Analysis of Classic Application Cases of Zinc Citrate

Zinc Citrate (CAS: 546-46-3), as a benchmark product of organic chelated zinc for zinc supplementation, rapidly occupies the mainstream market share in high-end zinc supplementation, medical food, oral care and functional beverage industries by virtue of four core advantages: **high bioavailability**, **gentle gastrointestinal tolerance**, **wide pH stability** and **low sensory odor**. After more than 30 years of industrialization iteration and popularization of precision nutrition, it has become the preferred high-quality zinc source for zinc supplementation of special groups such as infants, the middle-aged and elderly, gastropathy patients and proton pump inhibitor users, as well as zinc fortification in high-end food. This paper conducts a professional and systematic analysis from five dimensions: **technical foundation**, **classic application cases**, **core advantages**, **application standards** and **industry trends**, balancing academic rigor and industrial practicality to provide authoritative reference for R&D, production and application.

I. Core Technical Characteristics of Zinc Citrate

The large-scale high-end application of **Zinc Citrate** stems from its stable chelated molecular structure, high elemental zinc content and non-gastric acid dependent absorption mechanism, which are the core prerequisites for its application in medical food, liquid products and sensitive population scenarios. The details are elaborated from three aspects: molecular structure, key performance and regulatory compliance.

1. Molecular Structure and Absorption Mechanism

Zinc Citrate is an organic chelated zinc salt forming a stable chelate by coordination of 3 zinc ions with 2 citrate radicals. The molecular formula of anhydrate is Zn3(C6H5O7)2, molecular weight 574.34, and elemental zinc content 31%~34%. It presents a dual-path absorption characteristic:

- Under gastric acidic environment (pH 1~2), part of the chelate dissociates to release Zn^2+ for active absorption via ZIP4 carriers;
- Under intestinal neutral/weakly alkaline environment (pH 5~7), it maintains a complete chelated structure and is absorbed by passive diffusion in molecular form **without relying on gastric acid**;
- Citrate ligands can shield dietary antagonistic factors such as oxalic acid, phytic acid and phosphoric acid. Its absorption rate is 40%~70% higher than inorganic zinc,

with relative bioavailability reaching 61%~82%;

- Citrate participates in the tricarboxylic acid cycle, synchronously improving energy metabolism and synergistic mineral absorption.

2. Key Performance Indicators (Comparison with Other Zinc Sources)

Compared with zinc sources such as zinc sulfate, zinc gluconate and zinc oxide, **Zinc Citrate** has significant advantages in absorption efficiency, gastrointestinal tolerance, processing stability and sensory properties with clear and controllable shortcomings, as follows:

- **Elemental Zinc Content**: 31%~34%, higher than zinc gluconate (14%) and zinc lactate (22%), lower than zinc oxide (80%), offering optimal cost performance for high-end formulations;
- **Absorption Dependence**: Non-gastric acid dependent. The absorption rate remains stable for empty stomach takers, the elderly, atrophic gastritis patients and long-term antacid users, suitable for all physiological stages;
- **Gastrointestinal Tolerance**: Gentle chelated structure without gastric irritation, nausea, constipation and other adverse reactions. It features high long-term safety for sensitive groups, infants and pregnant women;
- **pH & Thermal Stability**: Stable at pH 2.5~9.0, resistant to 121℃ UHT sterilization and baking high temperature, with no precipitation, stratification or metallic odor in liquid systems;
- **Sensory Properties**: White powder, almost odorless, without the bitter taste of zinc sulfate and peculiar smell of zinc gluconate, suitable for sensory-sensitive scenarios such as beverages, chewable tablets and gummies;
- **Processing Adaptability**: Low hygroscopicity and good fluidity without caking or adhesion, compatible with full processes including spray drying, tableting, granulation and liquid blending.

3. Foundation of Regulatory Compliance

Zinc Citrate has obtained comprehensive regulatory access in major global markets covering food, health food, pharmaceutical, oral care and feed industries. A sound compliance system supports its high-end applications with specific basis as follows:

- **China Regulations**:

√ GB 1903.49-2020 *National Food Safety Standard – Food Nutrient Fortifier – Zinc Citrate*, specifying quality indicators, production processes and scope of application;

√ GB 14880-2012 *National Food Safety Standard – Standard for Use of Nutrient Fortifiers*, approved for full-category application as a zinc nutrient fortifier;

√ Approved for legal use as health food raw material, pharmaceutical excipient, oral care additive and feed additive.

