Professional Operation Guidelines for Application and Addition Methods of Zinc Citrate

I. General Provisions and Core Principles

1. Scope of Application

This guideline applies to the industrial addition operation of **Food Grade / High-Purity Food Grade Zinc Citrate** (GB 1903.23-2021, GB 14880-2012) in eight major fields: infant formula and complementary foods, dairy products, grain baking, solid beverages, health foods, functional drinks, ordinary processed foods, feed and pet foods. It covers the whole process from raw material acceptance, process design, precise addition, process control to finished product inspection, providing standardized operation basis for production technology, quality control and R&D personnel.

2. Core Addition Principles

2.1. Compliance Priority: Strictly abide by the limit requirements of GB 14880-2012 and GB 1903.23-2021. Calculate the addition level based on **zinc element content**, and prohibit over-range and over-dose addition.

2.2. Uniform Dispersion: Follow the core logic of "pre-mixing → gradient feeding → full homogenization" to avoid excessive local concentration, powder agglomeration, system precipitation and stratification.

2.3. Stability Adaptation: Adapt to the processing temperature, pH, shear force and shelf life characteristics of various fields, ensure the chelate structure of zinc citrate remains stable, with no loss, denaturation of zinc elements and no adverse impact on product sensory properties.

2.4. Synergistic Enhancement: Prioritize compounding with Vitamin C, Vitamin D3, calcium and magnesium; avoid antagonism with phytic acid, oxalic acid and high-concentration phosphate to improve bioavailability.

2.5. Safety and Controllability: Implement full-process HACCP and GMP management; achieve traceability throughout raw material acceptance, batching, mixing, processing, storage and transportation.

3. Basic Raw Material Parameters

- **Appearance:** White to off-white crystalline powder, no caking, no peculiar odor, no visible impurities to the naked eye
- **Zinc Content:** 31.0%~33.0%, Purity **≥99.0%**
- **Solubility:** Freely soluble in weak acidic water, insoluble in organic solvents such as ethanol
- **Stability:** Resistant to high temperature of 180~210℃; stable at pH 5.0~8.0; non-hygroscopic and non-caking at room temperature
- **Sanitation Indicators:** Heavy metals and microorganisms comply with GB 1903.23; free from pathogenic bacteria contamination

II. Standardized Addition Methods by Field

☑ Infant Formula & Complementary Food Field (0~36 Months, Infant Standard Compliance)

1. Applicable Categories

Infant formula milk powder, grain complementary foods, nutrition packs, infant snacks, multi-dimensional nutrients for young children

2. Core Pain Points

Delicate gastrointestinal tract prone to irritation and poor absorption; extremely high compliance requirements; uneven powder mixing; zinc loss under high temperature

3. Standard Addition Methods

3.1 Raw Material Selection: Food-grade high-purity zinc citrate (purity ≥99.5%), fine crystalline type (100~200 mesh)

3.2 Addition Dosage (Calculated as Zinc):

● Formula foods for 0~36 months: 30~80 mg/100g

● Complementary foods / nutrition packs for over 36 months: 25~70 mg/100g

3.3 Process Route (Spray-dried Milk Powder):

● Pre-mixing: Dry pre-mix zinc citrate with whey protein, lactose and vitamin premix at a ratio of 1:50~1:100 for 30~60 min to form uniform base material

● Dissolution: Add the premix to purified water at 40~50℃, stir to complete dissolution (concentration 5%~10%), filter to remove impurities

● Homogenization: Secondary homogenization with milk base liquid at 60~80℃ and 20~30 MPa to ensure uniform dispersion

● Drying: **Inlet air 160~180℃, exhaust air 80~90℃** for spray drying; zinc retention rate ≥95%

3.4 Complementary Foods / Rice Noodles (Extrusion Puffing / Baking):

● Dry pre-mix zinc citrate with rice flour and miscellaneous grain powder at room temperature for 15~20 min with gradient feeding

● Tolerate **180~210℃** puffing / baking with stable chelate structure and no metallic odor

