirements. In view of the key role that many trace minerals have in the development of essential tissues and maintenance of animal health this deficit can lead to production and welfare problems. The advent of new sources of trace minerals with improved absorption characteristics provide an opportunity to meet animal requirements and reduce trace mineral build up in the environment.

**Key words:** Requirements; Structure of Organominerals; Absorption; Performance; Welfare

**Introduction:**

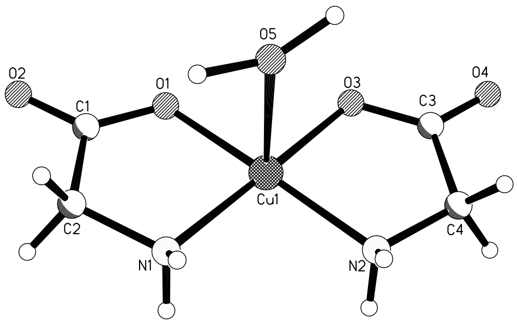
Trace minerals are essential components of all diets in order to ensure the health and productivity of livestock species. Trace mineral requirements are, in general, ill defined and our understanding of the relationship between mineral source and the ability to meet an animal's physiological demand lacks the precision with which nutritionists can, for example, formulate for protein requirements. This is partly a consequence of a lack of fundamental research in this area, most tables of requirements are based on research work carried out in the 1960s and 70s, and the fact that provision of essential trace minerals as inorganic salts is relatively inexpensive. Current prices for zinc sulphate (€550/MT) mean that providing 80mg/kg zinc in the diet costs around €0.19 per tonne of feed. As a consequence of this and the uncertainty as to the true availability of the trace element from its inorganic source diets tend to oversupply to ensure adequate provision. In addition the use of heavy metals such as copper and zinc as a means of modifying microbial balance in the gut in the absence of in feed antibiotics has encouraged this trend. Thus although NRC 1994 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.

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 and similar to that added from pig slurry (Nicholson and Chambers, 2008). Concern about the extent of environmental contamination by trace minerals through animal agriculture has prompted legislation within the EU which defined the maximum level for copper, zinc and manganese in animal feeds. This legislation (EC 1334/2003) enacted in January 2004 was designed to address the issue and can be seen as a starting point in this debate. Further pressure will undoubtedly be exerted on animal agriculture to further reduce these inputs into the environment.

This presents both a challenge and an opportunity to the animal feed industry. The challenge is to improve our understanding of the trace mineral requirements for livestock at each stage of the production cycle. The opportunity is to meet these needs more effectively lowering the inclusion rates in feeds and reducing environmental impact of animal production systems.

**Mineral Availability**:
Diet formulation dictates that nutritionists balance the requirements of the animal at each physiological stage with a sufficient supply of each nutrient. In the case of trace minerals this process is hampered by (a) our lack of understanding of the relationship between efficiency of supply in terms of the different sources and (b) biological demand such as tissue requirements during each stage of growth and development. In this respect "bioavailability" of trace minerals has been defined as: "The maximal tissue mineral utilization for biological functions in metabolism, based on the amount of ingested mineral" (Kirchgessner et al, 1993). When using inorganic trace mineral salts it is accepted that the availability of the mineral for absorption varies dependent upon the salt used and the other components of the diet. For example differences in availability of zinc between zinc sulphate and zinc oxide in a chick bioassay were demonstrated by Wedekind and Balker (1990). Their studies based on tibia zinc concentration showed that the bioavailability of zinc from the oxide was only 0.44 that from the sulphate. Studies of this type were summarized by NRC (2001) showing that in general sulphates have the highest availability and oxides the lowest. The true availability of a trace mineral can only be determined in closely controlled balance studies in which the endogenous turnover of the element is quantified using isotope techniques. Using this technique Wedekind et al (1991) were able to demonstrate that true Mn absorption was 8.4% in chicks fed diets supplemented with 100 mg/kg Mn and only 2.8% in an unsupplemented diet. There has been little further work reported using these techniques.

