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RESEARCH GUIDE

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CHELATED MINERALS

Addressing Key Challenges in Mineral Supplementation

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Minerals affect nearly all physiologic functions in the human body. Minerals are necessary cofactors for hundreds of biochemical reactions as well as essential for nerve conduction, muscle contraction, bone strength, immune function, energy production, and oxygen transport to name a few. Mineral status influences metabolic health, cardiovascular health, prostate health, reproductive health, cognition, and more.

Although the human body tightly regulates the availability of minerals and has mechanisms to store them for later use, minerals cannot be endogenously produced. To fulfill the ongoing requirements of the body, people must regularly consume the essential minerals (table 1) from exogenous sources.

Table 1. Essential Minerals*

Macro-minerals	Trace Minerals	Ultratrace Minerals
Calcium Chloride Magnesium Potassium Sodium Phosphorus	Copper Iron Zinc Fluoride Manganese Boron	Chromium Molybdenum Vanadium Iodine Selenium

* Macrominerals are present in large amounts in the body, trace minerals are present in small amounts, and ultratrace minerals are consumed in less than 1 mg/day. All are equally essential to physiologic function.

People have long relied on water and foods to fulfill their physiologic need for minerals, but modern agricultural practices and food processing compromise the mineral content of the food supply. As industrial farming techniques have shifted toward a reliance on monoculture, pesticides, herbicides, and synthetic fertilizers, the nutrient density of our soil and foods has declined. The refining of grains diminishes the mineral density of foods even more. The milling of whole wheat flour into white flour, for example, leads to a 90% loss of manganese, an 85% loss of zinc, and an 80% loss of magnesium.

Minerals become depleted further in the body by chronic stress, over-exercise, and excessive consumption of sugar, caffeine, and alcohol. Iron is the most common mineral deficiency worldwide and even in the US, it affects approximately 12% of women of childbearing age. Half of all Americans (and 2/3 of adolescents) have inadequate magnesium intake, and approximately 17%

Industrial agricultural practices, food processing, chronic stress, over-exercise, and poor dietary choices increase the risk of mineral deficiencies

of people worldwide have inadequate zinc intake. Insufficiencies in these minerals can contribute to anemia, mood disorders, infertility, and more.

Supplementation is sometimes the best or only way to correct mineral deficiencies and to achieve optimal physiologic levels. Choosing the best supplement, however, can be complicated. This research guide raises 3 key challenges posed by mineral supplementation and discusses how chelated minerals offer promise in overcoming these challenges. We also highlight 4 chelated minerals and their roles in health and disease.

3 Key Challenges with Mineral Supplementation

The only mineral forms available for dietary supplements until recent times were mineral salts, such as mineral sulfides, carbonates, and oxides. Minerals are now available as salts, ionic minerals, colloidal minerals, food-based minerals, and chelated minerals. They are delivered as liquids, capsules, tablets, powders, and functional foods. They are formulated alone, in combination, or with synergistic compounds purported to improve their deliverability.

There is a good reason for so many new forms and formulations of minerals on the market. Manufacturers are trying to overcome 3 key challenges posed by traditional mineral supplementation—poor tolerability, poor bioavailability, and chemical reactivity.

1. Tolerability

Tolerability refers to the ability of the body to handle a therapeutic dosage of a drug or supplement without side effects. Iron sulfate, prescribed to treat iron-deficiency anemia, provides a classic example of the poor tolerability of mineral salt supplements. Side effects at effective dosages include constipation, diarrhea, stomach cramps, and other digestive discomforts. A recent meta-analysis found that oral iron sulfate is more than twice as likely than placebo pills to cause side effects.

Other minerals also cause gastrointestinal distress. Mineral salts dissociate in the acidic contents of the stomach, and the mineral ions can irritate the gastrointestinal lining. Calcium carbonate is known to cause constipation, magnesium oxide can cause diarrhea, and zinc citrate can cause nausea when taken without food. Most minerals taste bad, and some leave a metallic taste in the mouth.

2. Bioavailability

Bioavailability refers to the amount of the nutrient that is absorbed and available for physiologic function. Part of what determines bioavailability is the absorption rate, and the mechanisms of mineral absorption are complex. Not only are different minerals absorbed via different transport mechanisms, but the same mineral can be absorbed via different mechanisms under different circumstances. In some instances, minerals compete for the same transport mechanism and can inhibit the absorption of each other.