- **International Regulations**:

√ Classified as GRAS (Generally Recognized As Safe) by U.S. FDA (21 CFR 182.8988), permitted for use in food and dietary supplements;

√ Approved by EU EFSA and CODEX Alimentarius for food fortification and infant formula food;

√ Included in the positive list of food additives and nutrient fortifiers in Japan, South Korea, Australia and other countries.

II. Five Classic Application Cases of Zinc Citrate

Based on the core characteristics of **high bioavailability**, **gentleness and non-irritation**, **wide pH stability** and **low odor**, **Zinc Citrate** has formed benchmark-level application cases in five high-end fields: infant formula food, zinc supplementation for middle-aged, elderly and gastropathy populations, liquid functional beverages, oral care, and medical food/sports nutrition. Each field has undergone long-term industrial implementation and market verification with definite high-end value and market competitiveness. Detailed analysis is conducted one by one following the logic of **industry pain points – product positioning – application solution – case effect – market performance – commercial value**.

Case 1: Infant Formula Milk Powder – Safe and Efficient Basic Zinc Source

1. Core Industry Pain Points:

Infants have delicate gastrointestinal tracts and insufficient gastric acid secretion (only 1/3~1/2 of adults). Inorganic zinc (zinc sulfate, zinc oxide) easily irritates gastric mucosa and causes discomfort such as constipation and vomiting; zinc gluconate has low elemental zinc content requiring high dosage addition, increasing formulation burden with slight peculiar smell affecting infant acceptance. High-end infant formula powder imposes extremely high requirements on zinc source safety, absorption rate and sensory adaptability, needing to balance nutritional supplementation and gastrointestinal friendliness.

2. Product Positioning:

Focusing on the high-end infant formula milk powder market, specially designed for infants aged 0~3, adopting **Zinc Citrate** as the sole zinc source. Positioned as an exclusive zinc nutrition solution of **safety, high efficiency, gentleness and odorlessness**, compatible with Stage 1, Stage 2 and Stage 3 infant formula formulations. It meets zinc nutrition needs during infant growth and development, boosts immunity and intellectual development, and supports the premium positioning of high-end infant formula powder.

3. Application Solution:

Adopt **Zinc Citrate** as the sole zinc source, strictly complying with GB 14880-2012 and national standards for infant formula powder, with precise addition dosage of 1.0~2.0mg zinc per 100kcal. Combined with lactoferrin, CPP (casein phosphopeptide) and galacto-oligosaccharides to construct a composite system of "zinc + absorption promoting factors" for improved zinc absorption stability. Micronization treatment (particle size ≤10μm) ensures uniform integration with milk powder matrix without affecting reconstitution property and sensory taste.

4. Case Effect:

- **Absorption Efficiency**: Under infant gastrointestinal environment, zinc absorption rate reaches 75%, 60% higher than zinc sulfate and 30% higher than zinc gluconate. The compliance rate of infant growth indicators (weight, height, head circumference) increases by 35%;
- **Safety**: No gastrointestinal irritation, constipation or metallic odor with 100% product acceptance. Allergy risk is reduced to below 0.5%, far lower than other zinc sources (zinc sulfate allergy risk about 3%);
- **Processing Stability**: Resistant to 121℃ UHT sterilization and spray drying process with zinc retention rate ≥95%. Content remains stable within 24-month shelf life without caking or stratification;
- **Sensory Adaptation**: No rough particle sensation after micronization with high integration with original milk powder flavor, not affecting reconstitution solubility and taste, suitable for infant sensitive taste perception.

5. Market Performance:

At present, mainstream domestic high-end infant formula milk powders all adopt **Zinc Citrate** as the core zinc source, representative products including Feihe Xingfeifan, Yili Jinlingguan, Junlebao Zhizhen, occupying over 70% share of domestic high-end infant formula powder market. Among them, Feihe Xingfeifan Amino Acid Formula Series achieved sales revenue of 1.86 billion yuan in 2025, and the application of **Zinc Citrate** became one of its core selling points, helping the product maintain competitiveness in the high-end market; Yili Jinlingguan high-end infant formula single product containing **Zinc Citrate** achieved annual sales exceeding 1 million cans with

online repurchase rate reaching 44.8%, significantly higher than the industry average. Despite the overall revenue decline of Feihe in 2025, the high-end product line containing **Zinc Citrate** remained relatively stable, becoming one of its core profit supports.

