

Chelated Minerals

Bridging Nutrient Gaps in Plant-Based and Weight Management Diets



balchem
HUMAN NUTRITION & HEALTH



The Plant-Based Nutrition Market Worldwide

The plant-based nutrition market has undergone a seismic transformation over the past decade, evolving from a niche lifestyle choice into a global phenomenon. Rooted in growing concerns about health and sustainability, this movement has catalyzed a wave of innovation, touching not just food and beverages but also beauty, personal care, and even fashion. Today, plant-based is not merely a diet; it is a dynamic, multi-faceted lifestyle resonating with diverse consumers worldwide.

From Germany to Thailand, the shift is undeniable. In Europe, for instance, **over 75% of German Gen Z regularly opts for plant-based options**, reflecting a generational commitment to more sustainable food choices. As Europe's largest plant-based food market, Germany has seen exponential growth driven by the rise of veganism and declining meat consumption. **With a burgeoning vegan population of 2.6 million, it sets the benchmark for sustainable food practices.**

Similarly, in Asia-Pacific, **51% of Thai consumers report they are more likely to embrace plant-based meat alternatives** if the taste matches traditional meat, underlining the importance of taste innovation in driving adoption.

Rising awareness about health benefits and celebrity-driven social media campaigns are propelling India's plant-based food market. Consumers are adopting dairy substitutes and vegan diets, influenced by sustainability and health narratives.

Meanwhile, in China, where over half of consumers consume dairy daily, the **growing interest in multi-protein plant-based beverages** presents a massive opportunity for product expansion. **Across Latin America, over 20% of Brazilian consumers are intrigued by milk alternatives** designed for athletic recovery, further highlighting the intersection of functionality and nutrition as a key growth driver.

Despite economic pressures in many regions, the long-term potential of the plant-based market remains robust. The global plant-based food market size is predicted to expand by 3x, witnessing an increase from USD 11.3 billion in 2023 to USD 35.9 billion by 2033. Overall plant-based food sales are poised to surge at a stupendous CAGR of 12.2% between 2023 and 2033 (1). This surge is powered by innovations in plant-based meat, dairy, and seafood alternatives, alongside increasing interest in high-protein and functional foods.

As brands navigate a competitive landscape, focusing on taste, texture, and nutritional quality will be critical. Innovations in plant-based seafood and diversified protein sources, such as black bean, pistachio, and cashew, are already capturing attention. Consumers are increasingly drawn to products that deliver both environmental benefits and uncompromised flavor. In a world where sustainability and wellness intersect, plant-based nutrition is not just a trend—it's a movement that holds the promise of a healthier, more sustainable future for all (2).

But with strong consumer interest and the presence of market leaders like Beyond Meat, the U.S. remains a global leader in plant-based food adoption. Over 70% of consumers cite health and environmental concerns as primary motivators for choosing plant-based options.

According to national estimates of the "Healthy Eating Index" – a measure which determines adherence to the Dietary Guidelines for Americans on a scale from

1-100 – Americans score between 51 and 63 depending on age (3). Put simply – the American diet has room for improvement. However, consumers are interested in making changes – in 2023, 54% of Americans reported following a specific dietary pattern within the past year, a 42% increase since 2019 (4).

When asked what motivated them to make these changes, the most common responses were (4):

- 1) "I wanted to feel better and have more energy" (45%),
- 2) "I wanted to lose weight" (43%), and
- 3) "I wanted to protect my long-term health" (41%).

While the specific lifestyle changes these consumers chose varied, the common thread between them is that they likely involved calorie control and an increase in physical activity.

While there is no shortage of approaches for "healthy eating", there are certainly mainstay elements. For example, the USDA MyPlate program recommends taking steps like

American consumers were asked what motivated them to make dietary changes, their most common responses were:

