Professional Operation Guide for the Addition Method of Calcium Citrate in Application Fields

Preface

This operation guide is compiled in accordance with the authoritative standards including GB 17203-1998 "National Food Safety Standard - Food Additive Calcium Citrate", GB 14880-2012 "National Food Safety Standard - Usage Standard for Food Nutrition Fortifiers", GB 15193 Series of Food Toxicology Evaluation Standards, FDA GRAS, EFSA, JECFA (53rd Session Specifications), and Codex.

Based on the physical and chemical properties, toxicological safety data, and regulatory permission scope of food-grade/medical-grade calcium citrate (Calcium Citrate, CAS: 813-94-5, molecular formula $C_{12}H_{10}Ca_3O_{14}\cdot 4H_2O$, labeled calcium content 20.0% ~ 22.0%), this guide uniformly standardizes the full-chain operation requirements including raw material access, warehousing control, general operation procedures, field-specific standardized addition processes, premix ratio, timing control points, pH/temperature tolerance range, compatibility synergy and taboos, process quality control, abnormal disposal, and compliance traceability.

It is applicable to the R&D, production process, workshop operation, quality control, and system internal audit of all positions in eight application scenarios: infant formula food, dairy products, grain baked food, solid beverage meal replacement, health food, special medical purpose formula food, condiments, feed and pet food, with professionalism, implementability, regulatory traceability, data accuracy, and process uniqueness.

Part One: Basic Specifications and Raw Material Access Control

1.1 Scope of Application and Compilation Basis

1.1.1 Scope of Application

This guide clarifies the full-process operation standards for food-grade/medical-grade calcium citrate from raw material acceptance, warehousing and storage, measurement conversion, premix dilution, addition process timing, system adaptation, compatibility combination, process detection, finished product release, and abnormal correction. It covers all compliant application scenarios such as dry/wet food production lines, fermented milk production lines, baking and extrusion production lines, tablet and capsule preparations, condiment brewing, feed and pet food processing, and agricultural foliar fertilizer/water-soluble fertilizer processing, providing a unified and implementable execution basis for operations in various positions.

1.1.2 Authoritative Compilation Basis

- National Standards: GB 17203-1998 "National Food Safety Standard - Food Additive Calcium Citrate", GB 14880-2012 "National Food Safety Standard - Usage Standard for Food Nutrition Fortifiers", GB 2760-2024 "National Food Safety Standard - Usage Standard for Food Additives", GB 15193 Series of Food Toxicology

Evaluation Standards, Feed Additives - Part 3: Mineral Elements and Their Complexes (Chelates) - Calcium Citrate (Revision Plan).

- International Standards: FDA GRAS (Generally Recognized As Safe for Food Additives), EFSA Food Additive Safety Assessment Report, JECFA (53rd Session) Calcium Citrate Specification Standard, Codex General Guidelines for Nutrition Fortifiers.
- Internal Control: General SOP for Food Nutrition Fortifier Production, Specification for Powder Uniformity Detection, Operating Procedures for Liquid Nutrition Fortification Feeding, and Specification for Mineral Element Premixing.

1.2 Core Physical and Chemical Properties and Process Tolerance Benchmark Parameters of Calcium Citrate (Authoritative Measured Values)

1.2.1 Appearance:

The standard index is white crystalline powder, free of caking, visible impurities, and peculiar smell; the process tolerance boundary is that it does not discolor or absorb moisture and cake when stored at room temperature in the dark. It is easy to absorb moisture after opening, so it needs to be sealed and protected immediately to prevent moisture absorption and agglomeration from affecting subsequent use, and avoid contact with carbon dioxide in the air leading to slight deterioration.

1.2.2 Calcium Content:

The standard index is 20.0% ~ 22.0%, and the unified engineering simplified calculation benchmark for the industry is 21.0%; the process tolerance boundary is that the range of calcium content between batches is ≤±0.5%, among which the calcium content of medical-grade calcium citrate shall be ≥20.5% to ensure the effectiveness and stability of medical-grade products.

1.2.3 Moisture:

The standard index is classified by grade: feed grade ≤12.0%, food grade ≤8.0%, medical grade ≤6.0%; the process tolerance boundary is that the critical environmental humidity for moisture absorption is ≤70% RH. When the environmental humidity exceeds this value, the raw material is prone to moisture absorption and caking, leading to decreased fluidity and poor mixing uniformity.

1.2.4 pH of 10g/L Aqueous Solution:

The standard index is 6.0 ~ 8.0, showing weak alkalinity; the process tolerance boundary is the stable range of pH 5.5 ~ 8.5. When the system pH < 4.0 (strong acid environment), calcium citrate is easy to dissolve excessively leading to rapid precipitation of calcium ions; when pH > 9.0 (strong alkali environment), it is easy to combine with other ions to produce precipitation, affecting product quality and bioavailability.

1.2.5 Temperature Resistance:

The standard index is short-term tolerance to 200℃. If it is in an environment of >220℃ for a long time, problems such as decomposition, yellowing color, and slight

attenuation of calcium content will occur; the process tolerance boundary is that high-temperature processes such as baking and spray drying need to strictly control the instantaneous temperature ≤200℃, and the feed granulation process temperature needs to be ≤90℃ to avoid nutrient loss caused by high-temperature decomposition.

1.2.6 Solubility:

The standard index is slightly soluble in cold water, easily soluble in hot water (above 80℃), dilute hydrochloric acid, dilute nitric acid, and insoluble in organic solvents such as ethanol and acetone; the process tolerance boundary is that pre-dispersion treatment is required in cold water systems to avoid local agglomeration, and the solution needs to be cooled slowly after dissolving in hot water systems to prevent calcium ion precipitation. Liquid systems need to be prepared and used immediately to avoid precipitation caused by long-term standing.

1.2.7 Physiological Properties:

The standard index is organic calcium form, with a bioavailability of about 85%, extremely low gastrointestinal irritation, no obvious peculiar smell, and no impact on the normal digestive function of humans/animals; the process tolerance boundary is suitable for people with gastrointestinal sensitivity and young animals, does not induce adverse reactions such as constipation and abdominal distension, and has good compatibility and strong synergy with most nutrients.

1.3 Raw Material Warehousing Acceptance Standards (Full-Process Control to Prevent Unqualified Raw Materials from Entering the Factory)

1.3.1 Mandatory Verification of Qualification Documents

Before raw materials are put into storage, the following qualification documents must be strictly verified to ensure legal sources and controllable quality: food-grade raw materials must provide food production license, type inspection report, batch factory inspection report, full-item heavy metal/microorganism inspection report, and compliance statement in line with the permitted scope of GB14880; export products must additionally provide HALAL/KOSHER certification documents; medical-grade raw materials must additionally provide sterility inspection report and internal control index statement stricter than national standards on the basis of food-grade qualifications; feed-grade raw materials must provide feed additive production license and relevant compliance certification documents to ensure compliance with feed industry usage specifications.

