Analysis of Unique Properties of Spirulina Powder

Overview:

Spirulina Powder is a natural microalgae powder refined from prokaryotes of the Cyanophyta phylum such as *Arthrospira platensis* and *Arthrospira maxima* through spray drying and ultrafine grinding. Endowed with a primitive cell structure formed by 3.5 billion years of evolution and an extremely concentrated full-nutrition spectrum, it exhibits irreplaceable physicochemical characteristics, functional properties and unique performances in the fields of functional food, nutritional fortification and biomedicine. It is certified by the **Food and Agriculture Organization of the United Nations (FAO)** as **"the most ideal nutritional source for the 21st century"**. As one of the core characteristic functional components of spirulina, **highly active natural chlorophyll** forms a complementary and synergistic active system with phycocyanin, spirulina polysaccharides, SOD and other substances, serving as the key core ingredient for realizing multiple physiological functions of spirulina.

Ⅰ. Physicochemical Characteristics

1. Appearance and Physical Properties

- **Color**:

Pure food-grade product presents uniform dark green to deep blackish green without variegated colors, white spots or yellowing; inferior or adulterated products show light green, yellowish green or contain black impurities. Its dark green color mainly comes from the compound color development of high-content natural chlorophyll and phycocyanin with a stable ratio, which is an intuitive physical feature for identifying high-quality spirulina powder.

- **Morphology and Texture**:

Loose powdery form with delicate and smooth hand feel and no gritty texture. High-quality product has a fineness of ≥120 mesh (particle size ≤125μm), good fluidity and no caking; unfiltered coarse product has an obvious rough feel.

- **Density and Solubility**:

Bulk density: 0.4~0.6g/cm³, true density: 1.3~1.4g/cm³; moderate water solubility (60%~70%) and good water dispersibility. It forms a uniform dark green suspension after stirring with no obvious stratification upon standing. After powder dispersion, chlorophyll can suspend evenly in aqueous solution and is not easy to precipitate.

- **Odor and Taste**:

It has a unique slight fishy algae fragrance without rancid or putrid odor; the taste is slightly salty with a faint seaweed umami flavor, free of bitterness, astringency and peculiar odors.

2. Core Physicochemical Indicators

Spirulina Powder adopts mature and standardized physicochemical quality control indicators, strictly complying with the specifications of **GB 16740-2014 Health Food**. All parameters are stable and controllable, which directly determine powder quality, stability of active ingredients and physiological efficacy. The detailed explanation of core physicochemical indicators is as follows:

- **Protein**:

Dry weight content ranges from 60%~72%, ranking top in protein density among natural raw materials. Its protein

content is far superior to common high-quality protein sources such as soybeans (35%) and beef (20%), acting as the core nutritional base of spirulina.

- **Moisture**:

Standard content ≤7.0%. A low-moisture environment can effectively inhibit microbial growth and raw material mildew, meanwhile maximally protect heat-sensitive active ingredients such as chlorophyll and phycocyanin, prevent component degradation and failure during storage and processing, and extend the product shelf life.

- **Ash Content**:

Standard content ≤8.0%. The ash of algae powder is mainly composed of natural carbonates and oxides of potassium, sodium, calcium, magnesium and other elements, representing the natural mineral system enriched by spirulina and reflecting its multi-dimensional mineral nutrition characteristics.

- **pH Value (5% Suspension)**:

Ranges from 8.0~9.5, belonging to a natural weakly alkaline raw material. It can help the human body neutralize gastric acid and regulate the body's acid-base balance. Meanwhile, this acid-base environment is highly compatible with chlorophyll, capable of stabilizing the molecular structure of chlorophyll and ensuring its stable biological activity.

- **Phycocyanin**:

Food-grade standard content ≥10%. It is an exclusive characteristic blue active protein of spirulina, as well as the core marker substance for identifying the quality authenticity of spirulina powder.

- **Chlorophyll**:

Content ranges from 0.5%~1.0%, serving as the characteristic green pigment source of algae powder. Different from the liposoluble chlorophyll of terrestrial plants, spirulina contains **cyanobacterial water-soluble chlorophyll** with better stability and biological activity, possessing multiple physiological activities including hematopoiesis, detoxification, antioxidation, mucosal repair and neuroprotection.

