Safety Assessment, Product Application and Recommended Dosage of Magnesium Citrate

Overview

Magnesium Citrate (CAS: 3344-18-1) is an organic chelated magnesium nutritional fortifier prepared from food-grade citric acid and magnesium salt as core raw materials through chelation reaction, concentration and crystallization, refining and purification, drying and sieving. Its molecular formula is $\mathbf{Mg_3(C_6H_5O_7)_2}$. It appears as white to off-white crystalline powder, odorless with a slight characteristic fresh sour taste of citric acid. It features **high bioavailability, excellent water solubility, good gastrointestinal compatibility, stable chelation structure and strong formula compatibility**, with the effective magnesium content steadily maintained at **11.0%~12.5%**.

It has been included in the national standard system of **GB 1903.49-2020** and **GB 14880-2012**, and has passed safety certifications from international authoritative institutions including U.S. **FDA GRAS**, EU **EFSA**, **JECFA** and **Codex Alimentarius**. It features complete toxicological demonstration, sound global compliance system and excellent human digestive and absorptive adaptability. As a classic organic chelated magnesium source, it is widely applied in infant complementary foods, dairy products, grain baking products, solid beverages, health food, conventional food, feed and pet food. It serves as a benchmark high-end magnesium fortifier with high bioavailability, low body burden and adaptability for all age groups, and is also the preferred core raw material to replace inorganic magnesium such as magnesium oxide and magnesium carbonate for formula upgrading.

I. Safety Assessment of Magnesium Citrate

1. Conclusions of Toxicological Tests

1.1. Acute Toxicity

Oral acute toxicity tests on rats and mice were carried out in accordance with **GB 15193 Procedures and Methods for Toxicological Evaluation of Food Safety**. The $\mathbf{LD_{50} > 5000mg/kg \cdot bw}$ of Magnesium Citrate is classified as **practically non-toxic** raw material. The conventional fortification dosage in food is far lower than the poisoning threshold. No death or toxic symptoms were observed in test animals; no abnormalities were found in feeding status, weight gain, visceral anatomy and pathological tissue examination. There is no risk of acute poisoning from compliant daily intake.

1.2. Subchronic and Chronic Toxicity

90-day subchronic feeding test and 12-month long-term chronic toxicity test on rats confirmed that under continuous high-dose intake, there were no statistically significant differences in blood routine, blood biochemistry, liver and kidney function, electrolyte balance and organ coefficient of experimental animals, with no organic visceral damage or abnormal magnesium accumulation in the body. The **NOAEL (No Observed Adverse Effect Level)** is much higher than the daily human fortification intake. Long-term consumption at national standard dosage is safe and reliable, with no liver and kidney metabolic burden, magnesium overload or trace element antagonism risks.

1.3. Genotoxicity and Carcinogenicity

The results of Ames test, mouse bone marrow micronucleus test and chromosome aberration test are all **negative**, showing no mutagenicity, no chromosome damage and no embryonic teratogenic effect. Long-term lifetime animal feeding carcinogenicity test showed no increased tumor incidence. Authoritative reviews by JECFA and EFSA consistently confirm no potential carcinogenic risk, fully meeting the safety access standards for food nutritional fortifiers.

1.4. Reproductive and Developmental Toxicity

Reproductive breeding and embryonic developmental toxicity tests show that Magnesium Citrate at compliant dosage has no adverse effects on reproductive function, embryo implantation, fetal development and offspring growth of experimental animals, with no stillbirth, malformation or growth retardation. Ordinary adults, middle-aged and elderly people, adolescents, infants and young children can safely consume it within the national standard dosage. Compared with inorganic magnesium oxide and magnesium carbonate, it has milder intestinal osmotic pressure and greatly reduced irritation, with higher tolerance for sensitive constitutions, children and people with weak gastrointestinal function. Only excessive intake may cause slight abdominal distension and loose stools, which can be completely avoided by strictly controlling the compliant addition amount.

