Safety Assessment, Product Application and Recommended Dosage of Calcium Citrate

Overview

Calcium Citrate (CAS: 813-09-2) is an organic calcium nutritional fortifier prepared from citric acid and calcium carbonate/calcium hydroxide through neutralization complexation, crystallization reaction, refining and purification, drying and crushing. Its molecular formula is \(\ce{Ca3(C6H5O7)2}\). It appears as **white to off-white crystalline powder**, odorless with slightly astringent taste.

It features **excellent solubility, high bioavailability, low absorption burden on human body, gastric acid-independent dissociation, good gastrointestinal tolerance**, and low tendency to form precipitates with oxalic acid and phosphoric acid. The effective calcium content is stably maintained at **21.0%~23.0%**.

It has been included in the national standard system of **GB 1903.15-2016** and **GB 14880-2012**, and obtained safety recognition from international authoritative institutions including **US FDA GRAS, EU EFSA, JECFA and Codex Alimentarius Commission**. It has complete toxicological data, a sound compliance system and strong formula compatibility.

It can fully replace traditional calcium sources such as calcium carbonate, calcium lactate and calcium gluconate, solving industry pain points of ordinary calcium sources including gastric acid-dependent absorption, constipation and abdominal distension, low absorption rate, high risk of stone formation and adverse impact on product taste and flavor. It is widely applied in **infant formula food, dairy products, grain baking, solid beverages, health food, special medical food, functional drinks, feed and pet food**. It is a benchmark high-end calcium fortifier with high absorption, mild stomach-friendly property and low stone risk.

I. Safety Assessment of Calcium Citrate

(I) Conclusions of Toxicological Tests

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 **LD_{50} of Calcium Citrate ＞5000mg/kg·bw**, classified as a **practically non-toxic raw material**.

The conventional fortification dosage in food is far lower than the toxic threshold. No death or toxic symptoms were observed in experimental animals; feeding behavior, weight gain and pathological examination of visceral organs all showed no abnormalities. There is **no risk of acute poisoning** from daily compliant intake.

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, bone development and organ coefficient of experimental animals. No organic visceral damage or calcium accumulation toxicity in vivo was found.

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 with no burden, without liver and kidney metabolic pressure, calcium overload or vascular hidden dangers.

3. Genotoxicity and Carcinogenicity

The results of **Ames test, mouse bone marrow micronucleus test and chromosomal aberration test** are all negative. It has **no mutagenicity, no chromosomal damage and no embryonic teratogenic effect**.

Long-term lifetime feeding carcinogenic tests on animals showed no increased tumor incidence. Authoritative reviews by **JECFA and EFSA** unanimously confirm no potential carcinogenic risk, fully complying with the safety access standards for food nutritional fortifiers.

4. Reproductive and Developmental Toxicity

Reproductive breeding and embryonic developmental toxicity tests show that Calcium Citrate at compliant dosage has **no adverse effects** on reproductive function, embryo implantation, fetal bone development and offspring growth of experimental animals. No stillbirth, malformation, growth retardation or abnormal bone calcification were observed.

Pregnant women, lactating mothers, infants, the elderly, people with weak gastrointestinal function and osteoporosis groups can safely consume it within the recommended national standard dosage. Only occasional transient intestinal adaptive reactions such as mild abdominal distension and constipation may occur after short-term excessive intake, without any irreversible physiological damage.

(II) Hazardous Substances and Limit Control

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

- Calcium Content: **21.0%~23.0%**
- Purity of Calcium Citrate: **≥99.0%**
- Moisture: **≤7.0%**
- pH (10g/L Suspension): **6.0~8.0**
- Stability: Stable at 180℃; not easy to dissociate, agglomerate or crystallize in the system of pH 4.0~9.0

2. Limits of Heavy Metals and Harmful Elements

- Lead (Pb): **≤2.0mg/kg**
- Total Arsenic (As): **≤2.0mg/kg**
- Cadmium (Cd): **≤0.3mg/kg**
- Total Mercury (Hg): **≤0.05mg/kg**

All heavy metal indicators are stricter than the general national standard limits. The internal control standard of high-purity grade can be further tightened, suitable for infant formula, special medical food and high-end health food scenarios.

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: **Not Detected /25g**

Free of pathogenic bacteria and heat-resistant spore contamination, it fully meets the hygienic access requirements for infant formula grade, special medical grade and health food grade.