45%

I wanted to feel better and have more energy

43%

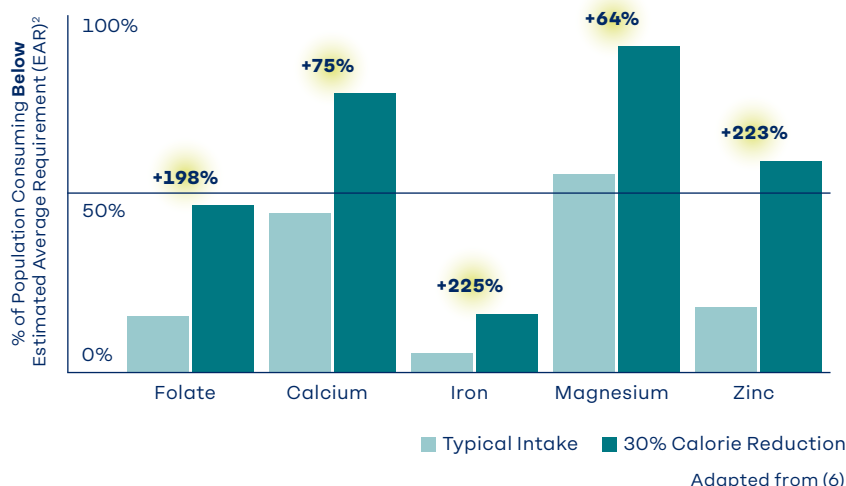
I wanted to lose weight

41%

I wanted to protect my long-term health

A 30% calorie reduction results in a significantly **higher prevalence of nutrient inadequacy**.

Dieting exacerbates nutrient gaps, **making supplements with well-absorbed nutrient forms crucial to support health**.



increasing your intake of fruits and vegetables and encourages adults to achieve or maintain a healthy weight by through calorie management. While this is sound advice, an unintended consequence of calorie control is that by reducing your intake of calories, you can often reduce your intake of essential micronutrients. According to the Academy of Nutrition and Dietetics (AND), a person's micronutrient intake may be inadequate when they are rescripting energy intake for weight loss/control ⁽⁵⁾. A striking example comes from a recent study which estimates that by reducing caloric intake by 30%, the prevalence of inadequate intakes of key minerals like Magnesium, Calcium, Zinc, and Iron can increase from 64% to up to 225% ⁽⁶⁾. Put simply, dieting can widen common nutrient gaps.

What if you're just trying to eat better, but not so worried about managing your weight? Often this involves the reduction or outright elimination of specific foods from your diet, which again, while well intentioned and not without some benefit, does have unintended consequences. Vegetarian / vegan dietary patterns are well recognized for their health benefits, like a reduced incidence of cardiovascular disease compared to non-vegetarian diets ⁽⁷⁾. However, one

challenge that follows is that people following vegetarian dietary patterns are also at a higher risk of inadequacy of key nutrients like choline and iron, for example ⁽⁸⁾.

Plus, lifestyle changes can change your body's requirement for specific nutrients. On this, the AND states that "exercise stresses many of the metabolic pathways in which micronutrients are required, and training may result in muscle biochemical adaptations that increase the need for some micronutrients" ⁽⁹⁾. For example, athletes can experience greater iron loss each day compared to the general population because of regular physical activity ⁽¹⁰⁾. As such, Institute of Medicine suggests that the requirement for iron is up to 70% greater for those who engage in regular exercise ⁽¹¹⁾. Similarly, due to differences in bioavailability between plant and animal-based foods, the Recommended Dietary Allowance (RDA) for iron is 80% higher for vegetarians compared to non-vegetarians ⁽¹¹⁾.

Vegetarian diets provide several challenges with respect to nutrient absorption. One factor is that of anti-nutrients, which are components of foods that can limit the absorption of key minerals, such as calcium, iron, zinc, and magnesium ^(11, 12). Anti-nutrients are generally found in plant-based foods such

as nuts, grains, and seeds, and commonly include components such as phytates and oxylates. The effect of these anti-nutrients can be significant – one study shows that just 10 mg of phytates in a meal can decrease iron absorption by 60% ⁽¹³⁾. Currently, the impact of anti-nutrients like phytates is not accounted for on national dietary intake surveys (e.g., NHANES), which is a significant limitation. One recent publication states **“by not considering phytate content, [calcium] absorption could be overestimated by <26%”** ⁽¹⁴⁾.

The impact of anti-nutrients are well recognized by various health authorities. A prominent example is in EFSA's scientific opinion on dietary reference values for

Zinc, which states that phytates “can have a major impact on the percentage of zinc that is available for absorption”. Due to this interaction, the population reference intake for Zinc is based in part on the phytate consumption of the individual, with higher phytate intakes resulting in a higher zinc intake recommendation ⁽¹²⁾. Similarly, Health Canada recommends a daily iron supplement during pregnancy, yet also warns: “Foods contain both enhancers and inhibitors. Paying attention to the foods that make up meals can help women reduce the effect of inhibitors and improve dietary iron absorption”, going on to cite phytates from plant-based foods as one of the main inhibitors ⁽¹⁵⁾.