1.3.2 Mandatory Physical and Chemical Sampling Inspection

After each batch of raw materials is put into storage, physical and chemical index sampling inspection must be carried out. The mandatory inspection items include: calcium (Ca^{2+}) content (must meet the range requirement of 20.0% ~ 22.0%), moisture (tested by food grade, medical grade, and feed grade), pH value of 10g/L aqueous solution, ignition residue, heavy metals (Pb, As, Cd, Hg), among which Pb≤0.5mg/kg and As≤0.5mg/kg; feed-grade raw materials additionally sample and inspect free citric acid content (≤2.0%) and particle size (pass rate of 0.84mm test sieve ≥95%) to ensure that the physical and chemical indexes of raw materials meet the standard requirements.

1.3.3 Microbial Access Threshold

Microbial indicators are controlled by raw material grade: food-grade raw materials must meet the requirements of total bacterial count ≤1×10^4 CFU/g, coliform ≤0.3 MPN/g, mold and yeast ≤100 CFU/g, Salmonella and Staphylococcus aureus not detected in 25g, and no thermophilic spores and pathogenic bacteria contamination; medical-grade raw materials must meet sterility requirements with no microorganisms detected; microbial indicators of feed-grade raw materials must comply with relevant standards of the feed industry to prevent breeding risks caused by microbial contamination.

1.3.4 Rejection Criteria (Rigid Standards, Strictly Implemented)

Raw materials with any of the following conditions shall be rejected and are strictly prohibited from being put into storage and used: raw materials are caked and hard, with obvious abnormal color (such as yellowing, graying, deviating from normal white); with pungent peculiar smell, not meeting the standard of no peculiar smell; microbial indicators exceeding the standard, or heavy metals (Pb, As, etc.) exceeding the limit value; calcium content deviating from the range of 20.0% ~ 22.0%, or feed-grade raw materials failing to meet the requirements of particle size and free citric acid content; incomplete, false or expired qualification documents, unable to provide effective inspection reports.

1.4 Warehousing and Unsealing Management Specifications (Moisture-proof, Pollution-proof, Deterioration-proof)

1.4.1 Warehousing Environment

The warehousing environment must meet the requirements of constant temperature ≤25℃, relative humidity controlled at 45% ~ 70% RH, keeping cool, dry, ventilated, and away from light, avoiding direct sunlight and humid environment; raw materials must be stored off the ground and away from walls, with a distance of ≥10cm from the ground and ≥20cm from the walls to prevent moisture erosion from the ground and pollution from the walls; the warehousing area must be far away from strong acids, strong oxidants, and volatile odorous raw materials to avoid structural changes, cross-contamination, or chemical reactions of raw materials.

1.4.2 Packaging and Sealing

The original packaging of raw materials adopts 25kg paper barrels or aluminum foil bags, lined with food-grade polyethylene bags to ensure airtightness and moisture-proof; after opening, it is necessary to immediately seal with double-layer food-grade inner membrane + aluminum foil, clearly mark the opening date, validity period, and user on the outer box, and do a good job in moisture-proof protection to prevent raw materials from absorbing moisture, caking, and deteriorating; unopened raw materials must be kept in intact packaging, and damage and incomplete sealing are strictly prohibited.

1.4.3 Service Life

The shelf life of unopened raw materials is distinguished by grade: 18 months for food grade and medical grade, 24 months for feed grade, calculated from the date of

production; opened raw materials must be used up within 45 days under airtight and moisture-proof conditions. For raw materials not used up after the expiration date, full-item re-inspection must be carried out. They can be used in limited quantities only after passing the re-inspection, and directly scrapped if failing the re-inspection, and are strictly prohibited from being put into production.

1.4.4 Warehousing Taboos

It is strictly prohibited to mix calcium citrate with strong oxidants, strong acids, high-phosphorus preparations, and fluoride-containing compounds in the same warehouse to prevent chemical reactions and structural changes of raw materials; feed-grade calcium citrate must be stored separately, and direct contact with dicalcium phosphate and copper sulfate is prohibited to avoid antagonistic reactions affecting raw material quality; smoking and open flames are strictly prohibited in the warehousing area, and it must be far away from fire sources to prevent potential safety hazards.

Part Two: General Standardized Operating Procedures (Applicable to All Fields, Mandatory Implementation)

1 Accurate Measurement and Conversion Formula (Legally Calculated by Calcium Element, Preventing Measurement Deviation)

1.1 Core Conversion Formula

The calculation of the actual addition amount of calcium citrate must strictly follow the following formula to ensure that the addition amount is accurate and controllable: $$\text{Actual Addition Amount of Calcium Citrate} = \frac{\text{Target Calcium Addition Amount (calculated as Ca)}}{\text{Actual Calcium Content of Raw Material}}$$; for the convenience of formula implementation and workshop operation, the industry uniformly adopts the engineering simplified value, calculated according to the benchmark of 21.0% (raw material calcium content). If the actual calcium content of the raw material deviates greatly from the benchmark value, it is necessary to recalculate according to the actual content to ensure the accuracy of the addition amount.

1.2 Requirements for Measuring Equipment

- Laboratory Test/Pilot Test Stage: Electronic analytical balance is adopted, with an accuracy of 0.01g. Calibration is required before measurement to ensure that the balance error is within the allowable range;
- Mass Production on Production Line: Automatic loss-in-weight measurement system is adopted, with a calibration cycle ≤3 months. Regular measurement accuracy detection is carried out to ensure that the measurement deviation is ≤±3%;
- General Requirements: All measuring instruments must be within the verification validity period. Estimated feeding and visual feeding are strictly prohibited. Records must be made during the measurement process, and measurement data must be retained for traceability; after measurement, the measuring instruments must be cleaned to avoid residual raw materials affecting the measurement accuracy next time.

2. Standard Premix Dilution Process (Key Control Point, Directly Affecting Product Quality)

Calcium citrate is slightly soluble in cold water and easy to absorb moisture and agglomerate. Direct feeding is likely to cause excessive local concentration, leading to system precipitation and caking, affecting product stability. Therefore, premix/pre-dispersion pretreatment must be implemented in all application scenarios, and the specific process is standardized according to solid and liquid systems respectively.

2.1 Premix Specifications for Solid Powder Products (Applicable to Solid Raw Materials of Food, Feed, and Health Products)

- Selection of Dilution Carrier: Neutral inert carriers are preferred. For food grade, lactose, maltodextrin, and corn starch (without phytic acid and high phosphorus interference to avoid affecting calcium absorption) can be selected; for feed grade, zeolite powder, rice hull powder, and soybean meal (suitable for feed system, controllable cost and no impact on palatability) can be selected; carriers with high phytic acid, high phosphorus, and high fluorine are strictly prohibited.
- Premix Ratio Control: The premix ratio of calcium citrate to carrier is 1:4 ~ 1:10, among which the premix ratio of food-grade and medical-grade raw materials is 1:4 ~ 1:6 (to ensure uniform calcium content after premixing, facilitating subsequent mixing), and the premix ratio of feed-grade raw materials is 1:6 ~ 1:10 (suitable for mass feed production, reducing cost).
- Premix Process Requirements: The equal incremental method is adopted for mixing. First, mix calcium citrate with a small amount of carrier evenly, then gradually add the remaining carrier, and the mixing time is ≥15 minutes; after mixing, pass through 80 ~ 100 mesh double-layer sieving to remove agglomerated particles, then perform secondary mixing to ensure uniform mixing;
- Control Target: The premixed powder has no visible agglomerated particles, the calcium distribution of the batch powder is uniform, and the mixing uniformity RSD ≤3.0%, ensuring that the calcium content of each part of the product meets the standard in subsequent production.

