LiposoMore

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Comprehensive Research Report and Technical Data Sheet: Liposomal Zinc Citrate

Liposomal Zinc Citrate: An Academic Overview of Advanced Nutritional Delivery Systems

In the field of contemporary trace element nutrition and pharmaceutical technology, Liposomal Zinc Citrate represents a major paradigm shift from traditional mineral salts to precision nano-delivery systems. Traditional zinc supplements, such as zinc sulfate or zinc oxide, have been used clinically for years, but their inherent low bioavailability, significant gastrointestinal side effects, and susceptibility to dietary factors (such as phytates) have greatly limited their therapeutic efficacy.[1] Liposomal Zinc Citrate constructs a biomimetic "Trojan Horse" delivery system by encapsulating zinc citrate molecules within nano-sized vesicles composed of phospholipid bilayers.[1] This structure not only protects zinc ions from stomach acid erosion but also alters the absorption pathway of minerals in the intestine, allowing them to enter the lymphatic system or blood circulation directly through cell fusion or endocytosis, thereby achieving the vision of "Zero-Loss Nutrition".[1]

Chemically, the product is a microencapsulated powder where the core ingredient, zinc citrate, is tightly enveloped in a composite matrix of sodium octenyl succinate starch and phospholipids.[3] This multi-component system enhances the stability of active ingredients through liposomal technology, maintaining the structural integrity of the liposomes even in powder form.[3] As the active substrate, zinc citrate is an organic acid salt with better pre-absorption characteristics than inorganic salts, and the addition of liposomes elevates its biological efficacy to an entirely new level.[2]

Chemical Composition and Molecular Structure

Characteristics

The chemical core of zinc citrate is typically in the trihydrate form, with the molecular formula $C_{12}H_{10}O_{14}Zn_3 \cdot 3H_2O$ and a molecular weight of approximately 574.34 g/mol.[7] In its non-encapsulated state, pure zinc citrate contains approximately 31% elemental zinc.[5] However, in liposomal powder formulations, because the encapsulation materials (such as phospholipids and starch matrices) occupy a significant proportion of the mass, the typical elemental zinc content is set at $\geq$ 24%.[3] This concentration is set as a balance between efficacy and stability, ensuring that sufficient trace elements are provided while maintaining the physical and chemical stability of the liposomes.[2]

Chemical and Physical Attributes	**Specification Parameters**
Product Name	Liposomal Zinc Powder (LiposoMore™-Zn)
Active Ingredient	Zinc Citrate
CAS Number (Zinc Citrate)	546-46-3
EINECS Number	208-901-2
Molecular Formula	$C_{12}H_{10}O_{14}Zn_3$
Carrier Materials	Phospholipids (Sunflower or Soy), Sodium Octenyl Succinate Starch
Physical State	White to light yellow powder

Solubility/Dispersibility	Uniformly dispersible in water

The encapsulation process involves the construction of nano-scale lipid vesicles, which are self-assembled from phospholipid molecules such as phosphatidylcholine, mimicking the structure of human cell membranes.[9] Through this molecular-level engineering, zinc citrate is transformed from a simple inorganic nutrient into a lipid complex with high biological affinity.[2]

Technical Data Sheet (TDS) and Quality Control Standards

As a high-specification food supplement grade raw material, Liposomal Zinc Citrate must comply with rigorous internal and international quality standards. The Technical Data Sheet (TDS) reflects not only its physico-chemical indicators but also its special properties as a nano-formulation, such as encapsulation efficiency and particle size distribution.[3]

Physico-Chemical Indicators Analysis

According to the typical Certificate of Analysis (COA), Liposomal Zinc Citrate powder shows high consistency in appearance, odor, and solubility. The odor is typically odorless or has a very slight characteristic fatty smell, thanks to the use of high-quality phospholipids.[3]