An infographic element consisting of a large blue upward-pointing arrow followed by the text '45%' in a large, bold, blue font.

Increase in iron requirements
with regular exercise ⁽¹¹⁾

An infographic element consisting of a large blue upward-pointing arrow followed by the text '80%' in a large, bold, blue font.

Increase in iron requirements
for vegetarians ⁽¹¹⁾

An infographic element consisting of a large blue upward-pointing arrow followed by the text '26%' in a large, bold, blue font.

Overestimation of calcium
absorption due to phytate
content ⁽¹⁴⁾

With this background in mind, this leaves us with 3 key considerations for formulating a dietary supplement targeting consumers with following specified dietary patterns:

- 1) **Include adequate amounts of key nutrients, particularly essential minerals like Calcium, Iron, Magnesium, and Zinc.** Higher amounts of these nutrients may be required in products designed to support consumers with active lifestyles or vegetarian diets.
- 2) **Include highly bioavailable forms.** As micronutrient intakes can be lower among people who are dieting, this means that every bit of a nutrient consumed needs to have high bioavailability to best support health.
- 3) **Be mindful of the interactions from other dietary components, such as anti-nutrients.** Look for product types that perform well in the presence of these dietary inhibitors.

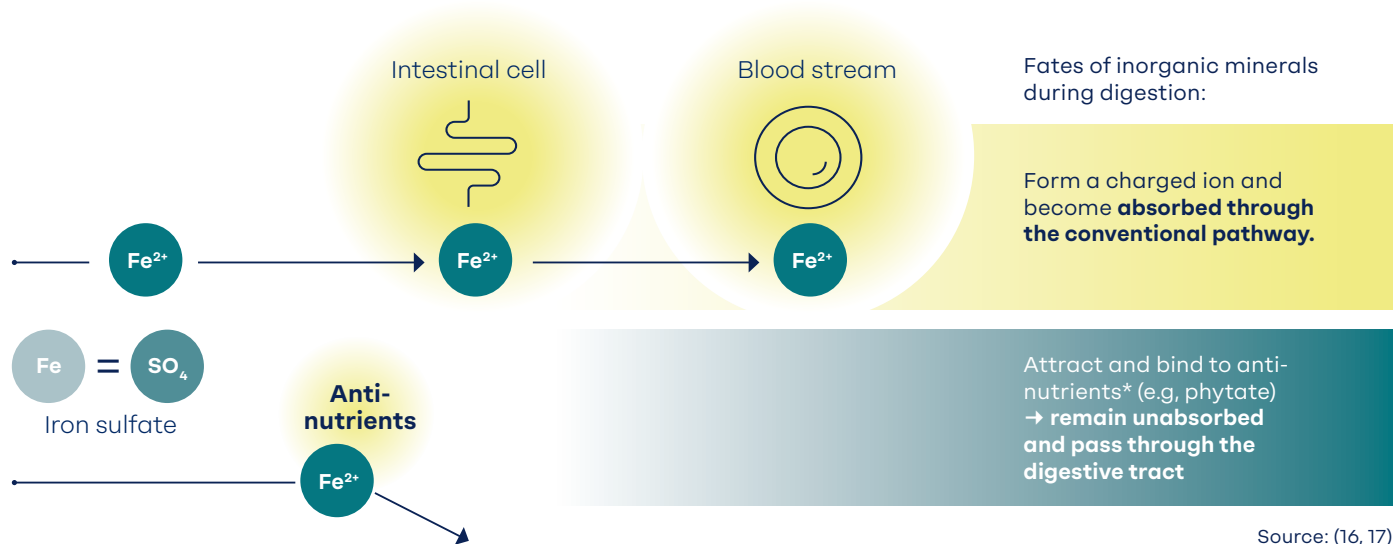


What are **Chelated Minerals**?