4. Allergenicity and Irritation

Calcium Citrate is an organic acid complexed mineral salt with **no plant protein allergens or exogenous allergen properties**. It can be directly dissociated and absorbed without participation of gastric acid, causing **no gastric mucosal irritation or acid regurgitation and heartburn**.

Compared with calcium carbonate and calcium lactate, it greatly reduces adverse reactions such as constipation, bloating and stomach discomfort, with excellent tolerance for sensitive constitutions, infants, the elderly and hypochlorhydria populations.

(III) Safety Conclusions by Authoritative Institutions

- **China**: Listed in **GB 14880-2012 Standard for the Use of Food Nutritional Fortifiers**, implemented the special national standard **GB 1903.15-2016**, allowing fortification of various foods within specified limits; included in the catalogue of raw materials for health food nutrient supplements, available for formula declaration of blue-capped health products.
- **United States**: Certified by **FDA GRAS**, officially recognized as safe and compliant, applicable to ordinary food, infant formula food, dietary supplements and functional food.
- **European Union**: Safety approved by **EFSA**, with no strict restriction on ADI value, legally allowed for addition in all categories of food.
- **FAO/WHO (JECFA/Codex)**: Passed the review of toxicology and bone nutrient absorption data, recognized its high safety and gastric acid-independent absorption characteristics, recommended as a **globally preferred organic calcium fortifier**.
- **Japan, South Korea, Australia and New Zealand**: Included in the positive list of food additives, approved for compliant application in health food, functional drinks and export food.

II. Product Application of Calcium Citrate

This section systematically elaborates on the core advantages, functional mechanism, application scenarios, solutions and core market selling points of Calcium Citrate. It fits the actual production of food, health products, special medical food, functional drinks, feed and pet industries, balances professional theory and practical operation, focuses on application pain points in various fields, and provides implementable solutions.

(I) Core Value

Different from conventional calcium sources such as calcium carbonate, calcium lactate and calcium gluconate, Calcium Citrate has eight core values:

Gastric acid-independent absorption, suitable for the elderly and children with insufficient gastric acid; good solubility and strong compatibility; hard to combine with phytic acid and oxalic acid to form stones; bioavailability far exceeds ordinary inorganic calcium; mild to gastrointestinal with low irritation, no acid regurgitation or constipation; strong stability under high temperature and wide pH range, no crystallization or agglomeration; clean label organic nutrition attribute; compliant in many countries with barrier-free export; effective with micro-addition and controllable formula cost. It is the **preferred organic calcium source** for high-end calcium supplementation formulas.

(II) Functional Mechanism

1. Efficient Calcium Supplementation and Bone Strengthening

It is directly dissociated and absorbed in the intestine in the form of organic complex molecules without gastric acid decomposition, avoiding low absorption efficiency caused by insufficient gastric acid of ordinary calcium sources. It rapidly replenishes body calcium reserves, promotes calcification of bones and teeth, and prevents rickets in children, osteoporosis in middle-aged and elderly people, and calf cramps caused by calcium deficiency during pregnancy.

2. Mild Stomach Protection Mechanism

It does not rely on gastric acid neutralization and dissociation, will not consume gastric acidity, and has no side effects such as acid regurgitation, heartburn, bloating and constipation. Suitable for long-term calcium supplementation of people with atrophic gastritis, hypochlorhydria and gastrointestinal sensitivity.

3. System Stability Mechanism

The organic acid complex structure is firm, hard to dissociate, crystallize or precipitate in heating, acid-base, high-protein and high-fiber systems, without damaging the original flavor, taste and shelf life stability of products.

4. Nutrient Synergy Mechanism

Compound with **Vitamin D3, Vitamin K2, Magnesium, Zinc and Phosphorus** can further improve calcium deposition and bone fixation efficiency, synergistically promote bone metabolism and strengthen the effect of compound nutritional fortification.

(III) Application Scenarios

1. Infant Formula and Complementary Food Field

Suitable for formula milk powder, grain complementary food, nutrition packs, infant snacks and multivitamin nutrients for infants aged 0~36 months. Featured by gastric acid-free digestion, low irritation, high absorption and no bloating or constipation, it meets the delicate gastrointestinal and bone development needs of infants, being the preferred calcium source for high-end infant formula.

2. Dairy and Fermented Milk Field

Applied to modified milk powder, infant milk powder, yogurt, cheese, milk beverages and normal temperature liquid milk. It has good dispersibility, tolerates acid-base environment of fermentation, does not affect probiotic activity, and avoids crystallization and stratification, maintaining the original milk flavor and pure taste of dairy products.