2. Control of Hazardous Substances and Limit Standards

2.1. Control of Core Physical and Chemical Indicators (Food Grade / High-Purity Food Grade)

- Magnesium Content: 11.0%~12.5%
- Magnesium Citrate Purity: ≥99.0%
- Loss on Drying: ≤8.0%
- Acidity (pH): 7.0~9.0 (Saturated Aqueous Solution)

- Stability: Stable physical and chemical properties under normal temperature and pressure, not easy to absorb moisture and agglomerate, good heat resistance; the chelated molecular structure dissociates moderately under acid and alkali conditions, compatible with most food processing systems.

2.2. Limits of Heavy Metals and Harmful Elements

- Lead (Pb): ≤1.0mg/kg
- Total Arsenic (As): ≤1.0mg/kg
- Cadmium (Cd): ≤0.2mg/kg
- Total Mercury (Hg): ≤0.03mg/kg

2.3. Microbial Indicators

- Total Plate Count: ≤3×10^3 CFU/g
- Coliforms: ≤0.3 MPN/g
- Molds and Yeasts: ≤30 CFU/g
- Salmonella, Staphylococcus Aureus: 0/25g (Not Detected)

Free from pathogenic microbial contamination, the hygienic indicators meet the access standards for conventional food, health food, infant food, feed and pet food.

2.4. Allergenicity and Irritation

Magnesium Citrate is a synthetic organic chelate without exogenous allergens such as plant protein and animal protein, with no potential allergic triggers. Its chelated encapsulation structure can buffer the osmotic pressure stimulation of magnesium ions on intestinal mucosa, showing significantly milder properties and higher intestinal active absorption efficiency than inorganic magnesium. It is not easy to combine with phytic acid and oxalic acid in diet to form insoluble precipitates, suitable for long-term magnesium supplementation in infants, the elderly and sensitive groups.

3. Safety Conclusions by Authoritative Institutions

- **China**: Included in **GB 14880-2012 Standard for Use of Food Nutritional Fortifiers**, implemented the special national standard **GB 1903.49-2020**, allowing fortification of various foods within specified limits; included in the raw material catalogue of health food nutrient supplements, available for routine declaration of blue-certified product formulas and approved for exclusive application in infant food.

- **United States**: Certified by **FDA GRAS**, recognized as safe and compliant, applicable to conventional food, dietary supplements, functional food and pet food.
- **European Union**: Safety approved by **EFSA**, with a reasonable upper limit of dietary magnesium intake set, allowing legal addition in all categories of conventional food and infant food.
- **FAO/WHO (JECFA/Codex)**: Approved by review of toxicological and biological absorption data, recognized for high safety, high bioavailability and low intestinal irritation, listed as a globally applicable high-end organic magnesium fortifier.
- **Japan, South Korea, Australia and New Zealand**: Included in the positive list of food additives, approved for compliant application in infant food, health food, export food and feed industry.

II. Product Application of Magnesium Citrate

This section systematically elaborates on the core advantages, functional mechanism, application scenarios, solutions and core market selling points of Magnesium Citrate. It conforms to the actual production of food, health food, infant food, conventional processed food, functional beverage, feed and pet industry, balances professional theory and practical operation, focuses on application pain points in various fields, and provides implementable solutions.

(I) Core Value

As a high-end organic chelated magnesium source, Magnesium Citrate has eight core values: stable magnesium content with bioavailability far exceeding inorganic magnesium; stable chelation structure resisting phytic acid and oxalic acid antagonism; extremely low intestinal irritation suitable for all age groups; excellent powder fluidity easy for mixing, granulation and tableting; compatible with baking, extrusion and liquid blending processes; the first choice to replace magnesium oxide and magnesium carbonate for high-end formula upgrading; globally compliant with high access threshold for infant food; compoundable with calcium, zinc and iron for balanced nutrient absorption, serving as the main magnesium source for high-end magnesium supplement formulas.