Mineral bioavailability is complicated even more by age, sex, nutrient status, gastrointestinal health, and overall health. The absorption rate of iron, for example, ranges from less than 1% to more than 20% in different individuals and is higher in women than in men because of a greater physiologic demand. Mineral absorption is also influenced by the presence of interacting compounds in foods or supplements—compounds that act as inhibitors, competitors, or enhancers of bioavailability (table 2).

3. Chemical Reactivity

Chemical reactivity refers to the likelihood that an element or molecule will react with other elements or molecules. Mineral salts readily dissociate into charged particles, which can react with other compounds. In a multivitamin and mineral supplement or fortified food, mineral salts can ionize and react with vitamins—rendering the vitamins degraded and useless. In the gastrointestinal tract, mineral salts can ionize and become bound by food compounds—leaving a lesser quantity of mineral available for absorption.

A study published in 2000 in the *Journal of Food Composition and Analysis* evaluated vitamin degradation over time in a multivitamin and mineral supplement. In the formula that included mineral salts (as mineral sulfates), the percentage of vitamin C lost over 6 months was 40% (when stored at 20 degrees C). In the formula that included mineral amino acid chelates, the percentage of vitamin C lost over the same time period was less than 10%. Studies like this demonstrate that some mineral complexes are more or less reactive than others.

Table 2. Factors that Influence Mineral Bioavailability

Category	Examples	Effect
Inhibitors	Phytic Acid (in beans, legumes, grains, and nuts) Polyphenols (in tea, coffee, and wine) Oxalates (in spinach and rhubarb) Fiber (in plant foods)	Phytic acid, polyphenols, oxalates, and fiber bind with charged mineral ions in the intestinal tract to reduce absorption.
Competitors	Calcium and Iron Calcium and Zinc Zinc and Copper	Several minerals compete with each other for absorption and transport across intestinal cells. A supplement containing a high quantity of calcium, for example, could compete with the absorption of iron.
Enhancers	Vitamin C and Iron Vitamin D and Calcium	The presence of vitamin C enhances intestinal absorption of iron, and the presence of vitamin D improves absorption of calcium.

Fiber, phytates, and oxalates in plant foods can diminish mineral bioavailability in the gastrointestinal tract.

Chelated Minerals

The 3 key challenges posed by mineral supplementation are known to be problematic for mineral salts—the only form of minerals available in the past. But advances in technology are beginning to overcome these challenges. The greatest promise for improving the tolerability, bioavailability, and stability of mineral supplements may lie in mineral amino acid chelates.

Structure of Mineral Amino Acid Chelates

A chelate is a ring-shaped compound that has a metal ion (mineral) in the center and 2 or more organic molecules (ligands) bonded around the sides. This ring is referred to as a heterocyclic ring because the atoms involved in the ring structure are different from each other. This ring is a key feature of chelates. The ligands can be glycine, methionine, or other organic molecules. The choice of ligand determines the molecule size and can influence the absorbability and usability by body tissues.

Mineral amino acid chelates (also called metal amino acid chelates) are a specific category of chelated minerals that utilize amino acids as ligands. Several different amino acids might be used as ligands, but glycine is particularly well suited because of its small size and ability to form tight and stable bonds with the metal ion at the center of the chelate. When 2 glycine molecules bond with the same mineral ion, the resulting molecule is called a mineral bisglycinate chelate.

Spotlight on 4 Chelated Minerals

Calcium Bisglycinate Chelate

Calcium is one of the most popular mineral supplements on the market—and for a good reason. Calcium is the primary mineral in the crystalline complex of bone, helping to provide mechanical strength to the bones as measured by bone density. Calcium is required for heart muscle contraction, nerve signal transmission, blood clotting, and more. Calcium is a macromineral and needed in large amounts for physiologic function. The recommended intake is 1,000 mg per day for adults and children over the age of 4, with higher intakes advised for adolescents, women after menopause, and older adults.