2.2 Pre-dispersion Preparation Specifications for Liquid Systems (Applicable to Beverages, Oral Liquids, Condiments, and Foliar Fertilizers)

- Preparation Water Temperature Control: Use 60 ~ 80℃ purified water or softened water for dissolution. Too low water temperature will lead to slow and insufficient dissolution of calcium citrate, and too high water temperature will accelerate water evaporation, leading to calcium ion precipitation;
- Dispersant System Configuration: For food-grade liquid systems, 0.1% ~ 0.2% citric acid can be added to adjust the pH of the aqueous solution to 5.5 ~ 7.5, maintain system stability, and promote the dissolution and dispersion of calcium citrate; for feed-grade and agricultural liquid systems, an appropriate amount of dispersant can be added as needed to ensure uniform system without precipitation;
- Stirring Operation Requirements: Adopt medium-speed stirring for 8 ~ 15 minutes. During the stirring process, continuously observe until the solution is completely transparent, without precipitation and stratification, ensuring that calcium citrate is completely dissolved and dispersed;
- Usage Requirements: The pre-dispersed liquid system must be prepared and used immediately, and the standing time shall not exceed 4h to avoid calcium ion

precipitation and sedimentation segregation, affecting the addition effect.

3 General Principles for Addition Timing and Process Temperature Control (Adapting to Different Production Processes, Ensuring Product Quality)

3.1 High-Temperature Processes (Baking, Extrusion Puffing, Spray Drying):

The addition timing is the powder pretreatment stage. Mix the premixed calcium citrate with the basic powder evenly, avoiding the continuous high-temperature insulation section; the process temperature is controlled at an instantaneous temperature ≤200℃, and long-term heating above 220℃ is prohibited to prevent the decomposition of calcium citrate, calcium content loss, and product yellowing, while ensuring that the bioavailability of calcium does not decrease.

3.2 Fermentation Processes (Yogurt, Fermented Milk):

The addition timing is the low-temperature section (≤60℃) after the end of fermentation and before sterilization. It shall not be added in the early stage of fermentation to avoid calcium citrate affecting the metabolic activities of fermentation flora, and prevent abnormal fluctuations of system pH, ensuring the flavor and quality of fermented products; after feeding, stir at low speed for 15 minutes to ensure uniform mixing and lock the system pH at 5.5 ~ 7.5.

3.3 Liquid Beverages, Oral Liquids, Condiments:

The addition timing is the medium-low temperature (50 ~ 65℃) homogenization and stirring stage. At this time, the system temperature is appropriate, the dissolution and dispersion effect of calcium citrate is good, and it is not easy to precipitate; the system pH is controlled in the stable range of 5.5 ~ 7.5 throughout the process, avoiding strong acid and strong alkali environments to prevent calcium ion precipitation, and ensuring that the product has no peculiar smell and no precipitation.

3.4 Solid Preparations (Meal Replacement Powder, Nutrition Packs, Tablets, Capsules):

The addition timing is after the premixing of trace elements and vitamins is completed, and calcium citrate is added last in compatibility to reduce the damage to its structure caused by long-term mechanical grinding and high-temperature granulation; medical-grade solid preparations must be operated in a light-proof and moisture-proof environment to prevent raw materials from absorbing moisture and caking, ensuring product effectiveness.

3.5 Agricultural Foliar Fertilizers/Water-Soluble Fertilizers:

The addition timing is the normal temperature dissolution and dilution stage. After dissolution, it must be used up within 4 hours, and spraying should be avoided during high-temperature and strong-light periods (before 10 am and after 4 pm) to improve the absorption efficiency of calcium elements and avoid calcium ion precipitation caused by high temperature and strong light, affecting the calcium supplement effect of crops.

4 Judgment Standards for Mixing Uniformity (Quantifiable and Detectable, Ensuring Product Uniformity)

4.1 Powder Products (Food, Feed, Health Products):

The multi-point random sampling method is adopted. 5 samples are randomly taken from each batch, the calcium content of each sample is detected, and the relative standard deviation (RSD) is calculated. RSD ≤3.0% is qualified; if RSD >3.0%, re-mixing is required until it meets the standard to ensure that the calcium content of each part of the powder product is uniform.

4.2 Liquid Products (Beverages, Oral Liquids, Condiments, Foliar Fertilizers):

Let the prepared liquid product stand for 60 minutes, observe whether there is stratification and precipitation, and detect the calcium content of the upper and lower layer samples at the same time. A deviation of ≤5.0% is qualified; if stratification and precipitation occur, or the calcium content deviation between the upper and lower layers is too large, re-stirring and dispersion are required, and unqualified products are prohibited from entering the next process.

4.3 Terminal Finished Products:

The allowable deviation of the labeled calcium content of terminal products must comply with the legal range of ±10% of the labeled value in GB 14880, and the terminal feed-grade products must comply with relevant specifications of the feed industry to ensure that the product label is consistent with the actual content and protect the rights and interests of consumers and breeders.

5 General Guidelines for Synergistic Effect and Compatibility Taboos (Clarifying Red Lines, Avoiding Quality Hidden Dangers)

5.1 Recommended Synergistic Compatibility (Improving Absorption Rate, Stabilizing System, Optimizing Product Quality)

- Nutritional Synergy: A reasonable ratio of vitamin D_3 (addition amount 0.005% ~ 0.01%), vitamin C (addition amount 0.1% ~ 0.3%) and calcium citrate can significantly improve the intestinal absorption efficiency of calcium elements. At the same time, vitamin C can adjust the system pH and maintain the stability of calcium citrate;
- Flavor Optimization: Food-grade products can be compounded with flavor substances such as vanilla and fruit juice to effectively mask the slight astringency that calcium citrate may produce and improve product palatability;
- Feed Adaptation: Feed-grade calcium citrate can be used synergistically with zinc methionine and vitamin D_3 to alleviate the competitive antagonism between minerals, improve the absorption effect of calcium and zinc elements, and optimize breeding benefits.

5.2 Strictly Prohibited Compatibility (Mandatory Red Lines, Strictly Prohibited Illegal Matching)

- High Phytic Acid Raw Materials (concentration >0.5%), High-Phosphorus Preparations, Excessive Fluorides: These substances will have a strong chelation reaction

with calcium citrate to form insoluble complexes, inhibit the absorption of calcium elements, and reduce product effectiveness;

- Strong Acid and Strong Alkali Environment: When the system pH <4.0 (strong acid) and pH >9.0 (strong alkali), it will lead to abnormal dissolution or precipitation of calcium citrate, affecting product quality;
- Strong Oxidants and Chlorine-Containing Strong Fungicides: When coexisting with calcium citrate in the same system, they will induce slight decomposition of calcium citrate, leading to sensory deterioration of products (such as yellowing), and reduce the bioavailability of calcium;
- Imbalanced Calcium-Phosphorus Ratio: When the calcium-phosphorus ratio >2:1, competitive absorption antagonism of minerals will occur, affecting the absorption effect of calcium and phosphorus elements. The ratio of the two elements must be strictly controlled;
- Direct Contact Taboos: Food-grade calcium citrate is prohibited from direct mixing with high-phosphorus raw materials, and feed-grade is prohibited from direct contact with dicalcium phosphate and copper sulfate to avoid chemical reactions and damage to raw material quality.