In terms of defining requirements for poultry the most frequently used reference is NRC (1994). In a recent review of the NRC (1994) values Leeson (2005) highlighted the point that despite the fact that commonly used feed raw materials often meet the requirements for copper and zinc these are still added to the diet as inorganic salts with a final concentration of up to four times published recommendations. Nutritionists point to the uncertainties associated with availability of trace elements from both feed sources and inorganic salts plus our lack of quantitative knowledge of requirements under modern production conditions as a rationale for this "blanket" approach. The development of organominerals as an alternative source of trace minerals with specific characteristics has been suggested as a way of improving delivery of key minerals to the tissues of the animal and reducing levels in the diet. An essential characteristic proposed for such a product is the ability to remain stable during passage through the gut preventing interactions between the mineral cation and digesta components such as phytic acid which will inhibit absorption (Windisch and Kirchgessner, 1999). Apart from the selenomethionine source of selenium from selenized yeast, organomineral products licensed for use in animal feeds within the EU include amino acid complexes, proteinates and specific chelates of glycine and more recently the Cu chelate of the hydroxy analogue of methionine. Chelation of the trace mineral with the organic ligand is regarded as the most stable structure with a 2:1 ratio between the ligand and the trace mineral showing particular stability over a wide pH range. The advantage of these latter products is that they are chemically defined and the structure can be determined by physico-chemical methods such as X-ray crystallography (Fig 1 molecular structure of Cu glycinate and Zn chelate of hydroxy analogue of methionine). A number of reports (Cao et al, 2000;Guo et al, 2001 and Li et al, 2004) have attempted to correlate chemical structure with availability in the animal and these studies underline the difficulty in developing chemical assay procedures to evaluate the structure and stability of the organominerals and the importance of correlating *in vitro* assays with *in vivo* effects. The evaluation of bioavailability of organominerals has been reviewed by Schlegel (2005) who highlighted the impact of assessing these parameters below or above requirements on different biological parameters. Many studies have tended to focus on effects such as increases in tissue or bone levels when compared to an inorganic source. Such studies in poultry with Cu (Guo et al, 2001; Wang et al, 2007); Mn (Yan and Waldroup, 2006) and Zn (Ao et al, 2006) conclude that the availability of trace minerals from the organomineral source ranges between 110 and 180% when compared to the most available inorganic salt.




GlyTrex™Cu

Mintrex® Zn

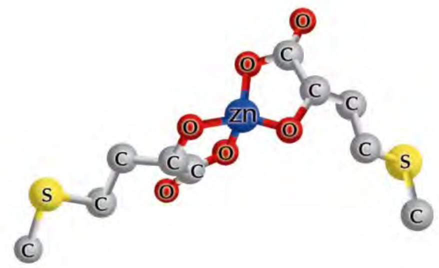



**Fig. 1 Molecular structure of GlyTrex™Cu and Mintrex® Zn showing the two ligand molecules covalently bonded to the mineral. For GlyTrex™ the ligand is glycine, for Mintrex® the ligand is methionine hydroxy analogue**

Changes in the tissue or blood levels of the target mineral, however, are subject to homeostatic control within the animal and may not reflect actual changes in mineral supply (Mohanna and Nys, 1999). In recognition of this two recent reports have focused on development of assays which evaluate the effect of increased mineral supply at a more fundamental level within the cell. Luo et al (2007) published a method based on the expression of the gene encoding manganese-containing superoxide dismutase in broiler heart tissue which is sensitive to Mn supply. The method discriminated between an inorganic Mn supply and chelated sources of Mn in terms of m-RNA levels in heart tissue of birds fed the different sources for seven days. Richards et al (2007) have evaluated to expression of m-RNA for metallothionein in tissue from the small intestine in chickens exposed to different Zn sources. Metallothionein expression is regulated by Zn status and birds fed a diet containing a stable chelated form of Zn showed a significantly higher expression of the m-RNA in intestinal tissue than birds fed equivalent levels of Zn as the inorganic salt, Zn proteinate or as an amino acid complex (Fig. 2). These data support the proposition that feeding the chelated source resulted in an increased delivery of Zn to the gut tissues. These molecular techniques allow for discrimination between trace mineral sources at the tissue level and may help explain some of the benefits in terms of animal performance and health when using particular organominerals.