● Package after cooling; zinc content remains stable within 24-month shelf life

4. Critical Control Points (CCP)

- Coarse crystal and low-purity raw materials are strictly prohibited to avoid gastrointestinal irritation
- Pre-mixing must be fully uniform to prevent excessive local zinc content
- Strictly follow infant standard limits; no compounding with inorganic zinc (exclusive use for infants)

☑ Dairy & Fermented Milk Field

1. Applicable Categories

Modified milk powder, liquid milk, yogurt, milk beverages, cheese

2. Core Pain Points

Zinc ions complex with milk protein to affect stability; precipitation occurs during high-temperature sterilization; astringent taste is induced

3. Standard Addition Methods

3.1 Raw Material Selection: Crystalline zinc citrate (good fluidity and excellent dispersibility)

3.2 Addition Dosage (Calculated as Zinc):

● Modified milk powder / infant milk powder: 200~500 mg/kg

● Yogurt / fermented milk: 5~15 mg/100g

● Liquid milk / milk beverages: 10~30 mg/kg

3.3 Process Route (Liquid Milk / Yogurt):

● Dissolution: Prepare 10% zinc citrate solution with purified water at 30~40℃ and pH 6.0~7.0, stir for 30 min until clear

● Feeding Timing: Post-add at low temperature (≤50℃) after fermentation / sterilization to avoid protein complexation

● Homogenization: Homogenize at **15~25 MPa and 40~50℃** to improve dispersion stability

● Sterilization: Pasteurization / UHT sterilization (135℃/3s); zinc retention rate ≥98%

3.4 Yogurt: Add after fermentation, store at 4℃ refrigeration; no precipitation or stratification

4. Critical Control Points (CCP)

- Direct addition before fermentation / high temperature is forbidden to prevent protein denaturation and system turbidity
- Control system pH at 6.0~7.5 to avoid free precipitation of zinc ions
- Compound with stabilizers such as monoglyceride and sodium caseinate to enhance shelf life stability

☑ Grain & Baked Food Field

1. Applicable Categories

Oatmeal, nutritional rice flour, biscuits, cakes, bread, puffed grains, meal replacement grains

2. Core Pain Points

High-temperature oxidation, uneven mixing, adverse impact on baking flavor, powder caking

3. Standard Addition Methods

3.1 Raw Material Selection: Ordinary food-grade zinc citrate (high temperature resistance and strong stability)

3.2 Addition Dosage (Calculated as Zinc):

- Wheat flour / miscellaneous grain powder: 15~40 mg/kg
- Oatmeal / grain cereal: 10~35 mg/100g
- Biscuits / bread / puffed foods: 8~25 mg/100g

3.3 Process Route (Baking / Puffing):

● Pre-mixing: Pre-mix zinc citrate with flour, powdered sugar and miscellaneous grain powder at 1:100~1:200 for 20~30 min for gradient dispersion

● Feeding: Mix with other raw materials at room temperature and directly enter dough kneading / powder conditioning process

● Processing: Tolerate **180~210℃** baking / extrusion puffing with no loss or denaturation of zinc elements

● **Cooling:** Package finished products after cooling and store moisture-proof with stable shelf life performance

4. Critical Control Points (CCP)

- Pre-mixing must be uniform to prevent abnormal flavor caused by excessive local concentration
- No special protection required; the chelate structure is high-temperature resistant and superior to inorganic zinc
- No metallic astringency after replacing zinc sulfate, without affecting product taste and aroma

☑ Solid Beverage & Meal Replacement Sports Nutrition Field

1. Applicable Categories

Multi-dimensional meal replacement powder, sports protein powder, nutrient instant granules, grain brewed beverages

2. Core Pain Points

Large powder density difference, uneven blending, caking during brewing, astringent taste, layered precipitation

3. Standard Addition Methods

3.1 Raw Material Selection: Fine crystalline zinc citrate (150~250 mesh) with excellent fluidity

3.2 Addition Dosage (Calculated as Zinc):

● Ordinary solid beverages / meal replacement powder: 15~45 mg/100g

● Sports protein powder / multi-dimensional instant granules: Follow internal formula standards without exceeding national standard upper limit