Part Three: Refined Addition Operation Guide for Eight Application Fields (Targeted Control, Adapting to Different Scenarios)

1 Infant Formula Food and Grain Complementary Food Field (High Safety Standards, Adapting to Infant Physiological Characteristics)

1.1 Legally Limited Addition Amount (Legal Value of GB14880, Calculated by Calcium Element)

- Infant Formula Milk Powder for 0 ~ 36 Months Old: 30 ~ 60 mg/100g, which needs to be accurately adjusted according to the infant's age to ensure it meets the needs of infant bone development and avoid excessive intake;
- Infant Grain Complementary Food and Nutrition Packs: 300 ~ 600 mg/100g, adapting to the needs of infant complementary food addition, facilitating accurate control of daily calcium intake;
- Preschool Children's Formula Food: The recommended daily intake is 300 ~ 600mg/day. Calculate the raw material addition amount according to the daily food intake of children to ensure nutritional balance.

1.2 Raw Material Grade Requirements (Strict Control to Ensure Infant Safety)

Only food-grade high-purity calcium citrate can be selected, with calcium content ≥20.5%, heavy metals implementing internal control standards stricter than national standards (Pb≤0.3mg/kg, As≤0.3mg/kg), and zero pathogenic bacteria detected in microorganisms; industrial-grade and ordinary feed-grade raw materials are strictly prohibited to ensure that the raw materials have low gastrointestinal irritation and no peculiar smell, adapting to the delicate gastrointestinal function of infants and avoiding causing gastrointestinal discomfort.

1.3 Addition Process SOP (Refined Control to Ensure Product Safety and Quality)

- Dry Process:
- First, premix calcium citrate with lactose, whey protein, and vitamin D_3 in the ratio of 1:4 ~ 1:6 by equal incremental method, pass through 100 mesh double-layer sieving to remove agglomerated particles, then mix with basic powder, the total mixing time is ≥20min, and the moisture is controlled at ≤5.0% throughout the process to prevent raw materials from absorbing moisture and caking; after mixing, detect the mixing uniformity, and it can enter the next process only if RSD ≤3.0%.
- Wet Process:
- First, prepare calcium citrate pre-dispersion solution with 60 ~ 80℃ purified water, add 0.1% ~ 0.2% citric acid to adjust the pH to 5.5 ~ 7.0, and stir until completely transparent without precipitation; before homogenization at 50 ~ 60℃, slowly add the pre-dispersion solution into the batching tank, and control the homogenization pressure at 18 ~ 22MPa to ensure uniform dispersion; monitor the system pH throughout the process to maintain it at 5.5 ~ 7.0, avoiding calcium ion precipitation caused by abnormal pH.
- System Control:
- Excessive compatibility of high-phytic acid and high-phosphorus raw materials is prohibited throughout the process to avoid inhibiting calcium absorption; during raw material mixing, avoid contact with copper and aluminum containers, and prefer 304/316 stainless steel equipment to prevent heavy metal ion pollution.
- Finished Product Control:
- The finished product must be free of astringency, yellowing, and precipitation, the calcium content attenuation during the shelf life is ≤5%, meeting the sensory requirements of infant food; each batch of finished products must undergo full-item detection before leaving the factory.

2 Dairy Products and Fermented Milk Field (Adapting to Milk System, Ensuring Flavor and Nutrition)

2.1 Legal Addition Amount (Calculated by Calcium)

- Modified Milk Powder: 300 ~ 1000 mg/kg, among which children's milk powder is 500 ~ 800mg/kg, and maternal and infant milk powder is 800 ~ 1200mg/kg. The addition amount is accurately adjusted according to the needs of the target group;
- Fermented Milk, Flavored Yogurt: 100 ~ 300 mg/100g, balancing nutrition fortification and product flavor, avoiding astringency caused by excessive addition;
- Liquid Sterilized Milk, Milk Beverages: 100 ~ 200 mg/kg, adapting to the liquid milk system, ensuring uniform dispersion of calcium elements without precipitation and peculiar smell.

2.2 Operation Control Points (Accurately Grasping the Process to Avoid Affecting Milk Quality)

- Fermented Milk:

- After fermentation, cool the system to 40 ~ 45℃. At this time, the activity of fermentation flora is reduced, and it is not easy to be affected by calcium citrate; slowly add the pre-dispersed calcium citrate solution, stir at low speed for 15min, lock the system pH at 5.5 ~ 7.5, and avoid stratification of the milk system caused by too fast stirring; immediately enter the sterilization process after feeding to prevent calcium ion precipitation.
- Modified Milk Powder:
- When adopting the wet process, enter the spray drying process after homogenization at 60 ~ 65℃, strictly control the inlet air temperature at 180 ~ 200℃, and the outlet air temperature at 70 ~ 80℃ to avoid damage to the calcium citrate structure by high temperature; when adopting the dry process, mix calcium citrate with milk powder raw materials evenly, and the mixing uniformity RSD ≤3.0% to ensure uniform calcium content per gram of milk powder.
- Liquid Milk:
- For products adopting the pasteurization process, feed at low temperature and aseptically after pasteurization to avoid yellowing of calcium citrate and astringency precipitation caused by high temperature; for products adopting the sterilized milk process, feed at medium-low temperature (50 ~ 65℃) before sterilization, stir evenly and then sterilize to ensure the stability of calcium elements.
- Characteristic Guarantee:
- Control the system pH at 5.5 ~ 7.5 throughout the process to avoid calcium ions reacting with milk protein to produce precipitation; after addition, ensure that the product does not damage the activity of probiotics (fermented milk), does not produce yellow precipitation, maintains the original milk flavor, has no obvious astringency, and improves product palatability.

3 Grain, Baking, and Puffed Food Field (Adapting to High-Temperature Processes, Ensuring Product Stability)

3.1 Legal Addition Amount (Calculated by Calcium)

- Wheat Flour, Rice Flour, Mixed Grain Flour: 1000 ~ 2000 mg/kg, adapting to the needs of grain processing to achieve daily nutrition fortification;
- Instant Oatmeal, Compound Grain Flakes: 300 ~ 600 mg/100g, balancing nutrition and taste, avoiding affecting the original flavor of grains;
- Biscuits, Cakes, Puffed Baking Products: 500 ~ 1000 mg/kg, adapting to the characteristics of baking and puffing processes, ensuring that calcium elements are not lost or invalidated at high temperatures.

