Zinc supplementation: what to look at?

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Zinc is an essential trace element for dairy cows, playing a vital role in numerous metabolic processes. Supplementation is a standard practice to meet the animal's requirements. Traditionally, comparisons between zinc sources have focused on their relative bioavailability or digestibility. However, this approach does not fully capture the complexity of zinc metabolism in ruminants.

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Trace mineral homeostasis is tightly regulated by the animal. For positively charged trace minerals such as zinc, once absorbed, they follow the same metabolic routes regardless of their source. Therefore, the main differences between zinc supplements are determined before absorption, particularly in the rumen, where environmental conditions strongly influence mineral solubility and microbial activity.

It is time to broaden our assessment criteria, looking beyond simple digestibility comparisons, to better understand the real effects of zinc sources in dairy nutrition.

What the literature tells us

Measuring trace mineral digestibility poses challenges. Standard fecal collection methods, which work well for macronutrients, tend to underestimate true absorption of micronutrients such as zinc. This is due to endogenous losses from sloughed intestinal cells and secretions from pancreas, bile and intestine, sometimes yielding negative apparent absorption values.

A comprehensive review shows that apparent zinc absorption in ruminants typically remains below 20%. Given the wide variability in experimental designs and animal status, direct comparisons between studies are unreliable. No significant difference has been demonstrated between inorganic and chelated zinc compounds in terms of apparent absorption. **Figure 1** summarises these findings, highlighting that source effects on digestibility are minimal, and differences in performance are unlikely to be explained by absorption alone.

Assessing zinc bioavailability

Liver zinc concentration is commonly used as a biomarker for bioavailability in ruminants, as it reflects the longer-term zinc status. However, the most accurate comparison of relative bioavailability values (RBV) ideally relies on bone zinc measurements, particularly tibia Zn or tibia ash in monogastric animals. These are more stable indicators but are rarely used in ruminants due to high cost and ethical constraints. As a consequence, most ruminant studies rely on hepatic Zn concentrations.

A comprehensive literature review, covering data from Journal of *Trace Elements in Medicine and Biology* (1996), *Journal of Animal Science* (1997, 2000, 2001, 2021), *Livestock Production Science* (2004), *Animal Feed Science and Technology* (1997), *Agriculture* (2021), and *Revista Brasileira de Zootecnia* (2012), confirmed that liver zinc concentrations generally average around 100 mg/kg dry matter when supplementation levels are within physiological ranges (normal supplementation between 15 and 30 ppm Zn). Only at excessively high zinc intakes (up to 1400 mg/kg) elevated liver zinc concentrations were observed.

Figure 2 illustrates this relationship between dietary zinc supply and hepatic zinc concentration. Again, it becomes evident that the animal's homeostatic regulation tightly buffers Zn absorption and tissue accumulation, minimising differences among zinc sources.

Therefore, the choice of zinc compound should not rely solely on bioavailability data. Furthermore, contrary to copper research, where antagonistic conditions can be manipulated to highlight differences in bioavailability, demonstrating significant differences in zinc bioavailability in ruminants remains challenging.

However, when assessing zinc compounds from dairy nutrition, the focus clearly should extend beyond classical bioavailability studies, considering practical parameters, such as rumen stability, solubility, interactions with antagonists, and functional outcomes such as immunity, reproduction, and hoof integrity.

The rumen: the first biological barrier

In ruminants, the rumen is the first compartment where feed and minerals interact. This makes rumen stability a crucial, yet often overlooked, factor when evaluating trace mineral sources. Differences in animal performance or milk composition observed in the field may not always reflect variations in zinc absorption, but rather of how the mineral behaves in the rumen environment.

If a zinc source dissolves too rapidly in the rumen, the released free zinc ions can become toxic to rumen microbes, disrupting fermentation and fiber degradation. Conversely, a stable mineral compound that resists dissolution at the rumen's near neutral pH can pass through intact, preserving microbial activity until it reaches the acidic conditions of the abomasum, where solubilisation occurs before intestinal absorption.

