Trace minerals: Chelation is not the only route to protection

The next step in trace mineral nutrition is to move beyond broad source categories and evaluate how each product behaves at biological pH: where it remains protected, where it dissolves and what additional function it can deliver.

BY ERLANDA UPTON AUGUSTSSON AND STÉPHANE DUROSOY, ANIMINE

Trace minerals are used at low inclusion levels, but their nutritional impact is substantial. Zinc, copper, and manganese support enzyme systems, antioxidant protection, tissue development, immunity, reproduction and animal robustness. For decades, however, mineral quality has often been discussed through a simple organic-versus-inorganic classification.

That binary classification is becoming less useful. The more relevant question is how a source behaves in feed and throughout the gastrointestinal tract. It should be judged by its consistency, purity, solubilisation kinetics and interactions under the pH conditions that the animal actually encounters.

Why the traditional categories emerged

Standard oxides have historically been viewed with caution. This perception did not arise without reason. Commercial oxides can vary widely in origin, crystal structure, particle characteristics and contaminant profile. Many conventional products show poor acid solubility and inconsistent bioavailability. As a result, the word 'oxide' has often become shorthand for a low-cost but nutritionally unreliable mineral source.

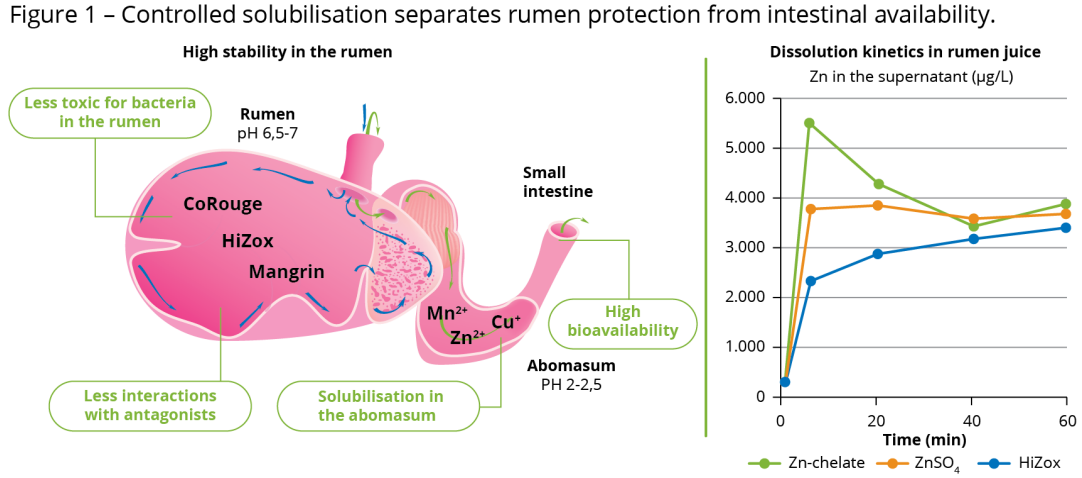
Sulfates developed the opposite reputation. Their manufacture is generally consistent, and their high water solubility makes them easy to use in premixes, feeds and liquid applications. They therefore became the reference inorganic source against which other forms were compared. Yet the same property that makes sulfates versatile also means that they dissociate rapidly. Free metal ions can then react with vitamins, enzymes, phytate and other dietary components before absorption.

Chelates were developed to address this issue. By associating the mineral with an organic ligand, they aimed to reduce premature interactions, improve handling through the digestive tract, and offer reassurance about product quality and contaminants. Chelation introduced an important concept in animal nutrition: mineral value is defined not only by concentration, but also by protection.

Maximum solubility: Not always optimal

The industry is now reconsidering the long-standing assumption that the most soluble source must be the most effective. Rapid dissolution may be useful when release is required, but it can be undesirable when it occurs too early. The rumen provides a clear example. It is a near-neutral, biologically active

Figure 1 – Controlled solubilisation separates rumen protection from intestinal availability.





Different routes can lead to the same goal: protecting trace minerals from premature interactions and ensuring release where they can be effectively absorbed. Photo: Animine

fermentation chamber. A highly soluble source can release metal ions in this compartment, increasing the opportunity for interactions with microorganisms and feed components. A source with low solubility at rumen pH, followed by greater dissociation in the acidic abomasum, can separate protection from availability: relative stability during rumen fermentation and release later in the digestive tract.

The same principle applies in monogastric diets. Copper and zinc released too early can associate with phytate or interact with supplemental phytase. High solubility therefore does not automatically translate into greater biological value. Instead, it may extend the period during which the free ion can react with nutrients and enzymes before reaching the site of absorption.

Chelates are not a single, uniform answer to this challenge. Their dissociation behaviour differs by ligand, binding strength, manufacturing process and surrounding conditions. Some complexes remain relatively stable, while others are soluble at neutral pH or dissociate as pH changes. It is therefore not scientifically meaningful to generalise about chelates as though all products behave in the same way (*Figure 1*). Specialty oxide minerals remain relatively stable under near-neutral rumen conditions, reducing premature dissolution and interactions with rumen microorganisms and dietary antagonists. Dissociation then increases in the acidic abomasum, supporting mineral availability in the small intestine.