Calcium carbonate is the most common form of calcium in supplements, but this mineral salt is poorly absorbed. A bioavailability study, published in 1990 in *Calcified Tissue International*, compared the bioavailability of 7 different calcium complexes. Results showed that (when taken without a meal) only 17% of calcium hydroxyapatite was absorbed, 24% of calcium carbonate was absorbed, 24% of calcium citrate was absorbed, and 44% of calcium bisglycinate chelate was absorbed. A subsequent study, published in 2006 in the *FASEB Journal*, confirmed that calcium chelate preparations had better bioavailability than calcium carbonate.

Iron Bisglcyinate Chelate

Iron is the central component of hemoglobin within red blood cells and essential for oxygen transport throughout the body. Iron deficiency is the most common mineral deficiency worldwide, affecting infants, women, and children more commonly than men. Other groups at high risk for iron deficiency include adolescents, pregnant women, and patients with inflammatory bowel diseases.

The recommended intake ranges from 7 mg to 27 mg per day, depending on age, sex and physiological stage.

The amount of iron that can be safely supplemented is often limited by gastrointestinal side effects, such as nausea and vomiting. The bioavailability of iron, particularly iron salts, is limited because the ionized iron can be bound by fibers, phytates, and phenols in the gastrointestinal tract. Heme iron (in meat) is unaffected by these issues because it has a porphyrin chelate structure that prevents it from dissociating. Iron bisglycinate chelate is more similar in structure to heme iron than to iron salts and therefore is less affected by food interactions.

Iron bisglycinate (Ferrochel® from Albion Minerals) has been evaluated in human clinical trials involving infants, children, adolescents, and adults. It has repeatedly demonstrated enhanced bioavailability with fewer side effects than iron salts. In infants and toddlers with anemia, iron bisglycinate chelate corrected anemia just as well as iron sulfate and also produced significant increases in plasma ferritin. In this study, the bioavailability of iron sulfate was calculated to be 27%, and that of iron bisglycinate to be 91%.

Magnesium Bisglycinate Chelate

Magnesium functions in more than 350 enzymatic reactions in the body. It supports bone health, regulates heart muscle contraction through allowing the muscle to relax, supports healthy blood pressure, and has a calming effect on the nervous system. The recommended intake of magnesium is 30 mg to 420 mg per day, depending on age, sex and physiological stage.

Several different magnesium salts are available for supplementation. Magnesium sulfate, also known as Epsom salt, is not well absorbed when taken internally and is best used in baths. Magnesium oxide is the least expensive form and commonly found in multivitamins. Although magnesium oxide provides a high percentage of elemental magnesium, its bioavailability is low. Magnesium malate has been evaluated in the context of fibromyalgia, whereas magnesium taurate and magnesium orotate may offer benefits for cardiovascular health. Magnesium bisglycinate is a good option when magnesium stores have been depleted and the goal is to recover optimal magnesium status.

Iron bisglycinate has been evaluated in human clinical trials...and has repeatedly demonstrated enhanced bioavailability with fewer side effects than iron salts.

Magnesium bisglycinate chelate (from Albion Minerals) has been evaluated in the context of supporting smooth muscle and skeletal muscle health. A clinical trial of magnesium bisglycinate chelate found that 300 mg per day for 4 weeks produced significant reductions in leg cramps and leg cramp intensity, with no differences in side effects, when compared with placebo. Another placebo-controlled trial of magnesium bisglycinate in patients with asthma found that 300 mg per day for 2 months reduced bronchial reactivity and reduced the need for rescue medication.

Zinc Bisglycinate Chelate

Zinc is a trace element that is required for the activity of more than 100 enzymes in the body. It is important for growth, wound healing, hormonal balance, and immune health. The recommended intake for zinc ranges from 2 mg to 13 mg per day, depending on age, sex and physiological stage.

Like magnesium, zinc is available for supplementation in many forms, including zinc sulfate, zinc oxide, zinc acetate, zinc orotate, zinc picolinate, and zinc citrate. Zinc gluconate is a popular form because of its superior bioavailability compared with lesser forms, such as zinc oxide. However, a comparison of zinc gluconate and zinc bisglycinate (from Albion Minerals) revealed that the bisglycinate chelate was 43% more bioavailable.