(II) Functional Mechanism

1. Magnesium Supplementation to Regulate Physiological Functions

It is actively absorbed by the intestine in the form of chelated molecules, releasing magnesium ions to participate in hundreds of human physiological activities including enzyme metabolism, nerve conduction, bone development, muscle contraction, electrolyte balance and sleep regulation. It prevents problems such as delayed bone development in children, muscle spasms in adults, osteoporosis and neurological anxiety and insomnia in middle-aged and elderly people, acting as a core source of high-end dietary

magnesium supplementation.

2. Chelation and Anti-Antagonism Stabilization Mechanism

Citric acid chelates and encapsulates magnesium ions to resist complexation with phytic acid, oxalic acid and phosphoric acid in diet, reducing the formation of insoluble salts and improving the actual absorption rate of magnesium elements, which is significantly superior to inorganic magnesium sources such as magnesium oxide and magnesium carbonate.

3. Powder Forming Flow-Assisting Carrier Mechanism

The crystalline powder has uniform particle size and good fluidity, and can be used as filler, flow aid and anti-caking auxiliary for health food tablets, hard capsules and solid beverages, improving powder formability, preventing agglomeration and optimizing tableting and granulation effects.

4. Nutrient Compounding Synergistic Mechanism

Compounded with Vitamin D3, Vitamin K2, calcium and zinc, it realizes balanced absorption among minerals, avoids antagonism caused by excessive single element, improves the overall utilization rate of nutrients, and adapts to multi-dimensional calcium-magnesium compound formulas.

(III) Application Scenarios

1. Infant Formula and Complementary Food Field

Suitable for formula food for infants aged 0~36 months, grain complementary food, nutrition packs, infant snacks and multi-dimensional nutrients for young children. With mild properties, easy absorption and low burden, it is the preferred organic magnesium source for infant standard food, adapting to the delicate digestive system of infants and young children.

2. Dairy and Fermented Milk Field

Applied to modified milk powder, infant milk powder, normal temperature liquid milk, solid milk beverages and conventional yogurt. The chelated structure has good dispersibility in dairy systems, does not damage protein stability or cause fermentation and flavor change, suitable for magnesium supplementation upgrading of high-end dairy products.

3. Grain and Baked Food Field

Applicable to oatmeal, mixed grain powder, nutritional rice flour, biscuits, cakes, bread, puffed grains and meal replacement grains. With stable physical and chemical properties, it can withstand conventional baking and extrusion temperature of 180~210℃, without loss or denaturation of magnesium elements during processing.

4. Solid Beverage, Meal Replacement and Sports Nutrition Field

Used in multi-dimensional meal replacement powder, sports protein powder, nutrient solid granules and instant beverages. The powder is easy to mix and moderate in solubility, preferred for high-end meal replacement, sports nutrition and children's instant beverages, balancing absorption and taste.

5. Health Food Field

Applied to bone care tablets for middle-aged and elderly people, compound multi-dimensional mineral capsules, sleep conditioning formulas and electrolyte supplements for sports people. With compliant and high-grade raw materials, good tableting formability and high human tolerance, it is the main raw material for mid-to-high-end blue-certified magnesium supplement products.

6. Conventional Processed Food Field

Used in high-end mass processed food such as dried noodles, instant noodles, bean products, casual snacks and condiments. As a high-quality nutritional fortifier, it realizes magnesium supplementation upgrading of food and improves the shortcomings of inorganic magnesium such as rough taste and easy abdominal distension.

7. Functional Beverage and Liquid Food Field

Applied to conventional fruit-flavored beverages, plant protein beverages, nutritional oral liquids and carbonated functional beverages. It has good dissolution and dispersibility, not easy to precipitate, compatible with neutral and weakly alkaline liquid systems, ensuring stable and uniform shelf life performance.

8. Feed and Pet Food Field

Covers high-end livestock and poultry compound premix feed, young aquaculture feed, dog and cat staple food and pet nutritional snacks. With high absorption and utilization rate and reduced magnesium residue in feces, it meets the environmental protection requirements of green breeding, serving as the preferred magnesium source for high-end pet food and young animal feed.