For most “conventional” minerals, the general pathway of absorption is similar. A mineral from either a food or dietary supplement enters the gastrointestinal (GI) tract, separates from its ligand (e.g., $\text{MgO} \rightarrow \text{Mg}^{2+} \text{O}^-$), gets absorbed by the intestine then enters the bloodstream, where it performs its specific function. However, in practice, these minerals do not act in isolation, but rather minerals interact with the environment of the GI

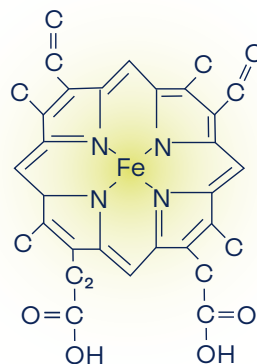
tract. This environment includes other nutrients found in foods, including anti-nutrients like phytates and oxylates. These anti-nutrients interact with minerals, limiting their absorption^(11, 16-18). The body is unable to absorb the resulting complexes, and they are simply passed out during the digestive process. The net result is that many of these inorganic salts suffer from relatively low bioavailability.

What Happens to Inorganic Minerals in the Body?

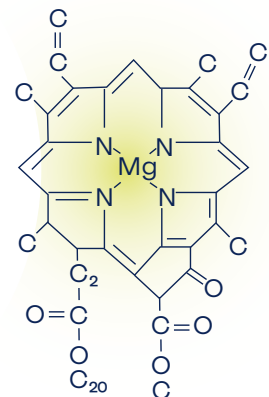


In nature, minerals are often found in chelated forms. In plants, the molecule chlorophyll is effectively a chelated complex of Magnesium⁽¹⁹⁾, which supports its important role in photosynthesis. In humans, hemoglobin is something of a natural chelate of iron⁽²⁰⁾, and this complex structure aids in hemoglobin's critical function of supporting oxygen transport in the body. Chelation is a way to deliver essential minerals as nature intended.

Human blood hemoglobin



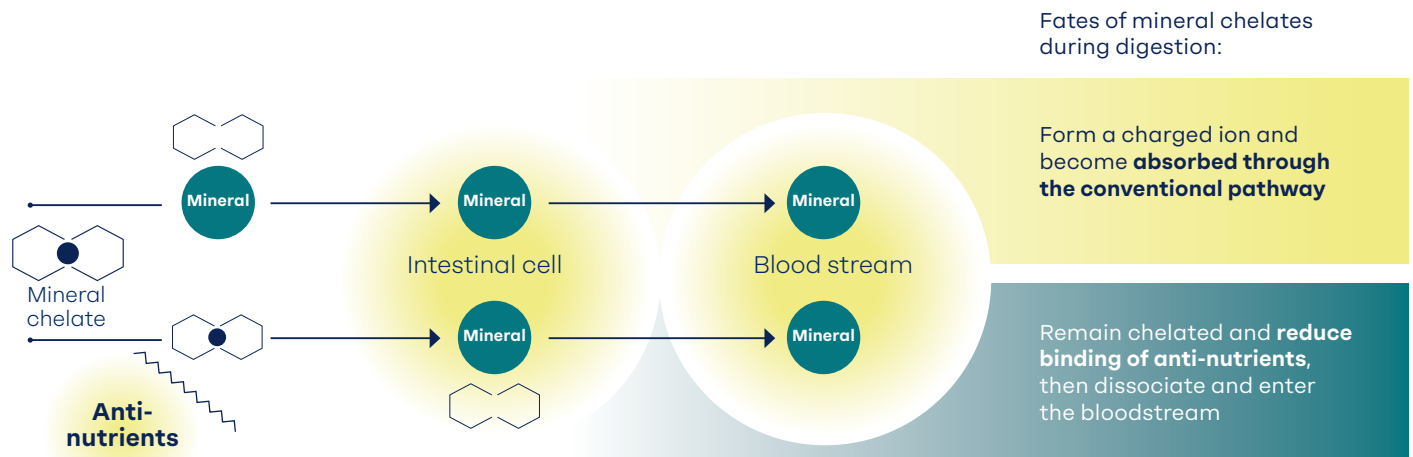
Plant chlorophyll



Many of the mineral chelates found in foods and dietary supplements are referred to as "bisglycinates" – meaning they are bound to two molecules of the amino acid glycine. The resulting ring structure has several features, namely a relatively low molecular weight and a neutral charge. These features facilitate the function of the mineral chelate within the context of nutrition. As mentioned before, mineral absorption begins with the mineral separating from its ligand, and in the case of bisglycinates, some portion of the mineral chelate

does separate from the glycine rings in the GI tract and is absorbed through the traditional pathway. However, evidence suggests there is a portion which does not and thus retains its neutral charge, making it less prone to interact with other components of the diet, such as phytates. This intact structure is then absorbed in the small intestine, where it then separates the mineral from the two glycine molecules, and goes into the bloodstream where it is delivered to its target tissue to perform its given function ⁽²¹⁾.