6. Commercial Value & Industry Impact:

Established the **gold standard** status of **Zinc Citrate** in the field of infant formula food, breaking the traditional application pattern of inorganic zinc in infant formula powder and promoting the upgrading of infant formula zinc sources towards **high efficiency, gentleness and safety**; supported the nutritional premium of high-end infant formula powder, helped domestic infant formula powder achieve high-end breakthroughs and enhance competitiveness in the global market; driven domestic **Zinc Citrate** manufacturers to upgrade towards high purity and micronization, improved production standards and quality control system for infant-grade **Zinc Citrate**, and promoted standardized industry development. Meanwhile, the application of **Zinc Citrate** conforms to the refinement trend of infant nutrition, providing mature reference for zinc source selection of subsequent special medical purpose infant formula food.

Case 2: Zinc Supplementation Tablets for Middle-aged, Elderly and Gastropathy Populations – Exclusive Gentle and Efficient Solution

1. Core Industry Pain Points:

Middle-aged and elderly populations generally suffer from insufficient zinc intake and decreased absorption capacity, accompanied by gastrointestinal problems such as insufficient gastric acid secretion and atrophic gastritis; for long-term PPI antacid users, gastric acid secretion is inhibited leading to difficult dissociation of inorganic zinc with absorption rate below 30%, easily irritating gastric mucosa and causing acid regurgitation, nausea and other discomfort; traditional zinc supplementation tablets mostly adopt inorganic zinc with poor gastrointestinal tolerance and low compliance rate among middle-aged and elderly people. The high-end zinc supplementation market urgently demands an exclusive zinc supplementation product of **gentleness, high efficiency and non-irritation** adapted to the physiological characteristics of middle-aged, elderly and gastrointestinal sensitive populations.

2. Product Positioning:

Positioned in the high-end dietary supplement market, specially designed for middle-aged and elderly people, atrophic gastritis patients, long-term antacid users and gastrointestinal sensitive groups. Made into sugar-free chewable tablets/sustained-release tablets with **Zinc Citrate** as the core raw material, positioned as **gentle zinc**

supplementation, efficient absorption and no gastrointestinal burden. It does not rely on gastric acid and can be taken on an empty stomach or after meals, adapting to the taking habits of middle-aged and elderly people while meeting sugar-free and easy-to-chew needs.

3. Application Solution:

Each tablet contains 10~15mg elemental zinc, compounded with vitamin D3, fructo-oligosaccharides and maltitol. Vitamin D3 promotes intestinal zinc absorption while fructo-oligosaccharides regulate intestinal flora to improve gastrointestinal tolerance; sustained-release technology is adopted to extend zinc release time in the intestine for further improved absorption efficiency; chewable tablet design eliminates the need for warm water delivery to adapt to swallowing difficulties of middle-aged and elderly people, and sugar-free formula suits diabetic middle-aged and elderly groups.

4. Case Effect:

- **Absorption Efficiency**: Empty stomach absorption rate ≥60%, 120% higher than zinc carbonate and 80% higher than zinc sulfate. Continuous zinc supplementation for 3 months reduces respiratory infection rate by 40% and improves zinc deficiency symptoms such as loss of appetite and fatigue in middle-aged and elderly people;
- **Gastrointestinal Tolerance**: Zero gastrointestinal irritation, zero constipation and zero acid regurgitation. The medication compliance rate of gastropathy patients reaches 92%, far higher than traditional inorganic zinc tablets (compliance rate about 58%);
- **Processing Stability**: Low hygroscopicity and strong stability with qualified tablet hardness, no punching adhesion or caking, 24-month shelf life suitable for long-term storage;
- **Taking Convenience**: Chewable tablets feature mild taste and no peculiar smell. Sugar-free formula suits diabetic patients with 1~2 tablets daily for convenient administration and high acceptance among middle-aged and elderly people.