Item	**Specifications**	**Result (Typical)**	**Test Method**
Appearance	White to light yellow powder, no foreign matter	Pass	USP
Odor	Odorless	Pass	USP
Assay (as Elemental Zinc)	$\geq$ 24.0%	24.8%	USP

Encapsulation Efficiency (EE%)	$>$ 80%	85.0% - 94.5%	In-house
Loss on Drying (LOD)	$\leq$ 14.0%	1.08%	USP
Particle Size Distribution (PSD)	$>$ 90% pass 80 mesh	Pass	USP
Bulk Density	Report as it is	0.38 g/ml	USP

Encapsulation Efficiency (EE%) is the core indicator for measuring liposome quality, defined as the proportion of zinc citrate locked inside the phospholipid bilayer. Top-tier manufacturing processes can achieve an encapsulation efficiency of up to 94.51%, far exceeding the industry average of 70%.[2] Extremely high encapsulation efficiency means that almost all zinc ions are protected behind the "Lipid Shield," thereby minimizing direct contact with taste buds or the gastric mucosa.[2]

Particle Size and Nano-Characteristics

Although it appears macroscopically as a powder passing through an 80-mesh sieve, its functional lipid vesicles are typically at the nano-scale (usually less than 300 nanometers) after re-dispersion in an aqueous medium.[1] The tiny particle size not only enhances stability in liquid applications but also greatly promotes penetration in the circulatory system, allowing it to enter tissue spaces more effectively.[2]

In-Depth Absorption Mechanism: The Trojan Horse Delivery System

To understand the core value of Liposomal Zinc Citrate, one must delve into its biological behavior within the human digestive tract. The absorption of traditional supplements is limited by saturable transporters (such as the ZIP family transporters) on intestinal epithelial cells. When high doses are ingested, these transport channels quickly saturate, causing excess zinc ions to remain in the intestinal lumen, producing a metallic aftertaste and inducing gastrointestinal discomfort.[1]

Evading Stomach Acid and Chemical Degradation

Liposomal technology provides a physical barrier for the active ingredient. In the acidic environment of the stomach (pH 1.2 - 3.5), ordinary zinc citrate salts quickly dissociate into free zinc ions, which easily form insoluble precipitates with phytates or tannins in food, thereby losing absorption activity.[2] The phospholipid shell of the liposome remains relatively stable in gastric juice, sealing the zinc ions inside the core and ensuring they reach the primary absorption site—the small intestine—in an intact molecular form.[1]

Bypass Transport and Cell Fusion

Once it reaches the intestinal mucosa, the liposome demonstrates its unique "bio-similarity." Because the phospholipid components are highly consistent with epithelial cell membranes, liposomes can be absorbed as a whole through endocytosis, or release the internal zinc citrate directly into the cytoplasm through membrane fusion.[2] This absorption mode is "non-saturable," meaning that even at high doses, the absorption rate does not drop sharply like traditional salts.[1] Furthermore, some liposomes can enter the lymphatic system through the chylomicron pathway, thereby bypassing the first-pass metabolism of the liver and further increasing systemic bioavailability.[2]

Bioavailability and Pharmacokinetic Advantages

Bioavailability is the ultimate indicator for evaluating the quality of nutritional supplements. Liposomal Zinc Citrate has demonstrated significantly superior pharmacokinetic characteristics compared to traditional formulations in multiple human and animal experiments. Studies show that liposomal delivery systems can increase mineral absorption by 2 to 5 times.[11]

Clinical Evidence Analysis

In a comparative experiment, liposomal zinc ascorbate produced using ActiNovo technology was confirmed to have 3.82 times the bioavailability of standard non-liposomal powder zinc ascorbate.[16] At 8, 10, and even 12 hours after ingestion, the serum zinc concentration in the liposomal group was significantly higher than that in the control group, indicating that liposomes not only increase the peak absorption (C_{max}) but also prolong the circulation time of zinc in the body.[16]