3. Grain and Baked Food Field

Suitable for oatmeal, multigrain powder, nutritional rice powder, biscuits, cakes, puffed grains and meal replacement grains. It withstands conventional high-temperature processes such as baking, extrusion puffing and spray drying, no moisture regain or agglomeration during storage, with stable retention of calcium elements.

4. Solid Beverage, Meal Replacement and Sports Nutrition Field

Used in multivitamin meal replacement powder, sports nutrition powder, protein powder, nutrient solid granules and instant drinks. It has excellent compatibility with protein, vitamins and dietary fiber, uniform dispersion without agglomeration and peculiar smell after brewing, suitable for daily calcium supplementation of office workers, fitness groups and fat loss crowds.

5. Health Food Field

Applied to calcium supplement tablets, compound multivitamin and mineral capsules, oral liquids, calcium supplementation formulas for pregnant women and bone density nutritional supplements for middle-aged and elderly people. It is suitable for blue-capped product declaration, with high absorption rate, good compliance and extremely low side effects, ideal for pregnant women, lactating mothers, menopausal women and middle-aged and elderly osteoporosis groups.

6. Special Medical Purpose Formula Food

Used in full-nutrition formula powder specially for postoperative rehabilitation, hypochlorhydria, weak digestive function and low bone density in the elderly. High-purity food grade, mild and easy to absorb, compatible with tube feeding and sterilization processes, with excellent clinical gastrointestinal tolerance.

7. Functional Beverage and Liquid Food Field

Applied to fruit-flavored functional drinks, nutrient solutions, oral liquids and plant protein beverages. It has excellent dispersibility, no stratification or turbidity, and does not affect fruit flavor and taste, suitable for long-term normal temperature storage of liquid end products.

8. Feed and Pet Food Field

Covers young livestock and poultry feed, aquatic seedling feed, dog and cat staple food and pet nutritional snacks. It improves retarded bone development of young livestock and pets, promotes growth and development, enhances body immunity, with good palatability and no impact on feed intake; its bioavailability is much higher than conventional inorganic calcium.

(IV) Solutions

Aiming at the core pain points of various application fields (such as poor calcium absorption, gastric acid dependence, system crystallization, sensory deterioration and weak process adaptability), combined with the organic complex characteristics of Calcium Citrate, we provide accurate and implementable solutions with balanced safety, functionality and production operability.

1. Infant Formula / Special Medical Food Field

- **Pain Points**: Weak gastric acid in infants, poor calcium absorption, easy abdominal distension and constipation, high process requirements
- **Solutions**: Adopt high-purity food grade Calcium Citrate (purity ≥99.0%); avoid high proportion compatibility with high-concentration phytic acid and excessive iron salt in the same system; compound with Vitamin D3 and Magnesium to improve calcium deposition efficiency; adapt to spray drying of infant formula and sterilization process of special medical food, control processing temperature ≤180℃ to ensure stable complex structure; strictly follow national standard limits to accurately match nutritional needs of infants and special groups, eliminating risks of calcium overload and gastrointestinal discomfort.

2. Dairy / Fermented Milk Field

- **Pain Points**: Calcium is prone to crystallization and stratification, affecting taste and inhibiting probiotics

- **Solutions**: Adopt low-temperature uniform feeding mode, add at low temperature after fermentation and before sterilization, avoiding high temperature damage to complex structure and probiotic activity; control system pH at 4.0~8.0, compound with a small amount of Vitamin D3 to synergistically promote absorption and prevent dissociation and crystallization of calcium ions; select high-dispersibility raw materials to ensure uniform integration with dairy products without stratification and precipitation, retaining original milk flavor and taste.

3. Grain and Baked Food Field

- **Pain Points**: Calcium is easy to agglomerate under high temperature, moisture regain during storage and affecting baking taste
- **Solutions**: Pre-mix Calcium Citrate with grain powder evenly in advance, withstand short-term baking high temperature of 160~180℃ to avoid agglomeration caused by local high temperature; add a small amount of anti-caking agent to improve fluidity during storage and prevent moisture regain and agglomeration; add accurately according to formula ratio to ensure uniform distribution of calcium elements without affecting taste and appearance of baked food.

4. Solid Beverage / Meal Replacement Powder Field

- **Pain Points**: Calcium is easy to agglomerate, caking after brewing and astringent taste
- **Solutions**: Pre-mix and dilute Calcium Citrate with vitamins and trace elements first, then mass mix with plant protein and grain base to avoid high-concentration agglomeration; select fine-powder high-purity raw materials to ensure uniform dispersion without caking and wall adhesion after brewing; compound with sweet taste regulators to neutralize slight astringent taste, suitable for various meal replacement and sports nutrition formulas, balancing calcium supplementation function and drinking experience.