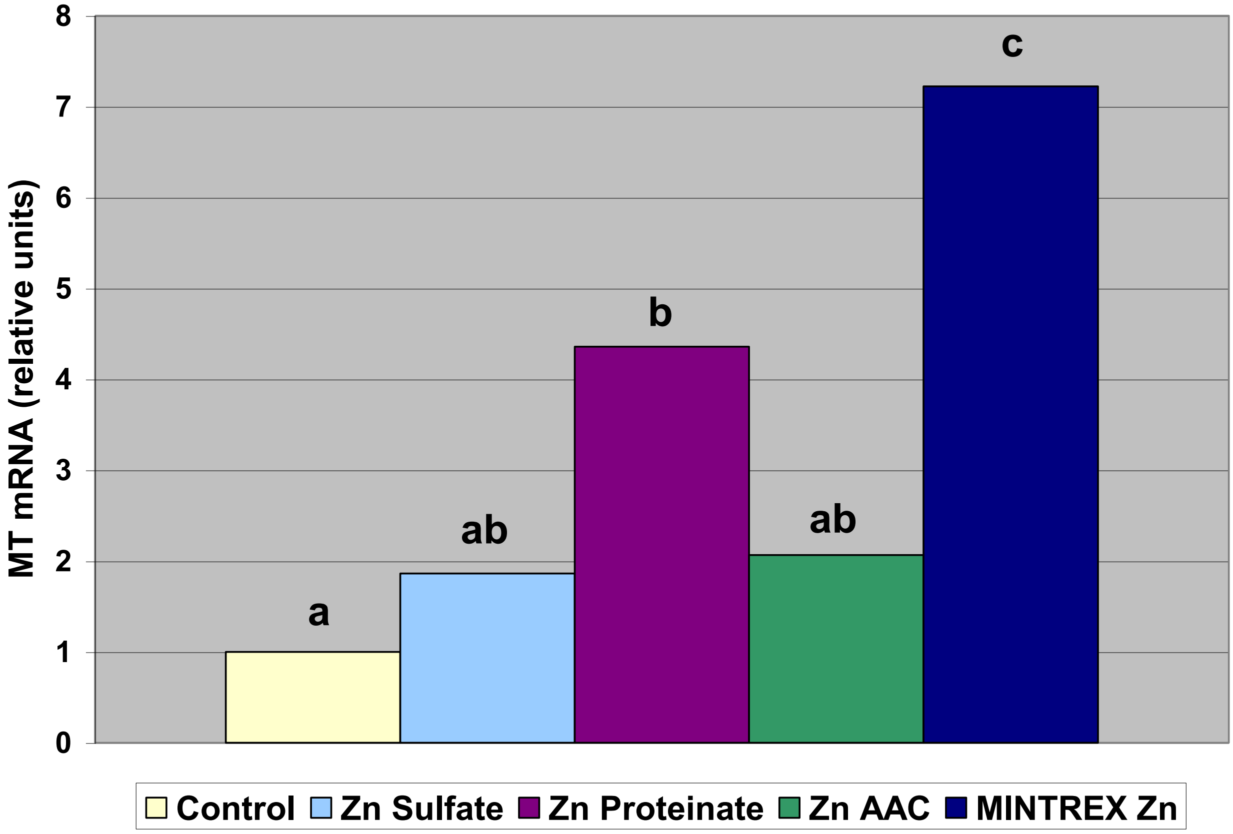



**Fig. 2 Effect of different Zn sources on gut tissue expression of metallothionein m-RNA in chickens**

**Impact On Performance**:
Evaluating the impact of changes in supply of individual trace minerals is not straightforward as they have a range of metabolic roles which can affect animal health and performance. In addition, many trial designs which compare responses to inorganic mineral sources and organominerals are compromised by working at trace mineral concentrations which are far in excess of animal requirements. There are, however, studies in which incremental levels of the target mineral have been fed as either the inorganic salt or the organomineral and effects on broiler performance reported. Burrell et al (2004) took this approach with Zn and showed that inclusion of the metal specific amino acid complex had a significant effect on FCR over the 45 day growth period when compared to zinc sulphate but not on growth performance. A similar experiment (Jahanian et al, 2008) in which 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. In addition to simply evaluating bird response several groups have used the availability of different forms of trace minerals to investigate requirements during the growth cycle. Ao et al (2006) compared growth response over 21 days in birds fed diets containing either a Zn proteinate source or zinc sulphate at 5, 10, 20 and 40 mg/kg and obtained a classical plateau in body weight gain. This occurred at 9.8 mg/kg with the organomineral source and 20.1 mg/kg with zinc sulphate. Inclusion of the Zn content of the basal diet resulted in "requirement" values of 33 and 43 mg/kg for the birds in the 0-21 day growth period. More recently Bao et al (2009) using a blend of mineral proteinates containing Zn, Mn, Cu and Fe reported that optimal supplementation with zinc changes over the growth cycle with lower requirements in the period 1-14 days when compared to 14-35 days. The levels proposed by the authors are higher than NRC and may reflect the increased requirements of modern broiler breeds.

The impact of use of organominerals on trace mineral excretion has been reported in a number of studies. In general excretion rates increase in line with inclusion rates in the diet and this effect is not significantly affected by mineral source (Mohanna and Lys, 1999). However, the opportunity afforded by organominerals to reduce dietary trace mineral levels while maintaining bird performance and health does have a direct effect on mineral output (Bao et al, 2007; Nollet et al; 2007).

