Innophos®

Whitepaper

Chelamax®

Chelated Minerals Show Increased Absorption

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Executive Summary

Innophos is committed to supplying the dietary supplement market with the highest performing minerals in the industry. Supporting this commitment, we continue to share evidence of the superior performance of verified chelated minerals. To date, in this series of scientific whitepapers, we have explained how to confirm chelation and then demonstrated a key advantage of chelation—enhanced solubility throughout the digestive tract, which is critical for bioaccessibility and mineral absorption.

This third whitepaper builds upon the foundational work of the series and presents new data from our in vitro digestion studies, which show the absorption advantage of Chelamax® zinc bisglycinate. Key findings include:

- Zinc bisglycinate is **10 times more bioaccessible** in the stomach and **five times more bioaccessible** in intestinal conditions than zinc oxide.
- Chelamax® zinc bisglycinate has an **absorption rate that is 10 times greater** than zinc oxide.
- The digestion model suggests the **superior bioavailability of Chelamax®** zinc bisglycinate over zinc oxide.

Building the Science

STUDY 1 → **Proven Chelation** (ANALYTICAL)

STUDY 2 → **Bioaccessibility** (SOLUBILITY STUDIES)

STUDY 3 → **Absorption** (IN VITRO)

FUTURE **Bioavailability** (IN VIVO)

SUPERIOR QUALITY

DIFFERENTIATED PERFORMANCE

Chelation Matters

Mineral supplements continue to grow in popularity with a 7% global CAGR (2019-2025)[1] driven by consumers' desire to enhance health and wellness. However, the effectiveness of these micronutrients can vary widely based on the mineral structure and reactivity in the gastrointestinal tract. Mineral oxides and salts dissociate in the stomach, allowing for undesirable reactions to occur. These reactions inhibit mineral absorption, leaving the consumer with no benefit from taking the supplement. Chelation protects the minerals and improves absorption efficacy.

Innophos Advances Research on Chelation

Studies have shown chelated minerals to have superior bioavailability to traditional mineral salts.[2,3] At Innophos, we have developed our Chelamax® product line of fully chelated minerals proven with the most advanced analytical testing in the industry—**our three-step verification process**. In our previous whitepaper, we demonstrated that chelated zinc bisglycinate has superior bioaccessibility to traditional zinc sources.[4] In this paper, we use an in vitro digestion model to demonstrate that chelated zinc bisglycinate also offers improved absorption.

Chelation protects the mineral and improves absorption efficacy.

In Vitro Absorption Model

A rigorous scientific approach is required to understand factors influencing mineral absorption. Therefore, an in vitro model that mimics the conditions of the digestive system was used. In the acidic stomach conditions, dietary supplements composed of mineral salts and oxides break down, forming free ions. However, the pH in the small intestine is neutral to slightly alkaline, which is necessary for optimal nutrient absorption. At this alkaline pH, mineral salts form insoluble hydroxides which hinder absorption, while chelated minerals remain intact and available for absorption in the small intestine. In this model, supplement samples are subjected first to low pH gastric conditions, and then to intestinal conditions, to gain a complete view of solubility and absorption.