● Brewed beverages: 5~20 mg/100ml

3.3 Process Route (Dry Mixing):

● Gradient Pre-mixing: Pre-mix zinc citrate with vitamins, maltodextrin and silicon dioxide (anticaking agent) at 1:30~1:50 for 30~45 min

● Secondary Mixing: Mix with **bulk raw materials (grain powder, protein powder)** for 20~30 min to ensure uniformity

● Sieving: Sieve with 80~120 mesh to remove agglomerated particles

● Packaging: Sealed and moisture-proof packaging; fast dissolution during brewing with no precipitation and refreshing taste

4. Critical Control Points (CCP)

- Gradient pre-mixing is mandatory to solve stratification caused by density difference
- Add 0.1%~0.3% silicon dioxide to improve fluidity and prevent caking
- Used alone in high-end formulas; moderate compounding with inorganic zinc is allowed in mass-market formulas to balance cost

☑ Health Food Field (Blue Hat Certified Products)

1. Applicable Categories

Zinc supplement tablets, compound multi-vitamin and mineral capsules, middle-aged and elderly immune formulas, male fertility supplements

2. Core Pain Points

Low absorption rate, gastrointestinal discomfort after long-term administration, poor tableting formability, slow disintegration

3. Standard Addition Methods

3.1 Raw Material Selection: Food-grade high-purity zinc citrate (≥99.0%), crystalline type with good fluidity

3.2 Addition Dosage (Calculated as Zinc):

● Adult zinc supplementation: 10~20 mg/day

● Middle-aged & elderly / children: 5~12 mg/day

● Tablets / Capsules: 50~150mg/grain (Zinc Citrate)

3.3 Process Route (Tablets):

● Formula: Zinc Citrate + Vitamin C, D3, Calcium & Magnesium, Microcrystalline Cellulose, Magnesium Stearate (lubricant)

● Pre-mixing: Pre-mix zinc citrate with auxiliary materials at 1:20~1:50 for 30 min for uniform dispersion

● Granulation: Wet / dry granulation for uniform particles and good fluidity

● Tableting: Press at 5~10 kN with good formability and disintegration time limit ≤30 min

● Packaging: Moisture-proof and light-proof packaging; stable content within 24-month shelf life

4. Critical Control Points (CCP)

- Take zinc citrate as the core zinc source, compound with vitamins scientifically to enhance absorption and reduce antagonism
- Optimize tableting formability and disintegration by utilizing its own flow-aiding and filling properties
- Strictly feed according to the health food raw material catalogue and national standard limits to adapt to Blue Hat certification application

☑ Functional Beverage & Liquid Food Field

1. Applicable Categories

Fruit-flavored beverages, plant protein beverages, nutritional oral liquids, sparkling functional drinks

2. Core Pain Points

Easy precipitation and turbidity, shelf life stratification, impaired transparency, astringent taste

3. Standard Addition Methods

3.1 Raw Material Selection: Fine mesh food-grade zinc citrate (200~300 mesh) with fast dissolution rate

3.2 Addition Dosage (Calculated as Zinc):

● Functional drinks / oral liquids: 3~15 mg/100ml

● Plant protein / grain beverages: 4~12 mg/100ml

3.3 Process Route (Liquid Blending):

● Dissolution: Prepare 5%~8% zinc citrate solution with purified water at 40~50℃ and pH 5.5~7.0, stir until clear

● Stabilizer Compounding: Add pectin, xanthan gum and CMC-Na (0.05%~0.2%) to improve suspension stability

● Blending: Blend at low temperature (≤50℃) with high-speed homogenization (25~35 MPa)

● Sterilization: UHT (135℃/3s) / Pasteurization, aseptic filling; no precipitation within 6~12 months shelf life