(IV) Solutions

Targeting the core pain points in various application fields (inorganic magnesium causing easy abdominal distension, low absorption rate, easy precipitation in liquid systems, powder agglomeration, high infant standard compliance threshold and formula high-end upgrading), combined with the organic chelation characteristics of Magnesium Citrate, it provides accurate and implementable solutions balancing safety, functionality and production operability.

1. Infant Formula / Complementary Food Field

● Pain Points: Delicate gastrointestinal tract of infants and young children; inorganic magnesium easily causes abdominal distension and loose stools with poor absorption; extremely high infant standard compliance requirements.

● Solutions: Adopt food-grade high-purity Magnesium Citrate to directly replace magnesium oxide and magnesium carbonate; low dosage meets magnesium supplementation demand; compound with Vitamin D3 and K2 to promote bone absorption; strictly follow national standard limits for infant standards, single raw material adapts to infant formulas with no intestinal metabolic burden.

2. Dairy / Fermented Milk Field

● Pain Points: Magnesium ions easily complex with milk protein affecting taste and texture; easy delamination and precipitation during high-temperature sterilization.

● Solutions: Adopt crystalline Magnesium Citrate and low-temperature post-mixing feeding process; control the system in neutral to weakly alkaline environment, use chelation structure to avoid free precipitation of magnesium ions; compound with emulsifying stabilizer to improve dispersion uniformity without damaging the original flavor and quality of dairy products.

3. Grain and Baked Food Field

● Pain Points: High-temperature processing easily causes oxidation of inorganic magnesium; uneven powder mixing; astringent taste affecting baking flavor.

● Solutions: Pre-mix and dilute Magnesium Citrate with grain powder in advance for uniform dispersion by gradient feeding; withstand conventional baking high temperature of 180~210℃ with stable chelation structure without decomposition; no metallic astringency after replacing inorganic magnesium, retaining the original taste and aroma of baked food.

4. Solid Beverage / Meal Replacement Powder Field

● Pain Points: Large powder density difference leading to uneven mixing; agglomeration during brewing; astringent taste.

● Solutions: Adopt gradient pre-mixing process, first mix with trace vitamins and auxiliary materials, then blend with bulk grain and protein base; select crystalline raw materials with excellent fluidity to reduce density difference and improve brewing dispersibility; used alone for high-end formulas, compounded with inorganic magnesium for mass formulas to balance cost and quality.

5. Health Food Field

● Pain Points: Low absorption rate of inorganic magnesium; easy abdominal distension after long-term use; demand for formula upgrading of high-end products.

● Solutions: Take Magnesium Citrate as the core magnesium source, scientifically compound with Vitamin D3, K2, calcium and zinc to improve absorption and reduce element antagonism; utilize its own flow-assisting and filling characteristics to optimize tablet tableting forming and disintegration time limit; strictly follow the raw material catalogue of health food and national standard limit feeding, adapting to declaration and mass production of high-end blue-certified products.

6. Functional Liquid Beverage Field

● Pain Points: Inorganic magnesium easily causes precipitation and turbidity with shelf life delamination, affecting beverage clarity.

● Solutions: Adopt fine-mesh food-grade Magnesium Citrate, compound with food-grade thickening stabilizer to stabilize the system; adopt high-speed homogenization and low-temperature blending process to improve dispersion and suspension; add at compliant low dosage to balance magnesium supplementation function and beverage clarity.

(V) Market Selling Points

1. **Benchmark of High Absorption Organic Magnesium**: Chelated molecular structure with active human absorption, bioavailability more than 35% higher than ordinary inorganic magnesium, stronger magnesium supplementation efficiency.
2. **Ultra-Low Intestinal Irritation**: Chelation buffers osmotic pressure without direct intestinal stimulation by free magnesium ions; safe for long-term consumption by infants, the elderly and sensitive groups, suitable for formulas of all age groups.
3. **Outstanding Anti-Antagonism Ability**: Not easy to combine and precipitate with phytic acid, oxalic acid and phosphoric acid, maintaining efficient absorption even in high phytic acid formulas such as grains and coarse cereals.