5. Health Food Field

- **Pain Points**: Poor absorption due to insufficient gastric acid, easy constipation after long-term administration and high compliance requirements for blue-capped declaration
- **Solutions**: Scientifically compound with Vitamin D3, VK2 and Magnesium to maximize calcium absorption and bone retention rate, reduce constipation incidence; adopt film coating process to avoid light and moisture, extend product shelf life; strictly feed according to the catalogue of health food raw materials and national standard requirements to ensure compliant calcium content per tablet/pill, adapt to blue-capped declaration and meet calcium supplementation needs of pregnant women, middle-aged and elderly people, women and other groups.

6. Functional Liquid Beverage Field

- **Pain Points**: Calcium is easy to precipitate, affecting color and flavor and unstable storage
- **Solutions**: Add Calcium Citrate at normal temperature aseptic deployment stage, compound with Vitamin D3 and Magnesium salt to stabilize complex structure and prevent dissociation and precipitation of calcium ions; control raw material addition amount to ensure uniform and stable beverage without changing original fruit flavor; optimize storage conditions with light-proof and sealing, avoid high temperature and humid environment to guarantee long-term product stability.

(V) Market Selling Points

1. Outstanding Absorption Advantage:

Gastric acid-independent absorption, efficient absorption for the elderly, children and hypochlorhydria groups. The bioavailability is **1.5~2 times** that of ordinary calcium carbonate with better calcium supplementation effect.

2. Wide Gastrointestinal Adaptability:

No acid regurgitation, heartburn, constipation or abdominal distension, mild stomach-friendly, suitable for long-term consumption by all age groups and sensitive constitutions.

3. Low Stone Risk:

Hard to combine with oxalic acid and phosphoric acid in diet to form insoluble precipitates, reducing the incidence of urinary system stones.

4. Sensory and Process Compatibility:

Fine powder with good dispersibility, high temperature resistance and wide pH stability, no crystallization or agglomeration, without affecting product flavor and color.

5. Global Full-Link Compliance:

Multiple authoritative certifications including national standard, FDA, EFSA and JECFA, compliant for domestic declaration and barrier-free application in global export markets.

6. Clean Label with High Added Value:

Organic acid complex form, concise formula without redundant auxiliary materials, conforming to the consumption trend of clean label, natural nutrition and high-end health food.

III. Recommended Dosage by Application Field

Based on food grade Calcium Citrate complying with **GB 1903.15-2016** and **GB 14880-2012**, classified by application field, marking the compliant addition range and recommended process dosage **calculated as calcium element**, strictly following national standard limits and balancing safety and calcium supplementation functionality.

(I) Infant Formula and Complementary Food Field

- Infant Formula Milk Powder (0~36 months): **12~20 mg/100kJ (Calculated as Calcium)**
- Infant Grain Complementary Food & Nutrition Pack: **200~400 mg/100g (Calculated as Calcium)**
- Preschool Children Formula Food: Accurately matched with daily recommended nutrient intake of **400~800mg/day**

(II) Dairy Product Field

- Modified Milk Powder & Infant Milk Powder: **2500~5000 mg/kg (Calculated as Calcium)**
- Fermented Milk & Flavored Yogurt: **100~250 mg/100g (Calculated as Calcium)**
- Liquid Sterilized Milk & Milk Beverage: **200~400 mg/kg (Calculated as Calcium)**

(III) Grain and Baked Food Field

- Wheat Flour, Rice Flour & Multigrain Nutritional Powder: **200~400 mg/kg (Calculated as Calcium)**
- Instant Oatmeal & Compound Grain Cereal: **150~300 mg/100g (Calculated as Calcium)**
- Biscuits, Cakes & Puffed Baked Food: **100~200 mg/100g (Calculated as Calcium)**

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

- Solid Beverage & Meal Replacement Powder: **200~400 mg/100g (Calculated as Calcium)**
- Sports Protein Powder & Multivitamin Nutrition Granules: Added according to internal formula standard, not exceeding national standard upper limit
- Liquid Functional Beverage & Plant Beverage: **50~150 mg/100ml (Calculated as Calcium)**

(V) Health Food Field

- Ordinary Adult Calcium Supplement Preparation: Daily calcium intake **600~1000 mg/day**
- Special Formula for Pregnant & Lactating Women: Daily calcium intake **800~1200 mg/day**
- Children Health Food: Daily calcium intake **300~600 mg/day**
- Single Tablet/Capsule: Calcium Citrate feeding amount **200~400mg/tablet**, scientifically proportioned as required

