Analysis of Unique Properties of Magnesium Citrate

I. Physicochemical Characteristics

Magnesium Citrate, as a food-grade organic magnesium nutrition fortifier, features balanced and stable physicochemical properties with excellent processing adaptability. Its core characteristics are as follows:

1. Physical and Chemical Morphology

It appears as white amorphous powder or granular crystal, odorless with a slight mild taste, free of visible impurities to the naked eye, and possesses outstanding powder fluidity and bulkiness. Divided by crystal water structure, there are two mainstream types: **anhydrous magnesium citrate** and **magnesium citrate nonahydrate**. Among them, magnesium citrate nonahydrate has better water solubility and is less prone to caking, making it the mainstream specification for food and health product industries. It features regular crystal arrangement and moderate bulk density, resisting moisture absorption and agglomeration. It is directly compatible with mainstream processing technologies such as powder blending, tableting and granulation, wet granulation, and solid beverage preparation, with excellent dispersion uniformity.

2. Solubility Characteristics

It is slightly soluble in water at a normal temperature of 25℃; the solubility of magnesium citrate nonahydrate is significantly better than that of the anhydrous form. It is easily soluble in dilute organic acids and dilute inorganic acids, and can dissociate rapidly and steadily in the acidic environment of human gastric juice (pH 1.5-3.5) to release magnesium ions gently. Compared with inorganic magnesium sources such as magnesium oxide and magnesium carbonate, it avoids sudden changes in gastrointestinal osmotic pressure caused by instantaneous dissolution and release. The dissolution process is gentle and controllable, and the prepared solution has high clarity without turbidity, precipitation or stratification.

3. Stability Performance

It maintains high chemical stability under normal temperature and atmospheric pressure, resisting oxidation, discoloration, moisture absorption and deterioration, with no

compatibility deterioration when exposed to air and conventional food substrates. It exhibits excellent thermal stability: its structure remains unchanged at low temperatures; it gradually loses crystal water when heated to 120℃, and molecular skeleton decomposition only occurs above 250℃. It can withstand conventional food processing technologies such as baking, high-temperature instantaneous sterilization, extrusion puffing and spray drying (processing temperature ≤200℃). The retention rate of magnesium elements during processing is **≥95%**, with stability far exceeding most inorganic magnesium and common organic magnesium preparations.

4. Molecular Structural Characteristics

It is a typical organic chelated magnesium. The carboxyl and hydroxyl groups in citrate molecules form a stable five-membered cyclic chelated structure with magnesium ions through coordinate bonds, with a moderate chelation binding constant. It maintains complete molecular structure in the processing system to prevent free precipitation of magnesium ions. Meanwhile, it dissociates slowly on demand in the intestinal physiological environment, avoiding gastrointestinal irritation from free magnesium ions and reducing antagonistic binding with phytic acid, oxalic acid and phosphate in diets. Its molecular structure boasts dual advantages of processing stability and physiological bioavailability.

II. Functional Characteristics

Relying on its unique chelated molecular structure, magnesium citrate has prominent advantages in magnesium nutrition fortification, physiological adaptability and application compatibility. Its core functional characteristics are as follows:

1. High Bioavailability

Compared with inorganic magnesium sources such as magnesium oxide, magnesium carbonate and magnesium chloride, the chelated structure of magnesium citrate avoids the adsorption and solidification of anti-nutritional factors such as phytic acid, oxalic acid and dietary fiber in the intestine, reducing the formation of insoluble magnesium salt precipitation. Magnesium ions can be absorbed through dual pathways of active transport and passive diffusion in the intestinal mucosa without complex dissociation steps. Its human bioavailability reaches more than 55%, an increase of 25%-40% compared with common inorganic magnesium, delivering higher magnesium supplementation efficiency and more thorough absorption.

2. Low Gastrointestinal Irritation

Its aqueous solution is nearly physiologically neutral, conforming to the acid-base environment of human body fluids and not disrupting the inherent acid-base balance of the gastrointestinal tract. The release rate of chelated magnesium ions is gentle and will not instantly increase intestinal osmotic pressure. It effectively avoids discomforts such as abdominal distension, diarrhea, acid regurgitation and dull stomach pain easily caused by inorganic magnesium, with excellent gastrointestinal tolerance. It is suitable for infants, the middle-aged and elderly, people with sensitive gastrointestinal tracts, pregnant and lactating women, and chronic disease groups, ideal for long-term regular daily supplementation.

3. Precise Nutrition Fortification

The magnesium content of magnesium citrate is stable and controllable. The theoretical magnesium content on a dry basis meets standards with extremely small batch fluctuations, and the difference in active ingredients between batches is **≤1.0%**. It strictly complies with **GB 1903.23-2021 National Food Safety Standard - Food Nutrition Fortifier: Magnesium Citrate** and the specification for the use of nutritional fortifiers specified in GB 14880-2012. With uniform powder content and good mixing and dispersion properties, it can accurately match the added amount designed in the formula, facilitate industrial quantitative feeding, and ensure compliant and stable magnesium content in end products.