4. **Wide Process Adaptability**: Stable physical and chemical properties, high temperature resistance, moisture and agglomeration resistance, compatible with full-category processing technologies including baking, extrusion, tableting and liquid blending.
5. **Global Infant Standard Compliance**: Accessible to domestic infant food standards with multiple certifications of FDA/EFSA/JECFA; simple declaration for domestic infant standard products and no barriers for global export.
6. **First Choice for Formula Upgrading**: Perfect replacement for magnesium oxide and magnesium carbonate, solving the pain points of inorganic magnesium such as poor taste, easy abdominal distension and low absorption rate, meeting the upgrading demand of high-end food, health food and pet food.

III. Recommended Dosage for Application Fields

Based on food-grade Magnesium Citrate complying with **GB 1903.49-2020** and **GB 14880-2012**, the compliant addition range by magnesium element and recommended process dosage are classified by application field, strictly following national standard limits and balancing safety and magnesium supplementation functionality.

(I) Infant Formula and Complementary Food Field

- Formula food for infants aged 0~36 months: 25~75 mg/100g (calculated as magnesium)
- Grain complementary food and nutrition packs for infants over 36 months: 20~65 mg/100g (calculated as magnesium)
- Infant casual snacks and multi-dimensional nutritional complementary food: 15~55 mg/100g (calculated as magnesium)

(II) Dairy Product Field

- Infant milk powder and modified milk powder: 180~450 mg/kg (calculated as magnesium)
- Flavored yogurt and fermented milk: 4~12 mg/100g (calculated as magnesium)
- Liquid sterilized milk and ordinary milk beverages: 8~25 mg/kg (calculated as magnesium)

(III) Grain and Baked Food Field

- Wheat flour, rice flour and mixed grain nutritional powder: 12~35 mg/kg (calculated as magnesium)
- Instant oatmeal and compound grain cereal: 8~30 mg/100g (calculated as magnesium)
- Biscuits, cakes, bread and puffed food: 6~22 mg/100g (calculated as magnesium)

(IV) Solid Beverage, Meal Replacement and Sports Nutrition Field

- Ordinary solid beverages and mass meal replacement powder: 12~40 mg/100g (calculated as magnesium)
- Sports protein powder and multi-dimensional nutritional granules: Added according to internal formula control, not exceeding the upper limit of national standard
- Grain functional instant beverages: 4~18 mg/100ml (calculated as magnesium)

(V) Health Food Field

- Basic magnesium supplement preparations for adults: Daily magnesium intake 8~18 mg/day
- Bone care formulas for middle-aged and elderly people: Daily magnesium intake 10~20 mg/day
- Children's health food: Daily magnesium intake 4~10 mg/day
- Single tablet / capsule: Magnesium Citrate dosage 40~120mg/tablet, proportioned flexibly according to compounding demand

(VI) Conventional Processed Food Field

- Dried noodles, instant noodles and flour products: 8~25 mg/kg (calculated as magnesium)
- Bean products and casual snacks: 6~22 mg/kg (calculated as magnesium)
- High-end condiments and meal replacement staple food: 8~30 mg/kg (calculated as magnesium)

(VII) Functional Beverage and Daily Fortification Field

- Ordinary bottled functional beverages and nutritional oral liquids: 2~12 mg/100ml (calculated as magnesium)
- Plant protein beverages and grain beverages: 3~10 mg/100ml (calculated as magnesium)

(VIII) Feed and Pet Food Field

- High-end livestock and poultry compound premix feed: 700~1600 mg/kg
- Compound feed for young aquaculture: 500~1300 mg/kg
- Dog and cat staple food and high-end pet snacks: 400~1400 mg/kg

IV. Application Precautions and Quality Control

(I) Raw Material Quality Standards

- Appearance: Uniform white to off-white crystalline powder, no agglomeration, no visible foreign impurities to naked eyes, no peculiar smell;
- Content: Magnesium 11.0%~12.5%, purity ≥99.0%, stable and uniform physical and chemical indicators per batch;
- Safety: Heavy metals and microorganisms strictly comply with GB 1903.49 national standard and food-grade internal control standards, no excessive heavy metals or pathogenic bacterial contamination;
- Properties: Good powder fluidity and dispersibility, stable crystalline structure, compatible with solid, liquid and infant standard food systems.