3.2 Operation Control Points (Adapting to High-Temperature Processes, Optimizing Product Quality)

- Premix Operation:
- Premix calcium citrate with grain powder and baking accessories (such as flour, sugar, oil) in the ratio of 1:4 ~ 1:6, mix by equal incremental method, pass through

80 mesh sieving to remove agglomerated particles, then mix with basic powder evenly, the total mixing time is ≥15min, ensuring the mixing uniformity RSD ≤3.0%, no need for secondary deployment later.

- Process Temperature Control:
- The baking process temperature is controlled at 160 ~ 200℃ with short-time baking (≤20 minutes) to avoid continuous high temperature; the extrusion puffing process temperature is controlled at 180 ~ 200℃, and rapid cooling after instantaneous extrusion to prevent calcium citrate decomposition and astringency precipitation; the inlet air temperature of the spray drying process (such as grain powder) is ≤200℃ to ensure the bioavailability of calcium.
- Control Points:
- The product shall not turn yellow or produce oily rancidity during the storage period, and shall not affect the fluffy structure of baked products and the crisp taste of puffed products; avoid excessive matching with high-phytic acid grain raw materials, and a small amount of vitamin D_3 can be added to improve calcium absorption efficiency; the finished product shall be free of astringency and meet the sensory standards of baked and puffed food.

4 Solid Beverages, Meal Replacement Powders, and Sports Nutrition Food Field (Adapting to Brewing/Edible Characteristics, Ensuring Nutritional Effectiveness)

4.1 Legal Addition Amount (Calculated by Calcium)

- Solid Beverages, Meal Replacement Powders: 1000 ~ 3000 mg/kg (converted to 100 ~ 300 mg/100g), adjust the addition amount according to the product positioning (such as ordinary solid beverages, high-protein meal replacement powders) to meet the needs of daily nutrition supplement;
- Sports Nutrition Powders: Added according to the internal control standards of the formula, not exceeding the upper limit specified in GB14880, adapting to the nutritional needs of sports people and supplementing calcium elements lost during exercise;
- Liquid Functional Beverages: 50 ~ 100 mg/100ml, adapting to the liquid system, ensuring no precipitation and no peculiar smell after brewing.

4.2 Operation Control Points (Adapting to Brewing Characteristics, Improving Product Experience)

- Feeding Sequence:
- Strictly follow the sequence of "trace element premix → vitamin premix → calcium citrate premix → protein base mixing". First, premix calcium citrate with 0.1% ~ 0.2% citric acid, then mix with other trace elements and vitamins, and finally mix into the protein base (such as whey protein, soybean protein) to avoid local high-concentration agglomeration and precipitation, ensuring uniform mixing.
- Solid Granules:
- After mixing, pass through 80 mesh granulation to remove agglomerated particles, ensuring rapid dissolution without precipitation and peculiar smell when brewed;

a small amount of solubilizing ingredients (such as maltodextrin) can be added to improve brewability; the aqueous solution after brewing is colorless and transparent or light milky white, with no obvious astringency and smooth taste.

- Liquid Functional Beverages:
- At the medium-low temperature (55 ~ 65℃) homogenization and stirring stage, slowly add the pre-dispersed calcium citrate solution into the batching tank, stir evenly and then filter to remove impurities and undissolved particles; control the system pH at 5.5 ~ 7.5, add 0.1% ~ 0.2% citric acid to adjust stability; the sterilization temperature is controlled at 105℃/15min, and quickly cool after sterilization to avoid calcium ion precipitation and system yellowing caused by high temperature, ensuring no precipitation of the product after long-term storage.

5 Health Food Field (Tablets, Capsules, Oral Liquids, Compound Nutrients) (Precise Dosage Control, Ensuring Health Care Efficacy)

5.1 Recommended Daily Intake (Calculated by Calcium)

- Ordinary Calcium Supplement for Adults: 800 ~ 1200 mg/day, adapting to the daily calcium supplement needs of adults, avoiding calcium accumulation caused by excessive intake;
- Special Formulas for Pregnant and Lactating Women: 1000 ~ 1500 mg/day, meeting the calcium needs of pregnant and lactating women and preventing osteoporosis;
- Children's Health Food: 300 ~ 600 mg/day, adjusted according to the child's age and weight, adapting to the characteristics of children's growth and development;
- Single Tablet Feeding: 3810 ~ 5715mg/tablet of calcium citrate (corresponding to 800 ~ 1200mg/tablet of calcium), precisely controlling the single tablet dosage for easy consumption by consumers.

5.2 Preparation Process Specifications (Refined Preparation, Ensuring Efficacy and Stability)

- Tablets:
- Adopt closed mixing process, mix calcium citrate with vitamin D_3, VC and accessories (microcrystalline cellulose, magnesium stearate) for 30min to ensure the mixing uniformity RSD ≤3.0%; adopt 16 ~ 20 mesh granulation, control the granulation temperature at 50 ~ 60℃ for low-temperature drying to avoid damage to the calcium citrate structure by high temperature; granulate after drying, then perform film coating. The coating layer must be light-proof and moisture-proof to prevent raw materials from absorbing moisture and caking; the moisture content of the finished product is controlled at ≤3.0% to ensure the stability of the tablets.
- Capsules:
- Premix calcium citrate with accessories evenly, control the moisture content of the premix at ≤5.0% to avoid moisture absorption and caking caused by excessive moisture; fill with automatic capsule filling machine, the filling accuracy deviation is ≤±3%; after filling, seal the package with light-proof and moisture-proof

packaging materials to prevent capsules from absorbing moisture and calcium element loss, ensuring stable efficacy of the product within the validity period.

- Oral Liquids:
- Dissolve calcium citrate with 60 ~ 80℃ purified water, add 0.5% ~ 1.0% VC (synergistic absorption) and 0.1% citric acid (adjust taste and pH), adjust the system pH to 5.5 ~ 7.0, and stir until completely transparent without precipitation; filter and sterilize at 105℃/15min, then quickly cool to room temperature; adopt aseptic operation during filling to avoid microbial contamination; the finished product must ensure no precipitation and no yellowing after long-term storage, with smooth taste and no obvious astringency.

6 Food for Special Medical Purposes (FSMP) (High Safety, High Adaptability, Meeting the Needs of Special Groups)

6.1 Process Control Indicators

- Total Nutrient Special Medical Powder: The feeding ratio of calcium citrate is 0.5% ~ 1.0%, which is accurately adjusted according to the product positioning (such as postoperative rehabilitation, elderly frailty, osteoporosis);
- Calcium Element Control: 300 ~ 600 mg/100g, adapting to the digestive absorption capacity of special groups, avoiding excessive intake, and meeting nutritional needs.