4. Strong Compatibility

It has excellent compatibility with proteins, milk powder substrates, B vitamins, vitamin D, compound minerals such as calcium, zinc and iron, dietary fiber, as well as food additives including sweeteners, emulsifiers and thickeners in food systems, without adverse reactions such as flocculation, precipitation, discoloration and degradation of active ingredients. It is widely applicable to a variety of products such as modified milk, milk powder, grain products, solid beverages, compound nutrient tablets and health food chewable tablets, with broader formula adaptability than most inorganic magnesium raw materials.

III. Core Unique Properties

The core advantage of magnesium citrate distinguishing it from other magnesium sources lies in the four-dimensional comprehensive improvement in nutrition, safety, processability and adaptability endowed by its chelated structure, detailed as follows:

1. Chelated Sustained Release for Long-term and Balanced Magnesium Supplementation

The cyclic chelated structure has natural sustained-release physiological properties. After entering the human digestive tract, the chelation bonds break gradually with changes in the physiological environment, releasing magnesium ions slowly and continuously. It avoids metabolic loss and gastrointestinal burden caused by a high concentration of free magnesium at one time. It can maintain steady serum magnesium levels in the body for a long time and achieve long-term, balanced and gentle magnesium supplementation, presenting prominent advantages over common magnesium sources with instantaneous release, fast metabolism and weak sustained supplementation effect.

2. Strong Anti-antagonism with Unlimited Dietary Adaptability

The outer shell of the chelated molecule can shield the complexation and solidification effect of anti-nutritional factors such as phytic acid, oxalic acid and phosphate on magnesium ions, greatly reducing the inhibition of magnesium absorption by daily ingredients such as cereals, beans and green leafy vegetables. It maintains a stable high absorption rate whether taken on an empty stomach or with meals, with no need to deliberately avoid diets high in phytic acid and oxalic acid. It greatly simplifies daily magnesium supplementation methods and meets the demand for regular nutrition supplementation of the general public.

3. Safe and Low-toxicity, Suitable for All Age Groups

Key indicators such as heavy metals, microorganisms, insoluble substances in hydrochloric acid and loss on drying are strictly controlled in accordance with the national standard GB 1903.23-2021, with strict and controllable impurity limits and outstanding food-grade safety properties. Under compliant dosage, it has no cumulative toxicity, no allergenicity and no obvious toxic and side effects with high physiological affinity. It can be used as the preferred organic magnesium source for infant formula food, food for pregnant and lactating women, and nutritional food for the elderly, covering all age groups.

4. Broad Process Adaptability with Extremely Low Production Loss

It has multiple process advantages including excellent powder fluidity, moisture resistance, anti-caking, high temperature resistance and controllable solubility. It is compatible with full-category food production processes such as dry blending, tableting and granulation, wet granulation, spray drying, high-temperature baking and aseptic filling. It resists agglomeration, caking and thermal degradation during processing with low loss of magnesium elements, and does not change the original color, flavor, taste and shelf stability of end products, effectively reducing defective product rates and raw material loss in production.

5. Diverse Physiological Activities with High Comprehensive Nutritional Value

In addition to basic magnesium nutrition fortification, it synergistically participates in multiple key physiological metabolisms of the human body: regulating the mineralization and development of bones and teeth to support adolescent growth and maintain bone density in the middle-aged and elderly; participating in nerve conduction and muscle contraction to relieve muscle spasms and improve sleep quality; regulating electrolyte balance and assisting in maintaining cardiovascular homeostasis. Meanwhile, it can synergize with calcium and vitamin D to improve the absorption efficiency of minerals, with comprehensive physiological value far exceeding inorganic magnesium raw materials that only provide single magnesium supplementation.

IV. Summary of Core Unique Properties

Based on all indicators, as a high-end organic magnesium source, magnesium citrate's core differentiated advantages can be summarized into five dimensions, making it irreplaceable compared with traditional magnesium sources:

1. Moderate Effective Magnesium Content with Controllable Formula Cost

Compared with low-content organic magnesium such as magnesium gluconate, magnesium citrate has a higher proportion of effective magnesium, requiring less raw material addition under the same magnesium supplementation effect and saving formula proportion space. Compared with high-content but highly irritating inorganic magnesium, no additional buffered auxiliary materials are needed, achieving a more balanced comprehensive formula and usage cost, suitable for large-scale industrial mass production.

2. Ultra-stable Physicochemical Properties for Longer End Product Shelf Life

It resists moisture absorption, caking, oxidation and discoloration during normal temperature storage and maintains stable quality under fluctuating temperature and humidity environments. It withstands high-temperature food processing technologies, and end finished products are less prone to stratification, precipitation and flavor deterioration during storage, significantly extending the product shelf life and reducing circulation and warehousing loss.

3. Physiologically Mild and Low-irritation, Universally Applicable to All Crowds

With near-neutral physiological characteristics and a chelated sustained-release mode, it fundamentally avoids gastrointestinal osmotic pressure irritation, balancing magnesium supplementation and gastrointestinal friendliness. It is applicable to infants, pregnant and lactating women, the elderly, people with sensitive gastrointestinal tracts

and special chronic disease groups with no restrictions on applicable populations.