INNOPHOS 3-STEP VERIFICATION

STEP 1 ••• ➤ **XRD**
CONFIRMS STRUCTURE

STEP 2 ••• ➤ **TGA**
CONFIRMS PURITY

STEP 3 ••• ➤ **FT-IR**
CONFIRMS CONSISTENCY

Dissolution Vessel and Permeation Chambers

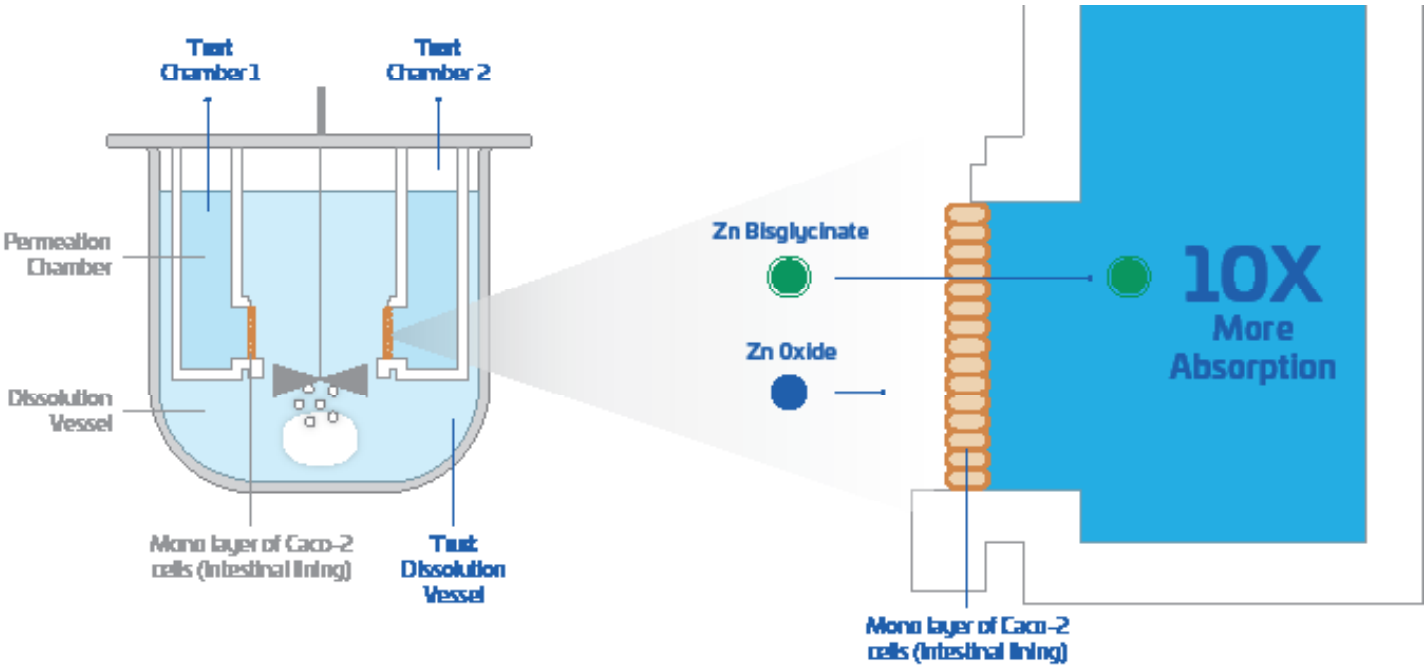
An in vitro system[5] (Figure 1) was used to track the dissolution of the mineral formulations and the natural permeation through living human intestinal cells. This in vitro study system is comprised of a dissolution vessel and permeation chambers, to model both stomach and intestinal conditions. To simulate stomach conditions, the dissolution vessel was first filled with simulated gastric fluid (SGF), which has a pH of ~1.6. The gastric conditions were held for 20 minutes and then fasting simulated intestinal fluid (FASSIF) was added to raise the pH to 6.5, to mimic the small intestine conditions.

Next, the permeation chambers, which were separated from the dissolution chamber by a polarized monolayer of human intestinal Caco-2 cells, were lowered into the dissolution vessel. The Caco-2 cells are mounted to the permeation ports so the only access to the port is via absorption through the intestinal cells.

The results demonstrate that chelated zinc bisglycinate offers improved absorption through a biological membrane, supporting enhanced bioavailability.

DISSOLUTION VESSEL & PERMEATION CHAMBERS

Figure 1. Zinc bisglycinate absorption in dissolution vessel and permeation chambers