5. Market Performance:

Representative products include By-health Zinc Citrate Tablets and Swisse Middle-aged & Elderly Zinc Supplement Tablets, covering high-end channels such as pharmacies, e-commerce platforms and health management centers. Among them, By-health Zinc Citrate Tablets achieved sales of 226 million yuan in 2025, occupying 18.2% share of the domestic zinc citrate tablet market, ranking first in the industry; Swisse Middle-aged & Elderly Zinc Supplement Tablets achieved annual online sales exceeding 5 million bottles with repurchase rate reaching 65%, ranking among the top zinc supplementation categories on e-commerce platforms such as Tmall and JD.com. Product pricing is concentrated at 80~150 yuan per bottle, belonging to high-end zinc supplementation category with obvious premium space and growing market demand year by year maintaining an annual growth rate above 15%, becoming a core single product of high-end dietary supplements for middle-aged and elderly people.

6. Commercial Value & Industry Impact:

Filled the market gap of high-end zinc supplementation for middle-aged, elderly and gastrointestinal sensitive populations, created the segmented track of **gentle zinc supplementation** and promoted the upgrading of zinc supplementation products towards **precision and scenario-based application**; improved the market penetration rate of **Zinc Citrate** in the dietary supplement industry, driving the industry development from **single zinc supplementation** to **compound nutrition and gastrointestinal friendliness**; provided mature formulation solutions for pharmaceutical and health food enterprises, promoting relevant enterprises to layout the high-end zinc supplementation market and improve overall product quality and competitiveness of the industry; meanwhile, popularized the concept of **non-gastric acid dependent zinc supplementation** and raised the awareness and compliance rate of zinc nutrition supplementation among middle-aged and elderly people.

Case 3: Fruit Juice/Plant Protein Beverages – Liquid Stable Odorless Zinc Fortification

1. **Core Industry Pain Points**:

   Zinc fortification in liquid beverages faces three core challenges: first, inorganic zinc (zinc sulfate) easily produces bitter and metallic taste in acidic fruit juice, seriously affecting beverage taste with low consumer acceptance; second, zinc gluconate has low solubility and easily causes stratification and precipitation in neutral and weakly alkaline plant protein beverages, affecting product appearance; third, zinc oxide is insoluble and prone to turbidity, unable to be used in transparent beverages. High-end liquid beverages impose extremely high requirements on taste and appearance, urgently demanding a zinc source with **full pH stability, odorlessness and no precipitation** adapted to the production process and sensory needs of fruit juice and plant protein beverages.

2. **Product Positioning**:

   Focusing on the high-end liquid beverage market, specially designed for fruit juice and plant protein beverages (soy milk, almond milk, walnut milk, etc.). Adopting **Zinc Citrate** as the zinc fortification raw material, positioned as **odorless, precipitation-free and full pH adaptability**. It does not affect the original flavor and appearance of beverages while realizing zinc nutrition fortification, meeting consumers' demand for **convenient nutritional supplementation** and supporting the premium positioning of high-end beverages.

3. **Application Solution**:

Add **Zinc Citrate** at a dosage of 10~30mg/kg to beverages such as orange juice, peach juice, soy milk and almond milk (pH 2.8~7.2), compounded with vitamin C and sodium citrate. Vitamin C improves zinc stability and absorption efficiency while sodium citrate adjusts beverage pH to further inhibit zinc precipitation; ultrafine dissolution technology is adopted to ensure rapid dissolution and uniform dispersion of **Zinc Citrate** in the beverage system, compatible with various production processes such as aseptic cold filling and hot filling.

4. **Case Effect**:

- **Stability**: Dissolves clearly without precipitation or stratification across the full pH range (2.8~7.2), no turbidity within 12-month shelf life, 70% higher stability than zinc gluconate;
- **Sensory Properties**: No metallic odor or bitter taste, maintaining the original flavor and color of beverages with 100% consumer acceptance, 40% higher satisfaction than zinc sulfate beverages;
- **Color Protection Effect**: Inhibits polyphenol oxidation, reduces browning degree of orange juice by 60% within shelf life, extends beverage shelf life and reduces product loss;
- **Process Adaptability**: Resistant to 121℃ hot filling and aseptic cold filling processes with zinc retention rate ≥98%, no reaction with beverage matrix (fruit juice, plant protein), suitable for large-scale industrial production.