Benefits of Mineral Amino Acid Chelates

The molecular structure of a mineral amino acid chelate—and particularly a bisglycinate chelate—has several characteristics that help it overcome the 3 key challenges of mineral supplementation: tolerability, bioavailability, and stability (table 3).

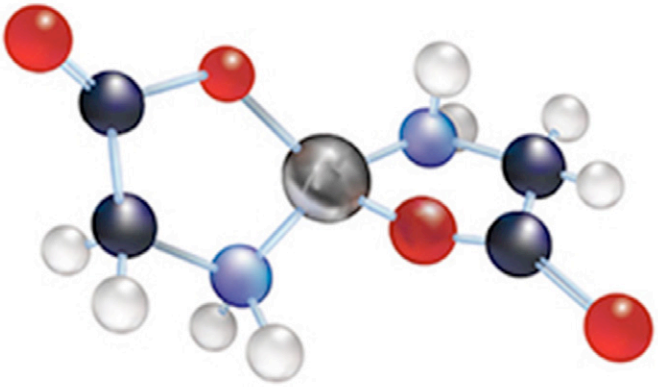
Table 3. Benefits of Mineral Amino Acid Chelates

Molecular Characteristic	Physiologic Significance
Stability	Less interaction with inhibitors (phytates, oxalates, etc.) Less interaction with other vital nutrients
Neutral charge	Fewer gastrointestinal side effects Increased tolerability Increased safety
Small size	Avoids digestive processes prior to absorption

Mineral amino acid chelates have demonstrated superior tolerability to other mineral forms. The 2:1 ratio of glycine molecules to mineral ions makes the bisglycinate chelate pH stable, even within the acidic contents of the stomach. This stability prevents dissociation of the mineral ion, reducing the risk of gastrointestinal side effects. A study of adolescents with anemia found that iron bisglycinate was equally effective as iron sulfate for correcting anemia, but it could be given at half the dosage with less than 10% of the side effects. Efficacy was maintained, and side effects were reduced to 0%, when iron bisglycinate was given at an even lower dosage for a slightly longer period of time.

Mineral amino acid chelates have also demonstrated enhanced bioavailability over other forms. The small size of bisglycinate chelates allows them to be absorbed intact into intestinal cells. When the bisglycinate chelate is absorbed this way, it does not compete with other minerals for transport across intestinal cell membranes. A comparison of bioavailability studies reported that zinc bisglycinate was nonreactive with other molecules, not affected by pH, and significantly more bioavailable than zinc gluconate—by 43%.

The chemical stability and nonreactivity of the mineral bisglycinate chelates explain much of why these complexes have enhanced bioavailability with fewer side effects than mineral salts. The glycine molecules wrap



around and protect the mineral ion at the center of the chelate, creating a neutral molecule that does not react with other food compounds, like phytates or fiber. This means that more of the mineral is delivered to the site of absorption in the small intestine. A study published in the *American Journal of Clinical Nutrition* in 2000 determined that when iron bisglycinate was mixed with cornmeal, it remained stable and did not mix with the iron from corn within the intestinal pool. The study also determined that the bioavailability of iron bisglycinate was 4 times that of iron sulfate, providing sound evidence that the nonreactivity of the chelated mineral enhanced its bioavailability.

Identifying Authentic Chelated Minerals

The manufacturing process of mineral amino acid chelates requires advanced technology. The goal of the manufacturing process is to create a fully reacted molecular structure, meaning that all of the bonds have been formed between the mineral ion and its ligands. To ensure that the chelate has been synthesized correctly, it is then tested to determine its molecular "fingerprint." This is a way to ensure that it has the correct molecular structure.

Albion Minerals holds more than 100 patents worldwide related to the processes of manufacturing mineral amino acid chelates. Albion Minerals is the only chelate manufacturer to certify the chemical structure and guarantee the mineral content of their chelated minerals. Albion certifies each product with a TRAACS® (The Real Amino Acid Chelated System) certification.

Albion Minerals is a raw ingredient manufacturer and does not sell finished products. Their mineral amino acid chelates are used by many quality supplement manufacturers in multivitamin and mineral combinations, multi-minerals, single minerals, and other formulas. You can look for the TRAACS® seal or the Albion Gold Medallion seal on the bottle to ensure the product contains an authentic chelated mineral.

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