6.2 Mandatory Operation Requirements (Strict Control to Ensure the Safety of Special Groups)

- Raw Material Control:
- Only medical-grade high-purity calcium citrate can be used, with calcium content ≥20.5%, heavy metal indicators stricter than national standards, qualified sterility test, and no microorganisms detected; food-grade and feed-grade raw materials are strictly prohibited to ensure that the raw materials have low irritation and no peculiar smell, adapting to the gastrointestinal function of special groups (postoperative rehabilitation, digestive disorders, elderly frailty, gastrointestinal sensitivity).
- Production Process:
- Adopt wet high-pressure homogenization process with homogenization pressure of 20 ~ 25MPa to ensure complete dispersion of calcium citrate without agglomerated particles; aseptic spray drying with inlet air temperature ≤200℃ and outlet air temperature 70 ~ 80℃ to avoid damage to the calcium citrate structure by high temperature and ensure product sterility; the entire production process is operated in an aseptic environment, complying with the production specifications of special medical food and eliminating microbial contamination.
- Product Adaptation:
- The product must be low-irritating, free of calcium accumulation risk, with excellent clinical tolerance, and does not induce gastrointestinal discomfort (such as

constipation, abdominal distension); the system pH is controlled at 5.5 ~ 7.0 to ensure the stability of calcium elements and facilitate digestion and absorption by special groups; the finished product must be free of astringency, yellowing, and precipitation, meeting the sensory and nutritional standards of special medical food.

7 Condiment Field (Brewed Soy Sauce, Compound Sauce, Edible Salt) (Invisible Fortification, No Impact on Flavor)

7.1 Legal Addition Amount (Calculated by Calcium)

- Brewed Soy Sauce, Compound Sauce: 500 ~ 1000 mg/kg (converted to 50 ~ 100 mg/100ml), adapting to the high-salt and fermentation system of condiments to achieve invisible daily calcium nutrition fortification;
- Edible Salt: 100 ~ 200 mg/100g, combining the daily intake of edible salt to achieve precise nutrition fortification without affecting the taste of salt.

7.2 Operation Control Points (Adapting to Condiment Process, Ensuring Flavor and Stability)

- Feeding Timing:
- Brewed soy sauce and compound sauce must be added at ≤70℃ in the later stage of brewing and before sterilization. At this time, the brewing system is stable, high-temperature sterilization can kill microorganisms, and avoid the decomposition and failure of calcium citrate during the high-temperature brewing process; stir at low speed for 30min after feeding to ensure uniform dispersion of calcium citrate, without precipitation and yellowing caused by excessive local concentration.
- Synergistic Effect:
- Add 0.1% ~ 0.2% citric acid, which on the one hand synergistically promotes calcium absorption, and on the other hand adjusts the system pH to avoid calcium ion precipitation and prevent affecting the appearance of condiments (such as soy sauce turbidity); citric acid must be premixed with calcium citrate before adding to ensure uniform dispersion.
- Flavor Control:
- The addition amount of calcium citrate must be strictly controlled within the legal range to avoid astringency caused by excess, which masks the original flavor of condiments (such as sauce flavor, umami taste); it adapts to the high-salt and fermentation system, does not react with the components in condiments, does not produce precipitation and yellowing, realizes invisible nutrition fortification, improves the nutritional value of condiments, and does not affect the consumer's eating experience.

8 Feed and Pet Food Field (Adapting to Breeding Needs, Improving Breeding Benefits)

8.1 Industry General Addition Amount (Calculated by Calcium)

- Compound Feed for Livestock and Poultry: 5 ~ 10g/kg for piglets/growing pigs, among which 8 ~ 10g/kg for weaned piglets (adapting to the gastrointestinal function

of weaned piglets and promoting bone development); 3 ~ 8g/kg for poultry (chickens/ducks), 5 ~ 7g/kg for young poultry (meeting the growth and development needs of young poultry);

- Compound Feed for Ruminants (Cattle/Sheep): 4 ~ 8g/kg, 6 ~ 8g/kg for calves (adapting to the digestive characteristics of ruminants and improving calcium absorption efficiency);
- Compound Feed for Aquatic Products: 3 ~ 6g/kg, adapting to the growth needs of aquatic animals (fish/shrimp), improving bone development and stress resistance;
- Dog and Cat Main Food, Pet Snacks: 2 ~ 5g/kg, meeting the daily calcium needs of pets, preventing pet osteoporosis, and improving pet immunity.

8.2 Operation Control Points (Adapting to Feed Process, Improving Palatability and Absorption Efficiency)

- Premix Operation:
- Using corn starch and soybean meal as carriers, premix calcium citrate and carrier in the ratio of 1:6 ~ 1:10, add 0.1% ethoxyquinoline for antioxidation to prevent raw material deterioration; mix by equal incremental method for ≥15min, with mixing uniformity RSD ≤5.0% to ensure uniform calcium content of each part of the feed.
- Granulation Process:
- The feed granulation temperature is ≤90℃, the pressure is ≤4MPa, and quickly cool after granulation, with moisture ≤12% after cooling to avoid damage to the calcium citrate structure by high temperature and prevent feed from absorbing moisture and caking; avoid direct contact with dicalcium phosphate and copper sulfate during granulation, and add them in layers or separate carriers to avoid antagonistic reactions.
- Category-Specific Control:
- Aquatic feed should focus on water-resistant dispersion, adopt post-spraying process (liquid dosage form) or dry mixing after crushing through 80 mesh to reduce the loss of calcium elements in water and ensure effective intake by aquatic animals; pet food should control the addition amount of calcium citrate to avoid astringency interfering with pet feeding preferences, and can be compounded with pet palatability improvers to improve pet acceptance; ruminant feed should avoid matching with high-phytic acid and high-phosphorus raw materials to improve calcium absorption efficiency.

Part Four: Process Quality Control, Detection System and Compliance Traceability (Full-Process Closed-Loop Control, Ensuring Compliance and Controllability)

1 Three-Stage Process Detection Specifications (Stage-by-Stage Control, Preventing Unqualified Products from Entering the Market)

1.1 Premix Link Detection:

After each batch of premixing is completed, the calcium content and powder uniformity RSD must be detected immediately. The calcium content must meet the formula

requirements, and the powder uniformity RSD ≤3.0% (food, health products) and RSD ≤5.0% (feed). Only after the premix is qualified can it enter the next process; if the detection is unqualified, re-premixing and re-inspection are required until it meets the standard.

1.2 Production Process Detection:

Fixed-point sampling is carried out every 2h during the production process to detect calcium content, system pH, and temperature. When the calcium content deviates from the labeled value by ±5%, the process is corrected immediately (such as adjusting measurement, supplementing premix); the premix uniformity and dissolution dispersion are monitored simultaneously, and production is stopped for rectification in case of abnormalities, and rectification records are made to ensure the production process is controllable.

1.3 Finished Product Release Detection:

Before each batch of finished products is released from the factory, a full-item inspection must be carried out in accordance with national and international standards and internal control requirements. The mandatory inspection items include: calcium content (must be within the legal range of ±10% of the labeled value), moisture, pH value (for liquid products), mixing uniformity (for solid products), heavy metals (Pb, As, Cd, Hg), microbial indicators (classified by raw material grade), and sensory indicators (no abnormal color, peculiar smell, precipitation or caking). Only products that pass all inspections can be released from the factory; unqualified products shall be isolated and disposed of in accordance with the "Unqualified Product Control Procedure", and records shall be made for traceability.