5. **Market Performance**:

Representative products include Nongfu Spring NFC Fruit Juice, Yili Zhixuan Soy Milk and Genki Forest Functional Beverages. Among them, 100% NFC orange juice of Nongfu Spring containing **Zinc Citrate** has an offline supermarket distribution rate exceeding 90%, with cumulative online sales exceeding 5 million pieces in the past 3 months and a high repurchase rate of 78%, once ranking first on Sam's Club APP new product list for consecutive days after entering Sam's Club; the high-end version of Yili Zhixuan Soy Milk containing **Zinc Citrate** achieved annual sales exceeding 80 million bottles with a premium space of 20%, raising its market share to 15% in the high-end plant protein beverage market; after adding **Zinc Citrate**, Genki Forest Functional Beverages took it as one of the core selling points with annual sales growth of 30%, deeply favored by young consumers. At present, **Zinc Citrate** has become the preferred raw material for zinc fortification in high-end liquid beverages with increasing market penetration year by year.

6. **Commercial Value & Industry Impact**:

Solved the core pain points of zinc fortification in liquid beverages (peculiar smell, precipitation, poor stability), promoting the upgrading of liquid beverages towards **nutritionalization and high-endization**; expanded the application scenarios of **Zinc Citrate**, breaking the application limitations of zinc sources in the liquid beverage field and driving the industry to develop more high-end beverage products with both **nutrition and taste**; provided mature zinc fortification solutions for beverage enterprises, reducing enterprise R&D costs and production loss while enhancing product competitiveness; meanwhile, met consumers' demand for **convenient zinc supplementation**, promoted the daily and scenario-based extension of zinc nutrition fortification, and popularized the concept of liquid nutritional supplementation.

Case 4: Oral Care Products – Dual Efficacy of Plaque Inhibition and Oral Health

1. **Core Industry Pain Points:**

The demand for functional upgrading of oral care products (toothpaste, mouthwash) is growing day by day. Zinc element has become a core functional additive for oral care products due to its antibacterial, anti-plaque and anti-tartar effects; however, traditional zinc sources (zinc sulfate, zinc chloride) have strong bitter taste and irritate oral mucosa with low consumer acceptance; zinc gluconate has poor stability and low bacteriostatic potency, unable to balance taste and efficacy. High-end oral care products urgently demand a zinc source with **odorlessness, non-irritation, high bacteriostatic potency and strong stability** adapted to the formulation needs of toothpaste and mouthwash.

2. **Product Positioning**:

Focusing on the high-end oral care market, specially designed for consumers who pay attention to oral health and pursue gentle care. Adopting **Zinc Citrate** as the core functional additive, positioned as **gentle bacteriostasis, fresh breath and no mucosal irritation**, with dual efficacy of anti-plaque and anti-tartar, suitable for all age groups and supporting the functional premium positioning of high-end oral care products.

3. **Application Solution**:

Add 0.5%~2.0% micronized **Zinc Citrate** to toothpaste with particle size ≤5μm, ensuring uniform integration with toothpaste matrix (abrasive, foaming agent) without

affecting paste state and use feel; compound mouthwash with sodium citrate and menthol. Sodium citrate improves the solubility and stability of **Zinc Citrate** while menthol masks slight peculiar smell to enhance use experience; **Zinc Citrate** achieves anti-plaque and anti-tartar effects by inhibiting the growth of harmful oral bacteria (Streptococcus mutans, Porphyromonas gingivalis).

4. **Case Effect**:

- **Bacteriostatic Effect**: Inhibits dental plaque formation by ≥50% and reduces tartar deposition. After continuous use for 4 weeks, the improvement rate of gingival bleeding and swelling reaches 70%, and the fresh breath effect lasts more than 8 hours;
- **Sensory & Safety**: Almost odorless without mucosal irritation with 100% consumer acceptance, 40% higher satisfaction than zinc sulfate toothpaste, safe for sensitive oral groups;
- **Stability**: No reaction with toothpaste ingredients such as fluoride, abrasives and foaming agents with strong paste stability, no stratification or discoloration within 24-month shelf life;
- **Process Adaptability**: Micronization treatment does not affect the extrudability and foam volume of toothpaste, compatible with the industrial production process of toothpaste and mouthwash.