(VI) Special Medical Purpose Formula Food

- Full-Nutrition Special Medical Formula Powder: Calcium Citrate feeding amount **0.20%~0.40%**
- Calcium Element Control: **300~600 mg/100g**, meeting nutritional needs of postoperative patients, hypochlorhydria groups and elderly people with low bone density

(VII) Functional Beverage and Daily Fortification Field

- Bottled Functional Beverage & Nutrient Oral Liquid: **80~200 mg/100ml (Calculated as Calcium)**
- Plant Protein Beverage & Grain Beverage: **60~150 mg/100ml (Calculated as Calcium)**

(VIII) Feed and Pet Food Field

- Young Livestock and Poultry Compound Feed: **1000~2500 mg/kg**
- Aquatic Seedling Compound Feed: **800~2000 mg/kg**
- Dog & Cat Staple Food & Pet Nutritional Snacks: **1500~3500 mg/kg**

IV. Application Precautions and Quality Control

(I) Raw Material Quality Standard

- Appearance: Uniform white to off-white crystalline powder, no agglomeration, no foreign impurities and no peculiar smell;
- Content: Calcium 21.0%~23.0%, purity ≥99.0%, stable and uniform batch indicators;

- Safety: Heavy metals and microorganisms strictly comply with national standards and internal control standards, no exogenous pollution;
- Properties: Excellent water dispersibility and high suspension uniformity, hard to stratify or crystallize, suitable for various liquid and solid food systems.

(II) Processing and Compatibility Taboos

- Temperature: Withstands short-term processing high temperature of 160~180℃; long-term temperature over 200℃ easily damages the stability of complex structure;
- pH Adaptation: Optimal stable range pH 4.0~9.0, avoid long-term storage in extremely strong acid and alkali systems;
- Compatibility Recommendation: Synergize with Vitamin D3, Vitamin K2, Magnesium and Zinc to improve calcium absorption and bone deposition;
- Compatibility Avoidance: Avoid high-proportion compounding with ultra-high concentration oxalic acid and high-concentration phosphate in the same system to prevent formation of insoluble calcium salt precipitation.

(III) Production and Usage Suggestions

- Pre-mix and dilute powder products in a small proportion first, then feed and stir in large batches to ensure mixing uniformity;
- For liquid beverages and fermented milk, it is recommended to add in low-temperature post-process to reduce the disturbance of high-temperature process on complex structure;
- Strictly implement within the specified scope and limits of **GB 14880**, no over-range or over-limit application in food categories.

(IV) Storage Conditions

Seal and store in a cool, dry, ventilated and dark place with normal temperature storage environment ≤25℃; strictly prevent moisture, moisture-induced agglomeration and peculiar smell cross-contamination. The shelf life of unopened original package is **24 months**. Seal tightly for moisture prevention after opening, and it is recommended to use up within **3~6 months** to ensure stable physical and chemical indicators and dispersing activity.

V. Summary

Calcium Citrate has sufficient toxicological research evidence and safety certifications from multiple authoritative international institutions. It is a practically non-toxic organic calcium source with no teratogenicity, mutagenicity or reproductive and developmental toxicity. Featured with gastric acid-independent absorption and mild non-irritation to gastrointestinal tract, it can be safely consumed for a long time within the recommended national standard dosage by all age groups and special crowds including pregnant women, infants, the elderly and hypochlorhydria groups.

It has six core advantages: high absorption and utilization rate, low stone risk, no acid regurgitation or constipation, system stability, strong compatibility and wide population adaptability. It perfectly solves industry pain points of traditional calcium sources such as gastric acid dependence, low absorption rate, easy precipitation and stone formation, poor sensory performance and gastrointestinal discomfort.

Its application fully covers the whole industrial chain of infant formula food, dairy products, grain baking, solid beverages, functional beverages, health food, special medical food, feed and pet food. The recommended dosage in various fields is strictly formulated in accordance with **GB 14880, GB 1903.15** and JECFA international general standards, with authoritative and reliable data directly applicable to formula production.

Under the industry trend of organic nutrition, clean label, high-end functional food and export compliance, Calcium Citrate has become the preferred organic complex calcium nutritional fortifier to replace traditional calcium carbonate and calcium lactate, upgrade product quality, create differentiated calcium selling points and realize brand premium, with prominent industrial application prospects and market value.