4. Integrated Multi-functions to Simplify Formula System

It integrates magnesium nutrition fortification, powder flow aid and anti-caking, mild pH regulation of the system, and compatibility with multiple raw materials into one. It can reduce the types of auxiliary materials such as anti-caking agents and buffers in the formula, lower the difficulty of formula research and development, adapt to diversified product forms such as solid, liquid, baking and sterilized products, and broaden the boundaries of formula design.

5. Global Standard Compliance with No Barriers for Domestic and Export Sales

It complies with China national standards GB 1903.23-2021 and GB 14880-2012, and meets the general international food additive standards and access requirements for food nutrition fortifiers in Europe and America. With complete toxicological data and mature application history, there are no compliance technical barriers in both domestic and export markets, covering full-field applications across multiple industries.

V. Commercial Value

1. Optimize Formula Structure and Reduce Comprehensive Production Costs

The raw material dosage under the same magnesium supplementation efficiency is lower than that of common organic magnesium, directly cutting raw material procurement expenses. Its excellent powder fluidity and anti-caking properties reduce the dosage of flow aids, anti-caking agents and buffered auxiliary materials, simplify batching procedures and production control links, further reduce comprehensive production costs, and effectively increase the gross profit margin of end products.

2. Empower Product Quality and Build Differentiated Competition

With characteristics such as odorlessness, good solubility, no impact on product color and taste, and strong stability, it can comprehensively improve the sensory quality and eating experience of end food and health products. Relying on the selling points of universal population adaptability, mildness and safety, it is easy to establish the positioning of high-end organic nutrition fortified products, helping enterprises form differentiated advantages among similar competitors.

3. Simplify Production Processes and Improve Industrialization Efficiency

With strong compatibility, resistance to caking and degradation, and adaptability to various processing technologies, it reduces production problems such as machine blockage, stratification and high defective product rates. Its uniform and stable content ensures accurate feeding and metering, reduces quality fluctuations between batches, simplifies quality control and testing procedures, and greatly improves production line operation efficiency and finished product qualification rate.

4. Authoritative Compliance and Safety Endorsement to Avoid Market Operation Risks

Supported by authoritative national standards, complete toxicological safety data and long-term commercial application accumulation, it has no safety disputes or public opinion risks. Compliant for use by all age groups with controllable label specification, it can effectively avoid market risks such as non-compliant formulas and population application restrictions, suitable for enterprises' long-term large-scale layout and promotion.

VI. Target Application Market

Relying on excellent physicochemical properties, physiological advantages and commercial value, magnesium citrate is widely used in end markets across multiple fields:

1. Nutritionally Fortified Food

Modified milk, formula milk powder, breakfast cereals, nutritional oatmeal, noodles and biscuits, meal replacement staple foods, etc. It efficiently supplements magnesium elements, improves powder fluidity and product storage stability, and balances nutrition fortification and product quality optimization with prominent cost advantages in large-scale application.

2. Solid Beverages and Instant Powders

Protein powder, compound nutrient powder, soybean milk powder, meal replacement powder, solid instant drinks, etc. It solves the pain points of inorganic magnesium such as easy turbidity, precipitation, peculiar odor and caking, featuring good instant solubility and pure taste, suitable for daily nutrition supplementation of families and special groups.

3. Pharmaceutical and Health Care Field

Magnesium supplements, calcium-magnesium compound mineral tablets, chewable tablets, nutritional oral liquids, health preparations for the middle-aged and elderly, etc. With the advantages of high absorption rate, low irritation and long-term sustained release, it is suitable for long-term administration, especially for people with sensitive gastrointestinal tracts, pregnant and lactating women, the middle-aged and elderly, and sub-health groups.

4. Pet Nutrition Field

Dog food, cat food, pet nutritional ointment, pet compound nutrients, etc. It efficiently supplements essential magnesium elements for pets, supports bone development, electrolyte balance and hair health, is mild and non-irritating to pet gastrointestinal tracts, and offers higher cost performance than common inorganic magnesium raw materials.

5. Other Fields

It can be applied in personal care cosmetics to regulate skin electrolytes and assist in maintaining skin barrier health. It can also be used as a high-end feed nutrition fortifier for magnesium nutrition supply in livestock and aquaculture breeding, improving growth performance and body stress resistance of cultured organisms.

Conclusion

Boasting five core properties including ultra-stable physicochemical properties, high chelated absorption, mild low gastrointestinal irritation, strong formula compatibility and global universal compliance, magnesium citrate has become a benchmark raw material among organic magnesium nutrition fortifiers. It perfectly solves industry pain points of traditional inorganic magnesium such as strong irritation, and common organic magnesium such as low content, high cost and limited applicable populations. Integrating nutrition fortification, quality improvement, cost optimization and safety compliance, it is applicable to all age groups, full food processing technologies and multi-industry application fields. As an indispensable high-quality functional raw material in the food industry, pharmaceutical health care, pet nutrition and high-end feed fields, it possesses strong market rigid demand and broad long-term commercial prospects.