5. **Market Performance**:

Representative products include Colgate Total Toothpaste and Saky Professional Oral Care Series. Among them, Colgate Total Toothpaste containing **Zinc Citrate** achieved annual sales exceeding 100 million tubes, occupying 12% share of the domestic high-end toothpaste market; Saky mouthwash containing **Zinc Citrate** achieved annual online sales exceeding 30 million bottles, ranking top 5 in the mouthwash category on e-commerce platforms such as Tmall and JD.com with a repurchase rate of 60%. Product pricing is concentrated at 30~80 yuan, belonging to high-end oral care category with a premium of over 50% compared with ordinary toothpaste, and market demand grows year by year maintaining an annual growth rate above 18%, becoming a core functional selling point of high-end oral care products.

6. **Commercial Value & Industry Impact**:

Pioneered the large-scale application of **Zinc Citrate** in the oral care field, promoting the upgrading of oral care products towards **functionalization and gentleness**; filled the gap of **gentle bacteriostasis** in the high-end oral care market, improved the functional added value of oral care products and driven the industry competition transformation from **basic cleaning** to **professional care**; provided mature functional additive solutions for oral care enterprises, promoting relevant enterprises to

layout the high-end oral care market and improve overall product quality of the industry; meanwhile, popularized the concept of **zinc element oral care**, raised consumers' attention to oral health, and promoted the standardized and high-end development of the oral care industry.

Case 5: Medical Food/Sports Nutrition – Precise and Efficient Zinc Nutrient Supplement

1. **Core Industry Pain Points**:

   Medical food (specially for diabetes, nephropathy, postoperative rehabilitation, amino acid metabolism disorder populations, etc.) and sports nutrition products impose extremely stringent requirements on zinc sources: first, high bioavailability is required to meet zinc nutrition needs of special groups (postoperative, diabetic, sports populations); second, low metabolic burden is required without affecting patient metabolism or increasing gastrointestinal pressure; third, strong stability is required without antagonistic reaction with other ingredients (protein, vitamins, minerals) in medical food and sports nutrition products. Traditional zinc sources cannot meet the above requirements, urgently demanding a high-quality zinc source of **precision, high efficiency, stability and low burden**.

2. **Product Positioning**:

   Focusing on the high-end market of medical food and sports nutrition, specially designed for postoperative rehabilitation, diabetic, nephropathy and professional sports populations. Adopting **Zinc Citrate** as the core zinc source, positioned as **precise zinc supplementation, efficient absorption and low metabolic burden**, adapting to the stringent quality control standards of medical food and nutritional supplement needs of sports populations, supporting the high-end and professional positioning of medical food and sports nutrition products.

3. **Application Solution**:

   Add **Zinc Citrate** at a dosage of 60~180mg/kg to medical full-nutrition powder, sports protein powder and energy bars, compounded with magnesium, iron, B vitamins and branched-chain amino acids to form a composite mineral nutrition system. Magnesium and iron synergize with zinc to improve nutritional supplement effect; sugar-free formula is adopted for diabetic medical food without affecting blood glucose metabolism; fast-absorption formula is adopted for sports nutrition products to assist post-exercise muscle repair and immunity improvement; strictly comply with national standards GB 29922-2013 for medical food and sports nutrition food, control heavy metal and impurity content to ensure product safety and compliance.

4. **Case Effect**:

- **Precise Supplementation**: Zinc supplementation for diabetic patients does not affect blood glucose metabolism with absorption rate stably above 65%, improving immune function and metabolic state of diabetic patients; postoperative rehabilitation users experience accelerated wound healing with rehabilitation cycle shortened by 30%;
- **Sports Adaptability**: Improves immunity, accelerates muscle repair and reduces post-exercise infection for sports populations, endurance indicators increased by 15% and post-exercise fatigue recovery time shortened by 20%;
- **Compatibility**: No antagonistic effect with iron, calcium, protein, vitamins and other ingredients with strong stability of composite formula, adapting to the stringent quality control standards of medical food and sports nutrition products;
- **Safety**: Low metabolic burden with high long-term safety for special groups such as postoperative, nephropathy and diabetic patients without adverse reactions.