1.4 Special Detection Requirements for Key Scenarios:

- Infant Formula Food and FSMP: In addition to the conventional full-item inspection, special inspections such as sterility (for medical-grade raw materials), mycotoxins, and heavy metal precision detection (Pb≤0.3mg/kg, As≤0.3mg/kg) must be carried out to ensure the safety of special groups.
- Feed and Aquatic Products: Additional detection of free citric acid content, particle size, and water resistance (for aquatic feed) is required to ensure that the feed meets the breeding needs and does not cause environmental pollution or animal health hazards.
- Health Food: Detection of active ingredient content (such as vitamin D_3, VC) and dissolution rate (for tablets and capsules) must be carried out to ensure the health care efficacy and bioavailability of the product.

2 Quality Control Measures for Key Links (Targeted Prevention, Eliminating Quality Hidden Dangers)

2.1 Raw Material Quality Control:

Establish a qualified supplier evaluation system, conduct annual on-site audits of suppliers, and strictly control the source of raw materials; each batch of raw materials must be accompanied by complete qualification documents and inspection reports, and sampling inspection must be carried out in accordance with the warehousing acceptance standards. Unqualified raw materials are strictly prohibited from entering the production link; establish a raw material batch management system to realize one-to-one

correspondence between raw material batches and finished product batches for full-process traceability.

2.2 Premix and Addition Process Control:

Specially assign personnel to be responsible for the premix operation, strictly implement the equal incremental mixing method and ratio requirements, and record the mixing time, speed, and other parameters in detail; the addition timing and temperature must be strictly controlled in accordance with the operating procedures, and the feeding speed and stirring intensity must be standardized to avoid local agglomeration and precipitation; regular maintenance and calibration of mixing equipment and measuring instruments must be carried out to ensure their normal operation and accuracy.

2.3 Environmental and Equipment Control:

The production workshop must meet the cleanliness level requirements (Class 100,000 for food and health products, Class 10,000 for FSMP), and regularly carry out cleaning and disinfection to avoid cross-contamination; production equipment (mixers, homogenizers, granulators, etc.) must be made of food-grade/stainless steel materials, and thoroughly cleaned and sterilized before and after use to avoid residual raw materials affecting product quality; the warehousing environment must be monitored in real time (temperature, humidity), and records must be made to ensure that raw materials and finished products are stored in a suitable environment.

3 Abnormal Disposal Procedures (Standardized Handling, Minimizing Losses)

3.1 Abnormal Raw Materials:

If unqualified raw materials are found during warehousing acceptance (such as exceeding the standard for heavy metals, microbial contamination, or caking), they shall be immediately isolated, labeled, and reported to the quality management department; the quality management department shall conduct re-inspection and evaluation, and decide on rejection, return, or destruction in accordance with the regulations, and all disposal processes shall be recorded in detail.

3.2 Abnormal Production Process:

- If the mixing uniformity is unqualified (RSD>3.0% for food/health products, RSD>5.0% for feed), the product shall be re-mixed, and the mixing parameters shall be adjusted (extending mixing time, optimizing premix ratio), and re-inspection shall be carried out after re-mixing. If it is still unqualified, the batch of products shall be disposed of as unqualified products.
- If calcium ion precipitation or system yellowing occurs during the production process, the system pH and temperature shall be checked immediately, and adjustments shall be made (adding an appropriate amount of citric acid to adjust pH, reducing process temperature); if the problem cannot be solved, production shall be stopped for rectification, and the cause shall be analyzed and recorded.
- If the calcium content deviates from the standard range, the measurement equipment shall be calibrated first, and the addition amount shall be recalculated and adjusted;

the unqualified semi-finished products shall be reworked or disposed of, and the correction measures and results shall be recorded.

3.3 Abnormal Finished Products:

If finished products are found to be unqualified during the release inspection (such as excessive heavy metals, unqualified sensory indicators, or inconsistent calcium content with the labeled value), they shall be immediately isolated and prohibited from being released from the factory; the quality management department shall analyze the cause (raw material problems, process errors, equipment failures, etc.), formulate correction measures, and conduct re-inspection after rectification. If they still fail to meet the standards, they shall be destroyed in accordance with the regulations, and the entire process shall be traced and recorded.

4 Compliance Traceability System (Full-Chain Traceability, Meeting Regulatory Requirements)

4.1 Traceability Content and Scope:

The traceability system covers the entire chain from raw material purchase, warehousing, production, inspection to finished product sales, including the following key information: supplier information (name, contact information, qualification documents), raw material information (batch number, production date, calcium content, inspection report), production information (production batch number, production date, premix ratio, addition timing, process parameters, operator), inspection information (inspection batch number, inspection items, inspection results, inspector), and sales information (sales batch number, sales date, customer information).

4.2 Traceability Implementation Requirements:

- Establish an electronic traceability management system, and input all key information into the system in a timely and accurate manner to ensure that each batch of products can be traced forward (to raw material suppliers) and backward (to end users).
- All records (raw material purchase records, warehousing records, production records, inspection records, sales records) must be kept for at least 3 years (5 years for infant formula food and FSMP) to meet regulatory inspection requirements; records must be true, complete, and unalterable.
- Regularly conduct traceability drills to check the effectiveness of the traceability system, and promptly rectify any problems found to ensure that the system can be quickly traced and disposed of in case of quality problems.

4.3 Regulatory Compliance Requirements:

In the process of production and operation, it is necessary to strictly comply with the requirements of national and international standards (GB series, FDA GRAS, EFSA, JECFA, Codex, etc.), and accept the supervision and inspection of regulatory authorities; if there are updates or revisions to relevant standards, the operation guide shall be revised in a timely manner to ensure that all operations are compliant; establish an internal audit system, conduct regular internal audits of the production process, quality control, and traceability system, and continuously improve the compliance level.

Part Five: Common Problems and Solutions (Practical Guidance, Solving On-Site Difficulties)

1 Common Problems in Premix and Addition Process

1.1 Problem: Calcium Citrate Agglomerates During Premixing

Causes: High environmental humidity (exceeding 70% RH), insufficient mixing time, improper premix ratio, or damp raw materials.

Solutions: Control the environmental humidity at 45% ~ 70% RH; extend the mixing time to ≥15 minutes, and adopt the equal incremental mixing method; adjust the premix ratio to 1:4 ~ 1:10 (food/medical grade) or 1:6 ~ 1:10 (feed grade); screen the raw materials before premixing to remove agglomerated particles; store the premixed powder in a sealed and moisture-proof container.

1.2 Problem: Calcium Ion Precipitation in Liquid System

Causes: System pH is too low (<4.0) or too high (>9.0), water temperature is too high or too low during dissolution, standing time is too long (exceeding 4h), or incompatible substances are added.

Solutions: Adjust the system pH to 5.5 ~ 7.5 by adding an appropriate amount of citric acid; control the dissolution water temperature at 60 ~ 80℃, and cool slowly after dissolution; prepare and use the liquid system immediately, and avoid long-term standing; avoid adding high-phytic acid, high-phosphorus preparations, strong acids, strong alkalis, and other incompatible substances.

1.3 Problem: Calcium Content Deviation Exceeds the Standard

Causes: Inaccurate measurement equipment, incorrect conversion of calcium content, uneven premixing, or errors in addition amount calculation.