What Happens to Mineral Chelates in the Body?



When tested across both preclinical and clinical models, chelated minerals have been shown to be more bioavailable than conventionally used forms. The effect can be substantial – studies show that the bioavailability of chelated forms of calcium, iron, magnesium, and zinc all outperform their conventional mineral counterparts ⁽²²⁻²⁶⁾. This effect appears especially apparent when the absorption of chelated minerals is compared to conventional mineral forms in the presence of phytates – where the relative difference in bioavailability is up to 5x greater for chelated minerals ⁽²²⁾.

The ability of mineral chelates to resist phytates is recognized by health authorities. In their Guidelines on Food Fortification With Micronutrients, the World Health Organization (WHO) states that the **"absorption [of ferrous bisglycinate] is 2-3x better than that of ferrous sulfate if the phytate content of the food vehicle is high"** ⁽²⁷⁾.

The unique chemistry of chelates helps limit the interaction of the minerals with their environment, but that environment isn't limited to just components of the diet. High dietary intakes of minerals are linked to GI upset, meaning GI adverse events such as nausea, upset stomach, diarrhea, and constipation. Use of ferrous sulfate, for example, increases the odds of GI side effects by more than 2-fold ⁽²⁸⁾. High intakes of magnesium oxide and magnesium citrate can lead to laxation effects ⁽¹⁸⁾, which is why these magnesium forms are commonly used specifically as a laxative to address feelings of constipation ⁽²⁹⁾.

Research shows that chelates offer greater tolerability compared to conventional mineral salts. For example, when comparing ferrous bisglycinate (Ferrochel®) to ferrous sulfate in a randomized trial, subjects reported preferring Ferrochel over ferrous sulfate nearly 2-to-1, largely citing experiencing fewer moderate to severe side GI side effects ⁽³⁰⁾.

5x

greater absorption than
ferrous sulfate⁽²²⁾

3x

greater absorption than
magnesium oxide &
magnesium citrate^(23,24)

1.5x

greater absorption than
zinc gluconate⁽²⁵⁾

1.8x

greater absorption than
calcium citrate &
calcium carbonate⁽²⁶⁾

**Albion iron bisglycinate
chelate (Ferrochel®)**

**Albion magnesium
bisglycinate chelate**

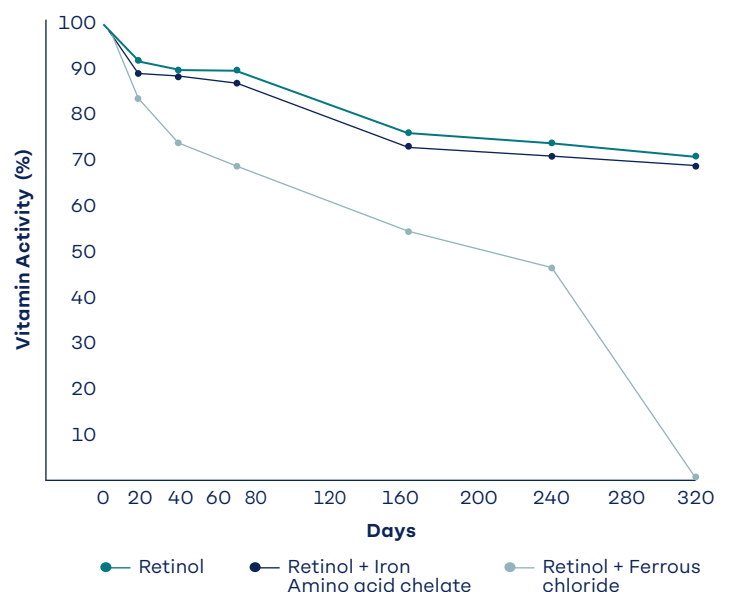
**Albion zinc
bisglycinate chelate**

**Albion calcium
bisglycinate chelate**

Lastly, chelated minerals deliver technical advantages to formulators looking to develop new food, beverage, or dietary supplement products. The presence of glycine molecules around these minerals results in significantly greater solubility compared to conventional forms, making them both useful and effective in fortification. For example, in laboratory tests, the solubility of calcium bisglycinate is exponentially higher than commonly used forms such as calcium carbonate or calcium citrate⁽²⁶⁾. In the previously mentioned WHO report, Ferrous Bisglycinate is listed as a suggested iron fortificant for fluid milk and juice/soft drink applications as a result of its high solubility⁽²⁷⁾.