Specialty oxides create another route to protection

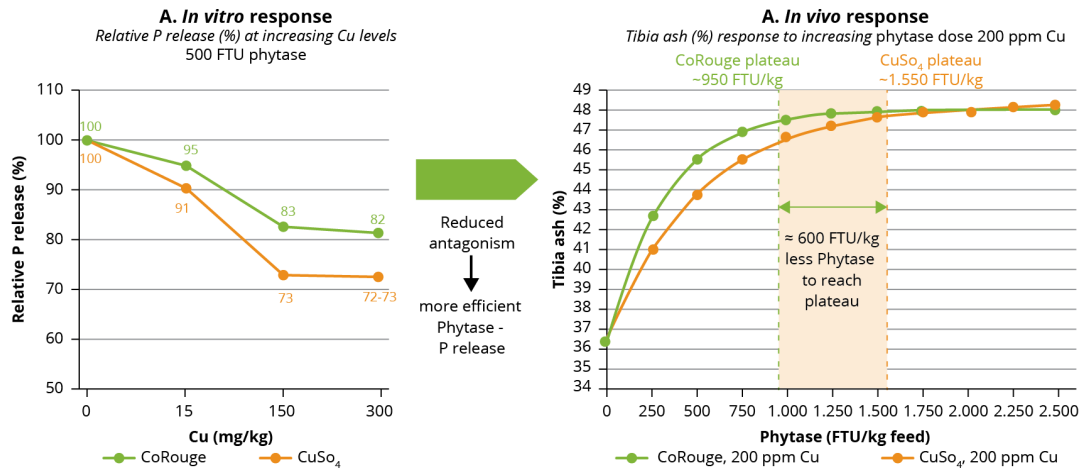
A new generation of specialty oxides challenges the assumption that all oxides share the limitations of conventional products. Through mineral engineering, it is possible to control purity, crystal structure, particle characteristics, surface properties and dissolution kinetics. These characteristics determine whether a mineral remains relatively unreactive under one set of conditions and dissociates under another.

The nutritional objective is not to keep the mineral insoluble. It is to control when and where solubilisation occurs. A well-defined specialty oxide can provide low water solubility and reduced premature reactivity in feed or near-neutral digestive compartments, followed by improved dissociation under acidic physiological conditions such as the stomach, gizzard, or abomasum.

This mechanism offers two effects from a single source. First, it protects the diet and the mineral from unnecessary early interactions. Second, controlled dissolution can secure bioavailability and, depending on the mineral and site of release, support a local functional effect. This may include antibacterial activity or a more favourable digestive environment while the source continues to fulfil its nutritional role.

This distinction matters because a generic chemical name does not define biological behaviour. Two zinc oxides, for example, may differ substantially in crystal form, surface area,

Figure 2 – Copper source can influence phytase efficiency.



particle distribution, impurities and acid reactivity. One may show poor nutritional availability, while another is designed to dissolve predictably at relevant biological pH. Category names, whether oxide or chelate, cannot replace physicochemical characterisation.

From broad source categories to controlled solubilisation

A more informative distinction is between sources that release ions rapidly and those that control release according to physiological conditions. Sulfates and oxides should therefore not be placed in one undifferentiated basket. Sulfates are water-soluble salts that release ions readily. Oxides are generally insoluble in water and depend more strongly on acidic conditions for dissolution. Within the oxide category, conventional and specialty products can differ markedly in purity and acid solubility (*Figure 2*). Together, the findings indicate that limiting premature copper–phytate interaction can improve how efficiently supplemental phytase supports phosphorus utilisation.

The same principle applies to chelated sources: the relevant comparison is not the marketing category but the actual dissociation profile. Protection is valuable only when it persists in the right place, and availability is valuable only when release occurs in time for absorption and biological use.

What nutritionists should ask their supplier

Purchasing decisions should therefore move beyond declarations of total mineral content and broad source class. Nutritionists need evidence that describes how the product behaves under conditions that reflect the animal. How consistent are purity, crystal structure and particle characteristics from batch to batch? What is the source's solubility or dissolution profile at relevant biological pH values, rather than only in water or strong laboratory acids? Does the product remain protected where premature release could create antagonism? Does it dissociate sufficiently in the acidic digestive compartment to secure bioavailability? Is any additional functional claim supported at nutritional inclusion levels?

These questions are more useful than relying on a broad source classification. They encourage suppliers to characterise products by measurable behaviour rather than assumptions tied to a generic category.

Protection is a function, not a product category

Chelates played an important role in changing how the feed industry thinks about trace minerals. They have demonstrated that protection from premature interaction matters. But protection is not exclusive to chelation, and it should not be assumed from a label alone.

Specialty oxides can combine protection in the upper digestive environment with controlled acid-responsive release. This creates the possibility of delivering nutritional availability and an additional local function from the same mineral source. Animine has applied this principle in purified specialty mineral sources, including HiZox, CoRouge and ManGrin. These products are designed around controlled physicochemical behaviour, with value demonstrated through purity, dissolution characteristics and biological response at nutritional inclusion levels. The next stage of trace mineral nutrition will be built on more precise language: not organic versus inorganic, but fast versus controlled solubilisation; not generic source names, but behaviour demonstrated at biological pH. The practical message for nutritionists is straightforward: ask where the product remains stable, where it dissolves and how consistently it does both.