Solutions: Calibrate the measuring equipment regularly (electronic balance once a week, automatic loss-in-weight measurement system once every 3 months); recalculate the addition amount according to the actual calcium content of the raw material (instead of the simplified benchmark of 21.0% if the deviation is large); ensure the premixing uniformity RSD meets the standard; assign special personnel to check the calculation process and addition amount to avoid errors.

2 Common Problems in Storage and Shelf Life

2.1 Problem: Raw Materials Absorb Moisture and Cake During Storage

Causes: Poor packaging sealing, high environmental humidity, or prolonged storage after opening.

Solutions: Ensure the original packaging is intact and airtight; store raw materials in an environment with relative humidity ≤70% RH and temperature ≤25℃; seal immediately with double-layer food-grade inner membrane + aluminum foil after opening, and use up within 45 days; regularly check the storage environment and raw material status, and handle damp and caked raw materials in a timely manner.

2.2 Problem: Calcium Content Attenuation and Product Yellowing During Shelf Life

Causes: High storage temperature, direct sunlight, poor packaging light-proof and moisture-proof performance, or decomposition of calcium citrate caused by contact with oxidants.

Solutions: Store finished products in a cool, dry, and light-proof environment; use light-proof and moisture-proof packaging materials (such as aluminum foil bags, paper barrels with inner membranes); avoid storing finished products together with strong oxidants; strictly control the shelf life, and re-inspect expired products before use.

3 Common Problems in Different Application Fields

3.1 Problem: Affecting the Flavor of Fermented Milk (Astringency, Stratification)

Causes: Adding calcium citrate during the fermentation stage, too fast stirring after addition, or excessive addition amount.

Solutions: Add calcium citrate at the low-temperature section (≤60℃) after fermentation and before sterilization; stir at low speed for 15 minutes after addition to ensure uniform mixing; strictly control the addition amount within 100 ~ 300 mg/100g (calculated by calcium).

3.2 Problem: Baked Products Turn Yellow and Taste Astringent

Causes: Excessive baking temperature (exceeding 220℃), long baking time, or uneven premixing.

Solutions: Control the baking temperature at 160 ~ 200℃ and the baking time within 20 minutes; ensure the premixing uniformity RSD ≤3.0%; add an appropriate amount of flavor substances to mask the slight astringency.

3.3 Problem: Feed Palatability Decreases and Animals Refuse to Eat

Causes: Excessive addition amount of calcium citrate, improper premix ratio, or direct contact with incompatible raw materials (such as dicalcium phosphate).

Solutions: Control the addition amount within the range of 3 ~ 10g/kg (calculated by calcium); adjust the premix ratio to 1:6 ~ 1:10, and use palatable carriers (such as soybean meal); separate calcium citrate from incompatible raw materials during mixing, and add them in layers.

Appendix: Relevant Standard Norms and Technical Parameters (Quick Reference)

1 National and International Standard List

- GB 17203-1998 "National Food Safety Standard - Food Additive Calcium Citrate"
- GB 14880-2012 "National Food Safety Standard - Usage Standard for Food Nutrition Fortifiers"
- GB 2760-2024 "National Food Safety Standard - Usage Standard for Food Additives"
- GB 15193 Series "Food Toxicology Evaluation Standards"
- FDA GRAS (Generally Recognized As Safe for Food Additives)
- EFSA Food Additive Safety Assessment Report
- JECFA (53rd Session) Calcium Citrate Specification Standard
- Codex General Guidelines for Nutrition Fortifiers
- Feed Additives - Part 3: Mineral Elements and Their Complexes (Chelates) - Calcium Citrate (Revision Plan)

2 Core Technical Parameters of Calcium Citrate (Summary)

Technical Indicators	Standard Index	Process Tolerance Boundary	Remarks
Appearance	White crystalline powder, no caking, no visible impurities, no peculiar smell	No discoloration, no moisture absorption and caking at room temperature in the dark	Seal immediately after opening
Calcium Content	20.0% ~ 22.0%	Batch-to-batch deviation ≤±0.5%; medical grade ≥20.5%	Industry simplified benchmark: 21.0%
Moisture	Feed grade ≤12.0%, food grade ≤8.0%, medical grade ≤6.0%	Critical moisture absorption humidity ≤70% RH	Avoid high humidity environment
pH (10g/L aqueous solution)	6.0 ~ 8.0	Stable range 5.5 ~ 8.5	Avoid strong acid and strong alkali environment
Temperature Resistance	Short-term tolerance to 200℃	Long-term >220℃ causes decomposition; feed granulation ≤90℃	Control high-temperature process parameters
Solubility	Slightly soluble in cold water, easily soluble in hot water (>80℃), dilute acid; insoluble in organic solvents	Pre-dispersion required in cold water; prepare and use immediately	Avoid long-term standing of liquid system

3 Common Conversion Formula and Calculation Example

3.1 Core Conversion Formula

\\text{Actual Addition Amount of Calcium Citrate} = \\frac{\\text{Target Calcium Addition Amount (calculated as Ca)}}{\\text{Actual Calcium Content of Raw Material}}

3.2 Calculation Example

Example: It is required to add 500mg of calcium (Ca) per 100g of modified milk powder, and the actual calcium content of the selected calcium citrate raw material is 20.8%. Calculate the actual addition amount of calcium citrate.

Calculation: Actual addition amount = 500mg ÷ 20.8% ≈ 2403.85mg/100g, that is, 2.40g/100g of calcium citrate needs to be added.

4 Glossary of Professional Terms

- Calcium Citrate: Organic calcium additive, CAS: 813-94-5, molecular formula $C_{12}H_{10}Ca_3O_{14}\cdot 4H_2O$, with high bioavailability and low gastrointestinal irritation.
- Premix: A homogeneous mixture made by mixing calcium citrate with an inert carrier in a certain ratio, used to improve mixing uniformity.
- Equal Incremental Method: A mixing method that first mixes a small amount of calcium citrate with a carrier, then gradually adds the remaining carrier, ensuring uniform mixing.
- RSD (Relative Standard Deviation): An indicator used to evaluate the mixing uniformity of powder products, the smaller the value, the more uniform the mixing.
- FSMP (Food for Special Medical Purposes): Food specially processed or formulated to meet the special nutritional needs of people with impaired digestive absorption, metabolic disorders, or specific diseases.
- Bioavailability: The proportion of calcium citrate absorbed and utilized by the human/animal body, which is an important indicator to evaluate the effectiveness of calcium supplements.

Epilogue

This operation guide is based on authoritative standards and practical application experience, comprehensively covering the full-chain operation requirements of calcium citrate in eight application fields, with strong professionalism, implementability, and compliance. All relevant operators must strictly follow the requirements of this guide to carry out production, operation, and quality control work, ensuring that the use of calcium citrate is safe, compliant, and effective.

With the continuous update and improvement of national and international standards, and the continuous expansion of application fields, this guide will be revised and improved in a timely manner to adapt to the new production and operation needs. If you encounter any problems during the use process, please contact the quality management department for consultation and solution in a timely manner.