From a quality perspective, mineral chelates offer stability advantages as well. In a stability test of multivitamin/mineral blends – where one blend contained all minerals as mineral chelates and the other as sulfate salts – there was significantly less degradation of vitamins A, K, B6, and C in the blend containing chelated minerals⁽³¹⁾.

Differences in Vitamin A degradation between chelated and inorganic iron



Adapted from: (31)

In sum, when compared to traditionally used mineral salts, mineral chelates offer multiple advantages to help both consumers and formulators alike. **Whether you are looking for food, beverage, and dietary supplement products to support your health as you look to control your diet or embark on a vegetarian lifestyle, or if you are a formulator looking to create these products, mineral chelates provide several key benefits:**

- Delivering essential nutrition which may be missing from their diets
- Superior bioavailability ⁽²²⁻²⁶⁾
- Enhanced tolerability ^(30, 32)
- Reduced interaction with anti-nutrients (e.g., phytates) ⁽²²⁾
- Greater stability ⁽³¹⁾
- Greater solubility ⁽²⁶⁾



How Brands Can **Benefit**

As the plant-based nutrition market continues to expand, driven by health, sustainability, and consumer demand, the role of chelated minerals becomes increasingly vital. This whitepaper highlights the transformative potential of mineral bisglycinate chelates in addressing nutrient gaps, enhancing bioavailability, and improving tolerability in plant-based and weight management diets.

Chelated minerals offer a solution to the common nutrient deficiencies associated with plant-based and calorie-restricted diets. By incorporating highly bioavailable forms of essential minerals like calcium, iron, magnesium, and zinc, supplement brands can help consumers achieve healthy nutrition. The unique chemistry of chelated minerals ensures superior absorption, even in the presence of dietary inhibitors like phytates, making them an ideal choice for plant-based diets where anti-nutrients can limit mineral absorption.

Moreover, chelated minerals are associated with fewer gastrointestinal side effects compared to conventional mineral salts. This enhanced tolerability can improve consumer compliance and satisfaction, making supplements more appealing. For consumers with active lifestyles, chelated minerals can meet the increased nutrient demands caused by physical activity. This is particularly relevant for athletes and individuals engaging in regular exercise, who may require higher intakes of certain minerals.

The solubility and stability advantages of chelated minerals provide technical benefits for formulators. These properties enable the creation of innovative food, beverage, and dietary supplement products that deliver essential nutrition effectively. By leveraging the benefits of mineral bisglycinates, supplement brands can differentiate their products in a competitive market. Highlighting the superior bioavailability, enhanced tolerability, and reduced interaction with anti-nutrients can attract health-conscious consumers.

This altogether is a strong package to align product offerings with the growing consumer demand for sustainable and health-conscious choices. Brands can emphasize the environmental benefits of plant-based diets and how chelated minerals contribute to a more sustainable future. By integrating chelated minerals into their product lines, supplement brands can play a pivotal role in supporting the health and wellness of consumers offering a solution to overcome several challenges which are associated with plant-based and weight management diets. This approach not only addresses tailoring nutrition to modern dietary trends but also positions brands as leaders in the evolving landscape of nutrition and wellness.

What Are **Albion® Minerals**?

Balchem's Albion® Minerals is comprised of over 30 chelated and specialty mineral ingredients that deliver innovative ways to help deliver essential nutrition. For over 70 years, Albion® Minerals have been pioneers in the field of chelated minerals. Our history began by being the first to show proof of chelation, and our commitment to the field is demonstrated with over 160 scientific publications on our full mineral portfolio. **Contact us today to learn more!**



References:

- 1) Future Market Insights. (2023). Plant-based food market. Future Market Insights. Retrieved December 9, 2024, from <https://www.futuremarketinsights.com/reports/plant-based-food-market>
- 2) Mintel. (2024). Emerging trends in the plant-based industry. Mintel. Retrieved December 9, 2024, from <https://www.mintel.com/insights/food-and-drink/emerging-trends-in-the-plant-based-industry/>
- 3) U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2020-2025. 9th Edition. December 2020. Available at: [DietaryGuidelines.gov](https://www.dietaryguidelines.gov).
- 4) International Food Information Council. 2024 Food & Health Survey. June 20, 2024. [<https://foodinsight.org/2024-food-health-survey/>]MyPlate - <https://www.myplate.gov/tip-sheet/healthy-eating-adults>
- 5) Marra MV, Bailey RL. *J Acad Nutr Diet* 2018; 118(11): 2162-2173.
- 6) Fulgoni VL, et al., *J Nutr* 2024; 154(9): 2732-2742.
- 7) Academy of Nutrition and Dietetics Evidence Analysis Library. "Vegetarian Nutrition". Accessed December 9, 2024: <https://www.andeal.org/topic.cfm?menu=5271>
- 8) Dietary Guidelines Advisory Committee. 2020. Scientific Report of the 2020 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Agriculture and the Secretary of Health and Human Services. U.S. Department of Agriculture, Agricultural Research Service, Washington, DC. Available at: <https://doi.org/10.52570/DGAC2020>
- 9) Thomas DT, et al., *J Acad Nutr Diet* 2016; 116(3): 501-528.
- 10) Weaver CM & Rajaram S. *J Nutr* 1992; 782-787.
- 11) Institute of Medicine (US) Panel on Micronutrients. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington (DC): National Academies Press (US); 2001. 9, Iron. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK222309/>
- 12) EFSA J 2014; 12(10): 3844.
- 13) Hallberg L, et al., *Am J Clin Nutr* 1989; 49: 140-144.
- 14) Weaver CM, et al., *J Nutr* 2024; 154(3): 921-927.
- 15) Health Canada. (2012). Iron and human health: A summary of current scientific knowledge. Government of Canada. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/fn-an/alt_formats/hpfb-dgpsa/pdf/pubs/iron-fer-eng.pdf
- 16) Institute of Medicine (US) Panel on Micronutrients. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington (DC): National Academies Press (US); 2001. 12, Zinc. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK222317/>
- 17) Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. Washington (DC): National Academies Press (US); 1997. 6, Magnesium. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK109816/>
- 18) Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. Washington (DC): National Academies Press (US); 1997. 4, Calcium. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK109827/>
- 19) Della-Rosa RJ, et al., *J Biol Chem* 1953; 202(2): 771-779.
- 20) Garcia-Santos D, et al., *Haematologica* 2017; 102(8): 1314-1323.
- 21) Hertrampf E, Olivares M. *Int J Vitam Nutr Res* 2004; 74(6): 435-443.
- 22) Bovell-Benjamin AC, et al; *Am J Clin Nutr* 2000; 71: 1563-1569
- 23) Hartle JW, et al., *FASEB J* 2016; 30: 128.6 (abstract).
- 24) Morgan S, et al., Balchem Internal Data.
- 25) DiSilvestro RA, et al, *Biol Trace Elem Res*, 2015; 168(1): 11-14
- 26) Heaney RP, et al; *Calcif Tissue Int* 1990; 46: 300-304
- 27) WHO/FAO, 2006. Guidelines on food fortification with micronutrients. Allen LH et al (ed). Available at: <https://www.who.int/publications/i/item/9241594012>
- 28) Tolkien Z, et al., *PLoS One* 2015; 10(2): e0117383
- 29) Mori H, et al., *Nutrients* 2021; 13(2): 421.
- 30) Coplin MS, et al., *Clin Ther* 1991; 13(5): 606-612.
- 31) Marchetti MA, et al., *J Food Comp Anal* 2000; 13: 875-884.
- 32) Ashmead S, et al., *The Toxicologist, Supplement to Toxicological Sciences*, 150(1), Abstract #2457, 2016.

This information is intended for industry professionals or customers of dietary ingredients, not consumers. Any explicit or implied claims included in this presentation may not necessarily be appropriate for marketing purposes and customers are responsible for their own compliance with relevant legal and regulatory requirements. These statements have not been evaluated by the US Food and Drug Administration. These products are not intended to diagnose, treat, cure, or prevent any disease.

All trademarks are property of Balchem Corporation or its respective subsidiaries.
Copyright © 2025 Balchem Corporation or its subsidiaries, all rights reserved.