Sulfates are well known for their high solubility under neutral conditions, explaining their potential to interfere with rumen fermentation. Chelated compounds, though often promoted for higher bioavailability, behave inconsistently depending on the strength of their metal–ligand bond and the surrounding microbial activity.

Recent studies have demonstrated that non-rumen-soluble trace minerals can improve fiber digestibility, improve energy metabolism and support more consistent animal performance compared to rumen-soluble sources. This growing body of evidence points to rumen stability as a key differentiator in trace mineral nutrition, one that better explains differences in animal performance than classical bioavailability metrics alone.

Figure 3 illustrates the comparative solubility of zinc sources, highlighting the distinct stability profile of a slow-release potentiated ZnO source (HiZox®) under rumen-like conditions.

Conclusions

Differences in zinc bioavailability among sources are generally too small to account for observed variations in animal performance. The rumen, where minerals first interact with feed and microorganisms, plays a far greater role in determining the effectiveness of supplementation.

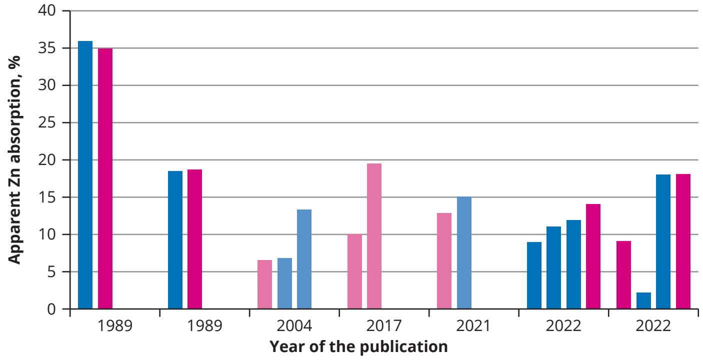
For modern dairy nutrition, evaluating zinc compounds should involve a holistic approach that integrates rumen stability, interaction with dietary antagonists, and functional animal responses.

The next frontier in trace mineral research lies in understanding how rumen-stable compounds maintain microbial balance and nutrient utilisation, ensuring optimal health, productivity and sustainability in dairy systems.

HiZox, as part of the AniMix range (with CoRouge and ManGrin), exemplifies this new generation of stable trace minerals designed to support rumen function while ensuring high downstream bioavailability.

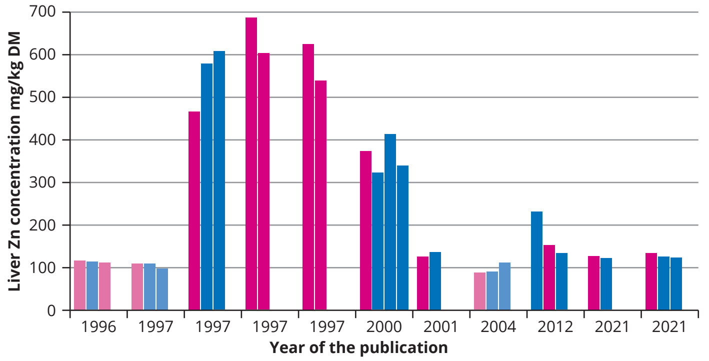
References available upon request

Figure 1 – Apparent absorption (in %) of zinc sources in ruminants.



Blue bars: chelated sources; Pink bars: inorganic sources (sulfate, oxide, chloride). Filled bars represent studies on ovine, while transparent bars represent studies on bovine

Figure 2 – Liver zinc concentration (in mg/kg of DM) of ruminants.



Blue bars: chelated sources; Pink bars: inorganic sources (sulfate, carbonate, oxide, chloride). Filled bars represent studies on ovine, while transparent bars represent studies on bovine sources.

Figure 3 – Solubility of zinc sources.