Testing Method and Statistical Validation

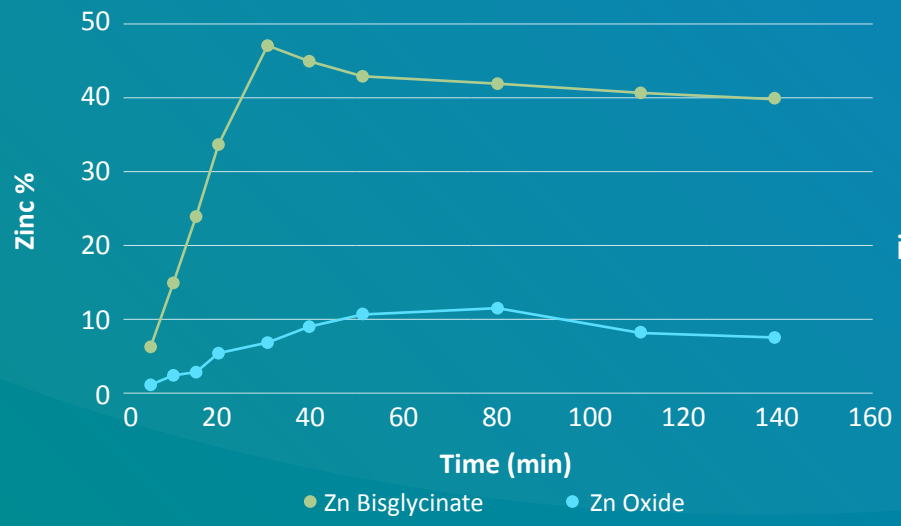
Two zinc formulations were prepared in tablet form, one containing traditional zinc oxide and the other containing Chelamax® chelated zinc bisglycinate. The trials were conducted in triplicate, with regular sampling from each permeation port as well as the dissolution chamber for a complete picture of the mineral dissolution and absorption. Atenolol was co-dosed as a negative control to verify the Caco-2 cells remained intact during the experiment, creating a robust set of data to statistically validate the results.

Results Show Increased Bioaccessibility

Our in vitro study results show chelated zinc is 10 times more bioaccessible than zinc oxide in stomach conditions (20 min.) and five times more bioaccessible in intestinal conditions (140 min.) as seen in Figure 2. The bioaccessibility of minerals is strongly correlated to solubility in the GI tract, especially the small intestine where minerals are absorbed.

Zinc Solubility Dissolution Chamber

Figure 2. Zinc bioaccessibility in vitro



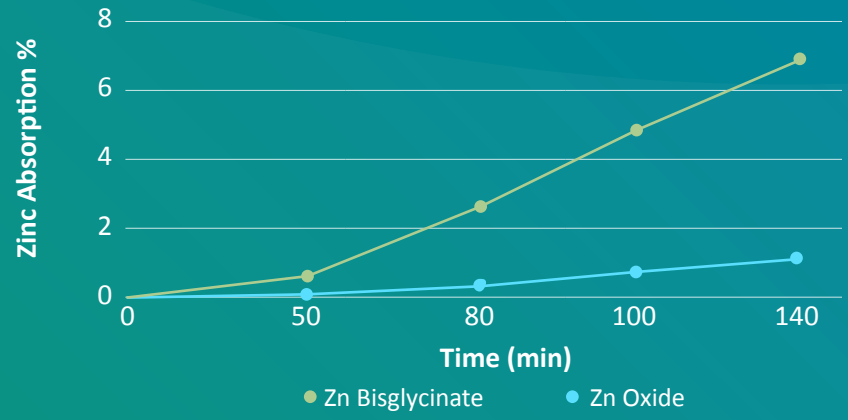
5x More Bioaccessible
in intestinal conditions

Study Results Show Increased Absorption

The concentration of chelated zinc absorbed under intestinal conditions was tenfold higher than the concentration of zinc oxide, as seen in Figure 3. Until now, there has been limited data that quantifies the benefits of chelation in an in vitro system.

Zinc Absorption Through Caco-2 Cells

Figure 3. Zinc absorption through Caco-2 cells to simulate intestinal absorption via in vitro