4. Critical Control Points (CCP)

- Control pH at 5.5~7.5 to avoid dissociation under strong acid and precipitation under strong alkali
- Adopt fine mesh raw materials and high-speed homogenization to ensure uniform dispersion and good transparency

- Low-dose addition (≤15mg/100ml) to balance functional efficacy and taste

☑ Ordinary Processed Food Field

1. Applicable Categories

Dried noodles, instant noodles, bean products, casual snacks, condiments, meal replacement staple foods

2. Core Pain Points

Poor taste and gastrointestinal irritation of inorganic zinc, poor processing stability, nutrient loss

3. Standard Addition Methods

3.1 Raw Material Selection: Ordinary food-grade zinc citrate with high cost performance and strong stability

3.2 Addition Dosage (Calculated as Zinc):

● Flour products: 10~30 mg/kg

● Bean products / snacks: 8~25 mg/kg

● Condiments / meal replacement staple foods: 10~35 mg/kg

3.3 Process Route:

● Dried noodles / instant noodles: Dry pre-mix with flour, followed by dough kneading, rolling and drying; zinc retention rate ≥95%

● Bean products: Add at low temperature after pulping / boiling pulp, stir evenly without affecting gel properties

● Snacks / condiments: Mix evenly with raw materials for conventional processing with no peculiar odor and good stability

4. Critical Control Points (CCP)

- Replace zinc sulfate and zinc oxide to solve the pain points of poor taste and strong irritation
- Direct addition via conventional process without special transformation, suitable for large-scale production
- Strictly follow national standard limits to improve nutritional added value of products

☑ Feed & Pet Food Field

1. Applicable Categories

Livestock and poultry premix, aquatic feed, dog and cat staple food, pet snacks

2. Core Pain Points

Poor absorption, high zinc residue in feces, failure to meet environmental protection standards, uneven powder mixing

3. Standard Addition Methods

3.1 Raw Material Selection: Feed-grade / food-grade zinc citrate with high absorption and low residue

3.2 Addition Dosage:

● Livestock and poultry premix: 800~1800 mg/kg

● Aquatic feed: 600~1500 mg/kg

● Pet food: 500~1600 mg/kg

3.3 Process Route:

● Pre-mixing: Pre-mix zinc citrate with vitamin and mineral carriers at 1:50~1:100 for 30~45 min

● Mixing: Fully blend with **bulk raw materials (corn, soybean meal, meat meal)**

● Processing: Granulation, puffing and baking (≤180℃) with good stability and high absorption and utilization rate

● Environmental Protection: Fecal zinc residue reduced by 30%~50%, complying with green breeding requirements

4. Critical Control Points (CCP)

- Superior to inorganic zinc with high absorption and low residue, suitable for high-end pet and young animal feed
- Synergize with calcium, phosphorus and vitamins to improve overall nutrient utilization
- Strictly abide by feed additive specifications to ensure animal safety and product compliance

III. General Operation Specifications (Applicable to All Fields)

1. Raw Material Acceptance and Storage

- Acceptance: Inspect COA and quality inspection report for each batch; verify zinc content, purity, heavy metals and microorganisms. Unqualified materials are prohibited from warehousing.
- Storage: Sealed storage in cool, dry, ventilated and dark environment; temperature ≤25℃; moisture-proof, caking-proof and odor cross-contamination prevention.
- Shelf Life: 24 months unopened; use up within 4~6 months after opening; regularly test fluidity and content.

2. Batching and Mixing Operation

- Metering: Precisely weigh with **electronic scale (accuracy 0.01g)**; convert zinc citrate dosage based on zinc element content (31.0%~33.0% zinc content).
- Pre-mixing: Follow the procedure of small proportion pre-mixing (1:30~1:200) → secondary mixing → tertiary amplification to avoid excessive local concentration.
- Mixing Time: Dry mixing for 20~60min (adjust according to equipment and batch size); qualified with **uniformity RSD≤5%**.
- Equipment: Use double cone mixer, three-dimensional mixer and V-type mixer to avoid dead corners and residue.