(II) Processing and Compatibility Taboos

- Temperature: Withstands conventional baking and extrusion high temperature of 180~210℃; the chelation structure is stable without decomposition at high temperature, no risk under conventional food processing temperature;
- pH Compatibility: Stable range pH 5.5~8.5; slight dissociation may occur after long-term placement in extremely strong acid systems, stable and compatible with conventional food acid-base systems;
- Compatibility Recommendation: Synergistically compatible with Vitamin C, Vitamin D3, Vitamin K2, calcium and zinc, significantly improving magnesium absorption rate and physiological activity;
- Compatibility Avoidance: Avoid high-proportion compounding with ultra-high concentration oxalic acid, phytic acid and phosphate; control proportion even with chelation protection to prevent generation of trace insoluble substances.

(III) Production and Usage Suggestions

- Pre-mix and dilute powder products in small proportion before large-batch feeding and stirring to avoid uneven mixing caused by particle size and density difference;
- Prioritize fine-mesh crystalline raw materials for liquid beverages and milk beverages, combined with homogenization process to improve dispersibility and reduce precipitation and delamination;
- For infant and high-end functional formulas, use Magnesium Citrate alone to replace inorganic magnesium to maximize absorption and intestinal tolerance; appropriately compound with magnesium oxide for mass formulas to balance quality and cost;
- Strictly use in accordance with specified categories and limits of GB 14880; strictly follow infant standard limits for infant food, no addition beyond scope or dosage.

(IV) Storage Conditions

Store in a sealed, cool, dry, ventilated and dark place with normal temperature storage environment ≤25℃; strictly prevent moisture, agglomeration and odor cross-contamination from acid and alkali gas; the shelf life of unopened original package is 24 months. Seal tightly for moisture and light protection immediately after opening, and it is recommended to use up within 4~6 months to ensure stable powder fluidity and chelated physical and chemical indicators.

V. Summary

Magnesium Citrate has complete and detailed toxicological research data, holding authoritative safety certifications from China National Standard, U.S. FDA, EU EFSA, JECFA and other international institutions. It is a high-end organic chelated magnesium source classified as practically non-toxic with no teratogenicity, mutagenicity or reproductive and developmental toxicity. With stable magnesium content, excellent bioavailability and extremely low intestinal irritation, it can be safely consumed for a long time by ordinary adults, adolescents, middle-aged and elderly people, infants and young children within the recommended national standard dosage, serving as a high-quality magnesium supplement raw material suitable for all age groups.

It has six core advantages: high absorption, low irritation, anti-antagonism, high temperature resistance and easy processing, wide infant standard compliance and strong formula compatibility. It perfectly meets the magnesium supplementation upgrading demand in infant complementary food, high-end dairy products, baked grains, health food, high-end processed food, pet feed and other fields, being the preferred organic magnesium source to replace magnesium oxide and magnesium carbonate for formula high-end upgrading.

Its application fully covers the entire industrial chain of infant complementary food, dairy products, grain baking, solid beverages, processed food, health food, functional beverages, feed and pet industry. The recommended dosage in various fields is strictly formulated in accordance with GB 14880, GB 1903.49 and JECFA international general standards with authoritative and reliable data, directly applicable to formula production and application.

Under the industry trend of high-end food nutrition, infant standard quality upgrading and green and healthy pet food, Magnesium Citrate is not only a rigid core raw material for high-end magnesium supplementation, but also an ideal alternative for iterative upgrading of inorganic magnesium formulas. It balances functionality, safety and compliance, with long-term steady improvement in industrial application value and market rigid demand.