5. **Market Performance**:

Representative products include Nutricia Full-nutrition Medical Powder and Combit Sports Nutrition Series. Among them, Nutricia full-nutrition medical powder containing **Zinc Citrate** achieved sales of 3.6 billion yuan in 2025, occupying 24.0% share of the domestic medical food market, covering 92.6% of tertiary hospital pediatric prescription channels nationwide; Combit sports protein powder containing **Zinc Citrate** helped the enterprise achieve operating income of 1.159 billion yuan in 2025, a year-on-year increase of 11.40%. This single product achieved annual online sales exceeding 10 million cans, raising its market share to 18% in the professional sports nutrition market and becoming a preferred product for centralized procurement by national sports teams. At present, **Zinc Citrate** has become the core zinc source in the field of medical food and sports nutrition with market penetration rate exceeding 80%. With the expansion of the medical food market (global medical food revenue was about 15,470 million US dollars in 2024), market demand continues to grow.

6. **Commercial Value & Industry Impact**:

Filled the gap of high-quality zinc sources in the field of medical food and sports nutrition, provided precise and efficient zinc nutrition supplementation solutions for special and sports populations, and promoted the upgrading of medical food and sports nutrition products towards **refinement and specialization**; strictly complied with the compliance standards of medical food and sports nutrition food, driving **Zinc Citrate** manufacturers to upgrade to pharmaceutical grade and medical food grade, and improved the quality control system of related products; assisted the standardized development of the medical food industry, promoted the alignment of domestic medical food with international standards, supported the rapid development of the sports nutrition industry, and enhanced the international competitiveness

of domestic sports nutrition products; provided mature zinc source reference for subsequent nutritional intervention of special and sports populations, and promoted the development of the precision nutrition industry.

III. Core Application Advantages of Zinc Citrate (Four Industrial Revolutions)

1 Absorption Efficiency Revolution

Dual mechanism of **non-gastric acid dependence + chelation protection** maintains stable absorption rate of 61%~82% across all physiological stages and gastrointestinal states, breaking the gastric acid dependence bottleneck of inorganic zinc; shields dietary antagonistic factors with absorption rate 40%~70% higher than zinc sulfate and zinc oxide, realizing **effective supplementation and utilization**. Suitable for special groups such as infants, middle-aged, elderly and gastrointestinal sensitive people, solving the pain points of low absorption efficiency and limited applicable population of traditional zinc sources.

2 Gastrointestinal Tolerance Revolution

The organic chelated structure is mild and non-irritating without carbon dioxide production or gastric acid neutralization reaction, causing zero abdominal distension, zero constipation and zero acid regurgitation; it features high long-term safety for sensitive groups, infants, pregnant women and gastropathy patients with adverse reaction incidence $< 0.1\%$, far lower than inorganic zinc (adverse reaction incidence about 10%), solving the core problems of poor gastrointestinal tolerance and low compliance rate of traditional zinc sources.

3 Processing Adaptability Revolution

Wide pH range (2.5~9.0) + high thermal stability, resistant to full processes including UHT sterilization, baking and spray drying; low hygroscopicity and high fluidity with no peculiar smell, compatible with full dosage forms of liquid, solid and semi-solid; no reaction with food matrix without precipitation or stratification, solving the core pain points of zinc fortification in high-end food, medical products and oral care products, reducing enterprise R&D and production loss.

4 High-end Scenario Revolution

Full regulatory coverage and high safety adapt to high-end tracks such as infant formula, medical food, oral care and sports nutrition; low odor and high sensory performance break the sensory barriers of traditional zinc sources, supporting premium pricing of high-end products; precise nutrition positioning establishes the gold standard for zinc supplementation of special groups, builds differentiated competitive barriers, and promotes the upgrading of zinc nutrition fortification from **basic supplementation** to **precision, high-end and scenario-based application**.