The role of trace minerals in the development of bone and connective tissues is well established with, for example, Zn and Cu supply shown as essential for the collagen synthesis and maintenance (Chou et al, 1969; Starger et al, 1980). These tissues mature early in the development cycle and damage caused by a lack of essential nutrients will have a lasting impact on bird health and welfare. The impact of supplying organominerals on these processes has been shown in a number of studies and has been reviewed recently (Dibner and Richards, 2006; Dibner et al, 2006) with examples of improvements in connective tissue strength, bone mineralization and immune response. While leg and footpad problems are evident in broiler production systems their incidence in turkey production is a significant cause of both welfare and economic concern. A recent publication from Ferket et al (2009) identifies the role that organominerals can play in promoting tissue development and leg strength and reducing varus defects and incidence of shaky leg throughout the production period. In these diets a proportion of the mineral requirement provided as the sulphate was substituted by the trace mineral chelate of the hydroxy analogue of methionine for Cu, Zn and Mn resulting in increased tibia bone strength. In addition, the authors reported an improvement in feed conversion over the growing period this effect also being attributed to decreased leg problems.

**Conclusions:**
Although organominerals have been available to poultry producers for some years their adoption in commercial practice has been slow. In part this has been due to the difficulty in discriminating between different claims made by manufacturers but also there has been a lack of understanding of the role the products can play in commercial poultry production. The advent of new products with clearly defined chemical composition and stability within the digestive tract provides an opportunity to develop nutritional strategies which will benefit both the producer and the target species. These products are already allowing nutritionists to reduce trace mineral inclusion rates without loss of performance. There are also opportunities to improve bird health and welfare by meeting the requirements for development of essential tissues in rapidly maturing birds. These applications will be extended as confidence in the products develops resulting in diets which are a closer match between physiological requirements and mineral supply reducing the environmental impact of poultry production systems.

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