Pharmacokinetic Parameter	Traditional Zinc Citrate Salt	Liposomal Zinc Citrate	Benefit/Significance
Relative Bioavailability	1.0 (Baseline)	2.0 - 5.0	Significantly enhanced systemic absorption [11]

Time to Peak (T_{max})	Shorter (limited by active transport)	Sustained-release characteristics	Provides more lasting nutritional support [16]
GI Tolerance	Poor (nausea prone)	Excellent	Eliminates gastric mucosal irritation [1]
Dietary Interactions	Easily hindered by phytates	Almost unaffected	Improves absorption in complex diets [2]

This innovation in pharmacokinetics means that clinicians can prescribe lower doses to achieve desired serum levels, thereby reducing potential metabolic imbalances caused by high mineral intake (such as copper deficiency caused by zinc).[1]

Manufacturing Process and Quality by Design (QbD)

The manufacturing of Liposomal Zinc Citrate is a highly controlled pharmaceutical engineering process involving the deep integration of nanotechnology and microencapsulation. The Quality by Design (QbD) concept is applied throughout to ensure the Critical Quality Attributes (CQA) of the final product by controlling Critical Process Parameters (CPP).[4]

Core Manufacturing Flow

1. **Lipid Phase Preparation:** High-purity phospholipids (usually sunflower lecithin rich in phosphatidylcholine) are dissolved in a suitable solvent or pre-heated liquid phase.
2. **Aqueous Phase Formulation:** Zinc citrate is dissolved under specific pH conditions, and stabilizers such as sodium octenyl succinate starch are added as needed.[3]
3. **High-Shear Emulsification and Sonication:** Through high-pressure homogenizers or sonication technology, the lipid and aqueous phases are forced to form a primary emulsion, and the droplet size is gradually reduced to the nanometer scale to form lipid vesicles.[15]
4. **Microencapsulation and Drying:** Spray drying or lyophilization (freeze-drying) technology is used to convert unstable liquid liposomes into stable solid powders.[22] In this process, the starch matrix acts as a "curing agent," protecting the lipid spheres from rupturing during drying.[3]

Safety, Toxicology, and Contaminant Control

As a product entering the human consumption chain, Liposomal Zinc Citrate must meet strict toxicological safety indicators. Since this product involves nanotechnology, its safety assessment covers not only chemical purity but also the biocompatibility of nano-scale particles.[4]

Heavy Metal Contaminant Limits

Trace element analysis conducted via Inductively Coupled Plasma Mass Spectrometry (ICP-MS) ensures that the concentrations of potentially harmful metals are far below international standards (such as USP).[3]

Contaminant Item	Specification Limits	Typical Value	Test Method
Total Heavy Metals	≤ 10 ppm	< 10 ppm	USP
Lead (Pb)	≤ 3.0 ppm	< 3.0 ppm	USP
Mercury (Hg)	≤ 0.1 ppm	< 0.1 ppm	USP
Cadmium (Cd)	≤ 1.0 ppm	< 1.0 ppm	USP
Arsenic (As)	≤ 1.0 ppm	< 1.0 ppm	USP

Microbiological Safety

Microbial control follows USP and standards, setting strict limits for total plate count, molds, yeasts, and pathogens (such as E. coli and Salmonella) for powdered dietary supplements.[3] Liposomes are susceptible to microbial growth due to their phospholipid content if handled improperly; therefore, the thoroughness of the drying process and the sealing of the packaging are key guarantees of microbiological safety.[1]

Item	Specifications	Result	Test Method

Total Plate Count	$\leq$ 1000 cfu/g	< 100 cfu/g	USP
Molds & Yeasts	$\leq$ 100 cfu/g	< 10 cfu/g	USP
E. coli	Negative/g	Negative	USP
Salmonella	Negative/25g	Negative	USP

Pharmacological Effects and Multi-Dimensional Health Benefits

Zinc is an essential cofactor for over 300 enzymes in the human body, participating in core biological processes such as protein synthesis, DNA replication, cell differentiation, and immune signaling.[2] The high absorption rate of Liposomal Zinc Citrate makes it significantly effective in the following areas:

- **Immune System Regulation:** Zinc is crucial for the development and function of immune cells, especially neutrophils and natural killer (NK) cells.[2] Liposomal zinc quickly replenishes intracellular zinc stores, providing timely immune support during infections.[2]
- **Antioxidant and Anti-inflammatory Effects:** Zinc is a key component of Superoxide Dismutase (SOD).[2] Liposomal technology ensures that zinc ions more effectively penetrate the cell membrane, enhancing SOD activity to neutralize harmful free radicals.[2]
- **Skin Integrity and Tissue Repair:** Skin tissue contains large amounts of zinc required for wound healing.[2] Bioavailable liposomal zinc accelerates skin wound closure and assists in treating acne by inhibiting bacterial growth.[2]
- **Reproductive Health and Metabolism:** Zinc is indispensable for maintaining normal testosterone levels and supporting fertility.[5] It also participates in the metabolism of Vitamin A and the storage of insulin.[5]

Regulatory Compliance, Certification, and Ethical Statements

Liposomal Zinc Citrate must meet multiple regulatory requirements to ensure legality and

ethical suitability across global markets.[4]

Statement Item	Status	Scientific Basis/Notes
Non-GMO	Compliant	Uses non-genetically modified sunflower lecithin [31]
Gluten-Free	Compliant	Verified content < 20 ppm [33]
Vegan/Vegetarian	Compliant	Contains no animal-derived raw materials or by-products [35]
BSE/TSE Free	Compliant	No contact with animal brain tissue or bone meal during production [31]
Halal & Kosher	Compliant	Clean production and alcohol-free processing [30]

Stability, Storage Conditions, and Packaging

Although powdering significantly improves stability, environmental factors can still lead to the degradation of the lipid membrane or leakage of internal components.[22]

- **Temperature Control:** Store in a cool, dry place (suggested 15 - 25°C), away from heat sources. High temperatures increase the fluidity of phospholipid molecules, accelerating oxidation.[3]
- **Light Protection:** Ultraviolet light induces lipid peroxidation; therefore, opaque packaging must be used.[22]
- **Humidity Management:** Maintain relative humidity (RH) below 60% and ensure the container is tightly sealed.[3]
- **Packaging System:** Typical industrial packaging includes food-grade HDPE drums with double-layer anti-static, moisture-proof poly liners.[12]

Dosage Guidelines and Safety Limits

When using Liposomal Zinc Citrate, one must strictly follow the Recommended Dietary Allowance (RDA) and Tolerable Upper Intake Level (UL).

Population Category	RDA (Elemental Zinc mg/day)	UL (Upper Limit mg/day)
Children (1-8 years)	3 - 5 mg	7 - 12 mg
Adolescents (9-18 years)	8 - 11 mg	23 - 34 mg
Adult Male (19+)	11 mg	40 mg
Adult Female (19+)	8 mg	40 mg

Industrial Vision and Conclusion

Liposomal Zinc Citrate (LiposoMore™-Zn) is more than just a new mineral raw material; it is a product of the deep fusion of material science and nutritional pharmacology. Through microparticle engineering, it resolves the long-standing contradiction between "high absorption" and "zero side effects" in the mineral supplement field.[1]

As a premium brand under **Joyful Nutritional Supply Co., Ltd.**, LiposoMore™-Zn's Technical Data Sheet reflects the highest standards of contemporary pharmaceutical processes: precise $\geq$ 24% assay, $>$ 85% high encapsulation efficiency, and comprehensive dietary certifications.[2] Its Trojan Horse delivery mechanism ensures that active ingredients can cross the gastric acid barrier and enter the circulatory system directly, achieving true "Precision Nutrition".[1] For brands and manufacturers committed to innovation, selecting Liposomal Zinc Citrate with high quality standards is the cornerstone for building product differentiation and winning consumer trust.