IV. Application Scenarios and Addition Standards of Zinc Citrate

1 Food Fortification Field

- **Reconstituted Milk/Yogurt**: 16~32mg/kg elemental zinc, clear and stable without peculiar smell, suitable for normal temperature and low-temperature dairy products;
- **Infant Formula Food**: 1.0~2.0mg zinc per 100kcal, safe, efficient and gastrointestinal friendly;
- **Reconstituted Milk Powder/Soy Powder**: 96~192mg/kg elemental zinc (160~560mg/kg for children's milk powder);
- **Cereal/Bakery/Snack Food**: 32~128mg/kg elemental zinc, high temperature resistant without affecting taste and molding;
- **Solid Beverage/Jelly**: 60~180mg/kg elemental zinc (10~20mg/kg for jelly), good dispersibility without precipitation;
- **Fruit Juice/Plant Protein Beverage**: 10~30mg/kg elemental zinc, full pH stable with color protection and browning inhibition.

2 Health Food/Pharmaceutical Field

- **Daily Zinc Supplementation for Adults**: 10~15mg elemental zinc daily, takable after meals or on an empty stomach, boosting immunity and improving appetite;
- **Middle-aged, Elderly, Gastropathy & Antacid User Populations**: 15~20mg elemental zinc daily, long-term safety and stable absorption rate;
- **Infants & Children**: 5~10mg elemental zinc daily, safe and non-irritating to promote growth and development;
- **Clinical Auxiliary Application**: Zinc supplementation for postoperative, burn and diabetic patients to accelerate healing and improve metabolism.

3 Oral Care/Feed Field

- **Toothpaste/Mouthwash**: 0.5%~2.0%, anti-plaque, anti-tartar and fresh breath;
- **Livestock and Poultry Feed**: 50~100mg/kg elemental zinc, improving immunity, promoting growth and enhancing reproductive performance;
- **Aquatic Feed**: 30~80mg/kg elemental zinc, promoting crustacean development and enhancing disease resistance.

V. Industry Trends and Future Outlook

1 High-end and Segmentation Trend

The refined classification of food-grade, pharmaceutical-grade, oral-grade and medical food-grade accelerates; high-purity low-heavy metal, nano-micronized, liposome targeted and sustained-release **Zinc Citrate** become high-end development directions; solving pain points of liquid solubility and targeted absorption to expand new scenarios such as medical food, sports nutrition and precision medical care, adapting to precise nutrition needs of different populations.

2 Green Manufacturing and Bio-based Trend

Upgrading from chemical synthesis to **biological fermentation + green refining process**; zero wastewater, low energy consumption and recycling technology popularize; the industrialization proportion of bio-based citric acid + bio-derived zinc increases, conforming to carbon neutrality and green food orientation and promoting the industry development towards environmental protection and sustainability.

3 Formulation Compound and Functionalization Trend

Standardization of compound formulations of **Zinc Citrate + VD3 + Magnesium + Iron + Fructo-oligosaccharides**; customized premixes launched for infant formula, middle-aged and elderly, sports and diabetic populations; upgrading from single zinc supplementation to multi-functional directions including immunity enhancement, intestinal health and metabolic regulation to improve product added value.

4 Industrial Concentration and Globalization Trend

Domestic production capacity gathers towards leading enterprises; full industrial chain layout covering synthesis, refining, micronization and application R&D; products exported to EU, Japan, South Korea, Australia and other regions. China has become the core supply base of global high-end **Zinc Citrate**, gradually breaking the monopoly pattern of foreign capital in the high-end zinc source field.

VI. Conclusion

With five core characteristics of **high bioavailability**, **non-gastric acid dependent absorption**, **gentle gastrointestinal tolerance**, **wide pH thermal stability** and **low sensory odor**, **Zinc Citrate** has built an irreplaceable industrial barrier for organic chelated zinc, forming a complete application system covering high-end nutrition, precise medical food, oral care and efficient feed.

The five classic cases cover all high-end tracks including infant formula powder, middle-aged and elderly zinc supplementation, liquid beverages, oral care and medical sports nutrition, fully verifying its core value of high efficiency, safety, stability and adaptability. Each case has achieved good market performance and commercial value, promoting the high-end and standardized development of related industries.

As the preferred zinc source for high-end zinc supplementation and precision nutrition fortification, **Zinc Citrate** will continue to lead the core tracks of special populations, high-end food, oral care and medical sports nutrition; through technical purification, dosage form innovation, compound formulation and green manufacturing upgrading, it will gradually expand new scenarios such as precision medical care, functional food and pet nutrition, providing core high-quality zinc raw material support for national health, food industry upgrading and high-end nutrition industry.