3. Processing Process Control

- Temperature: Safe for conventional processing ≤210℃; ultra-high temperature requires short time (≤10s) to prevent structural damage.
- pH: Control at 5.0~8.0; use cautiously or adjust process for strong acid (pH < 5.0) and strong alkali (pH > 8.0) systems.
- Shear Force: High-speed homogenization (15~35 MPa) for liquid systems; full mixing and sieving for solid systems.
- Monitoring: Sampling and testing zinc content, uniformity and sensory properties during processing; shut down for investigation immediately in case of abnormality.

4. Finished Product Inspection and Traceability

- Inspection: Test zinc content of finished products per GB 5009.14 and microorganisms per GB 4789 to meet standard requirements.
- Traceability: Fully record raw material batch number, batching records, mixing parameters, processing parameters and finished product batch number; retain records for ≥3 years.
- Stability: Conduct accelerated stability test (40℃/75% RH, 3 months) and long-term stability test (25℃/60% RH, 6 months); zinc content variation ≤5%.

IV. Common Problems and Solutions (Operation Troubleshooting)

1. Problem: Powder agglomeration and uneven mixing

- Causes: Raw material moisture absorption, uneven particle size, direct large-dose feeding
- Solutions: Dry storage, adopt fine mesh raw materials, gradient pre-mixing, add anticaking agent (SiO_2)

2. Problem: Precipitation, stratification and turbidity in liquid system

- Causes: Unsuitable pH, wrong feeding timing, insufficient homogenization, inadequate stabilizer dosage
- Solutions: Control pH at 5.5~7.5, post-add at low temperature, high-speed homogenization, compound with stabilizers

3. Problem: Metallic astringency and abnormal taste of products

- Causes: Excessive addition dosage, high local concentration, low raw material purity
- Solutions: Precise dosage control, sufficient pre-mixing, adopt high-purity raw materials, replace inorganic zinc

4. Problem: Low zinc content and loss after processing

- Causes: Excessively long high-temperature duration, strong acid and alkali environment, system antagonism, volatile loss
- Solutions: Control temperature and time, optimize pH value, avoid nutrient antagonism, protect chelate structure stability

5. Problem: Poor tableting formability and slow disintegration

- Causes: Poor fluidity, uneven particles, insufficient lubricant dosage
- Solutions: Adopt crystalline raw materials, optimize granulation, add magnesium stearate, adjust tableting pressure

V. Operation Records and Compliance Documents

1. Mandatory Records

- Raw material acceptance records (batch number, inspection results, quantity)
- Batching and weighing records (raw material name, weight, zinc content conversion)
- Mixing process records (time, rotating speed, temperature, uniformity)
- Processing parameter records (temperature, pressure, pH, time)
- Finished product inspection records (zinc content, microorganisms, sensory properties, uniformity)
- Storage and transportation records (temperature and humidity, shelf life, batch traceability)

2. Compliance Basis

- GB 14880-2012 **National Standard for Use of Food Nutrient Fortifiers**
- GB 1903.23-2021 **National Food Safety Standard - Food Nutrient Fortifier: Zinc Citrate**
- GB 2760-2024 **National Standard for Use of Food Additives**
- GB 5009.14 **National Food Safety Standard - Determination of Zinc in Foods**
- International Standards: FDA GRAS, EFSA, JECFA, Codex Alimentarius

VI. Summary

Based on the core characteristics of zinc citrate including organic chelate structure, high absorption, low irritation, high temperature resistance and wide adaptability, this guideline establishes a field-divided, standardized and implementable addition operation system covering the whole links of raw materials, technology, quality control, traceability and troubleshooting. Strict implementation of this guideline ensures uniform and stable zinc fortification, compliance and safety, excellent sensory performance and high bioavailability. It perfectly adapts to the industrial upgrading demands of food, health food, infant food and pet feed, and serves as the core technical basis for replacing inorganic zinc and realizing high-end formula upgrading.

Operation Code

Compliance as the guideline, uniformity as the foundation, stability as the priority, synergy for efficiency enhancement, and full-process controllability.