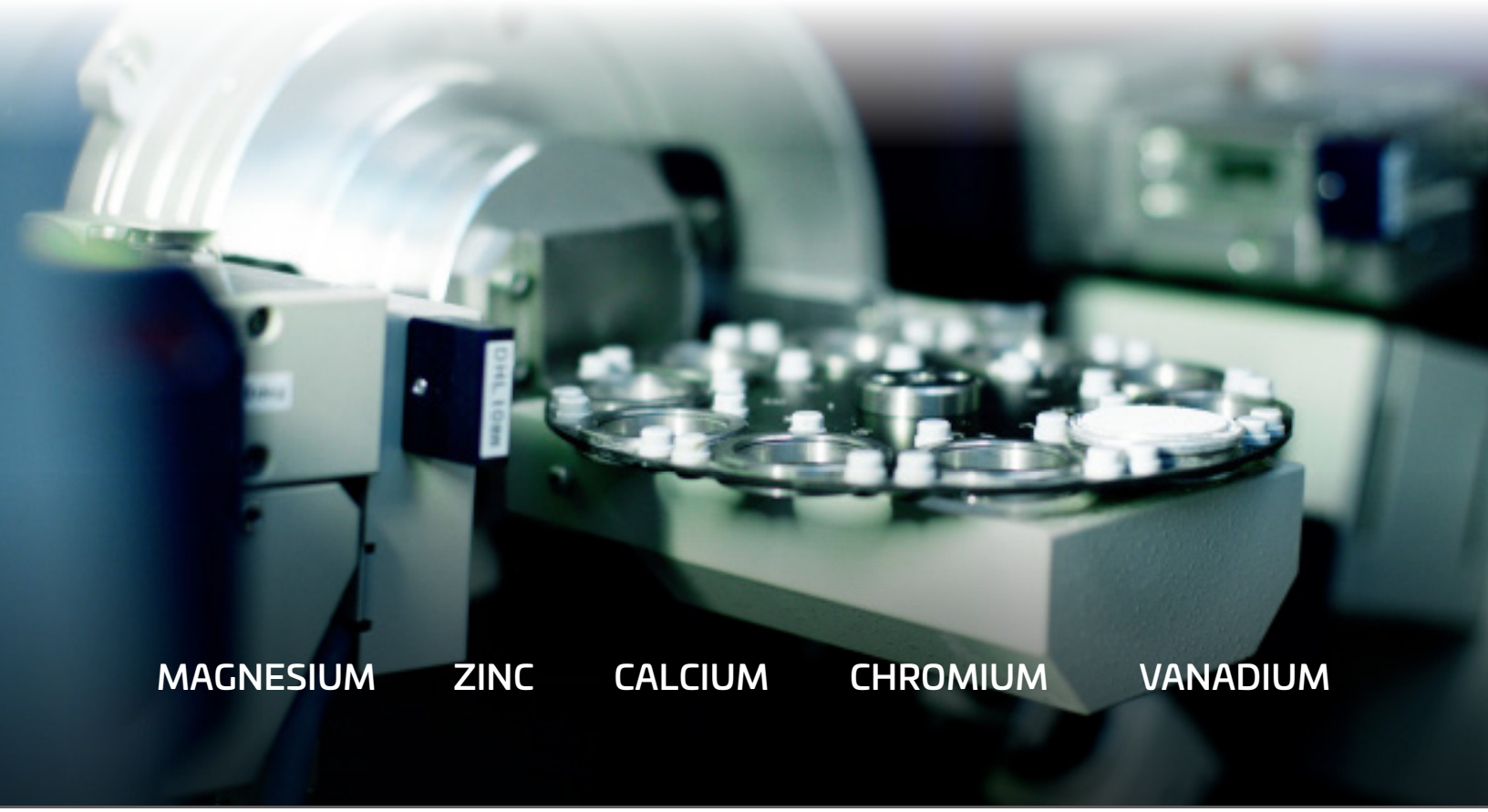
10x Greater Absorption

The in vitro model results predict that chelated zinc bisglycinate will be more bioavailable than zinc oxide, further demonstrating the performance and value of chelation.

Conclusion

Utilizing a widely recognized in vitro study system to mimic the gastrointestinal system, this study quantifies the magnitude of improved solubility and absorption of zinc bisglycinate vs. zinc oxide. This data offers valuable insights to the potential for enhanced mineral bioavailability in vivo. We continue to investigate the bioavailability of minerals and look forward to sharing these results in the future. We are committed to providing science-backed evidence of the benefits of Chelamax® chelated minerals as the best choice in the supplement space. For more information on this study, our previous two studies, and our entire Chelamax® product line, visit our website at Innophos.com.

When it comes to premium supplements, the Chelamax® brand represents proven, science-backed efficacy and quality.



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