- **Heavy Metals**:

Lead ≤1ppm, Arsenic ≤0.5ppm, Cadmium ≤0.2ppm. The stringent heavy metal limits fully comply with national health food standards in China. The raw material features high safety and is suitable for long-term consumption by people of all age groups.

3. Microstructure and Component Composition

1. Cell Structure:

It has no cell wall (only a thin cell membrane), with nutrients directly exposed. The digestive absorption rate reaches over 95%, much higher than plant protein (soybean 70%, grains 50%). The special cell structure of cyanobacteria enables intracellular chlorophyll to be rapidly released and absorbed by the human body without cell wall breaking and degradation, retaining complete biological activity.

2. Core Component Matrix:

- **Protein**:

  Contains a full spectrum of 8 essential amino acids, with an amino acid pattern close to FAO recommended standards, featuring prominent contents of lysine and leucine.

- **Lipids**:
  Total lipid ≤7%, 90% of which are unsaturated fatty acids. Gamma-Linolenic Acid (GLA) accounts for 20%~30% of total fatty acids, with trace amounts of DHA and EPA.
- **Carbohydrates**:
  15%~20%, mainly composed of spirulina polysaccharides (PSP, molecular weight 12kDa), dietary fiber 4%~8% (water-soluble proportion over 40%).
- **Vitamins**:
  β-carotene (10~15 times that of carrots), B-complex vitamins (B1/B2/B6/B12), vitamin E and K. Vitamin B12 is rarely found in plant sources (cobalamin analogues).
- **Minerals**:
  Bioavailable iron (200~300mg/100g), calcium, potassium, magnesium, zinc, selenium. The absorption rate of iron is higher than that of spinach and red meat.
- **Active Substances**:
  Phycocyanin, highly active water-soluble chlorophyll, Superoxide Dismutase (SOD), carotenoids, phycobilin and small molecular peptides. The molecular structure of spirulina chlorophyll is highly similar to human heme, making it a natural hematopoietic active ingredient. Its water-soluble property adapts to human body fluid environment, with absorption efficiency far exceeding liposoluble chlorophyll from terrestrial plants.

II. Functional Characteristics

1. Full-Nutrition Efficient Supplementation Function

● Supply of High-Quality Complete Protein

High content, high digestibility and full amino acid spectrum can rapidly repair tissues and supplement nitrogen sources. It is suitable for vegetarians, athletes, postoperative rehabilitation crowds and people with malnutrition, without the fat and cholesterol burden of animal protein.

● Synergistic Absorption of Multi-Dimensional Minerals

Iron combined with vitamin B12 synergistically improves iron deficiency anemia; calcium, magnesium and potassium maintain bone, cardiovascular and neurological functions; zinc and selenium enhance immunity and antioxidation. The absorption rate of natural chelated minerals is far higher than inorganic supplements. Meanwhile, chlorophyll can chelate minerals, promote the retention and absorption of trace elements in the intestinal tract and avoid nutrient loss.

● Precise Supply of Essential Fatty Acids

Gamma-Linolenic Acid (GLA) is essential for the human body but cannot be synthesized by itself. It regulates lipid metabolism, exerts anti-inflammatory effects and balances hormones, with better efficacy than ordinary linoleic acid, suitable for people with metabolic syndrome and skin inflammation.

2. Strong Antioxidant and Anti-Inflammatory Function

● Multi-Target Antioxidant Network

Phycocyanin (core ingredient) + SOD + β-carotene + chlorophyll + polysaccharides synergistically eliminate free

radicals (hydroxyl radicals, superoxide anions), inhibit lipid peroxidation, and protect cellular DNA and mitochondria from oxidative damage. Among them, chlorophyll can target and eliminate free radicals in the intestinal tract and blood, block oxidative chain reactions, and assist in reducing the body's oxidative stress level. Its overall antioxidant activity is **20 times that of vitamin E and 10 times that of vitamin C**.

● **Targeted Anti-Inflammatory Mechanism**

Phycocyanin inhibits the expression of Cyclooxygenase-2 (COX-2) and Inducible Nitric Oxide Synthase (iNOS), blocking the release of inflammatory factors (TNF-α, IL-6); spirulina polysaccharides regulate immune cell activity and relieve chronic inflammation (gastrointestinal, joint and vascular inflammation). Meanwhile, chlorophyll can repair damaged mucosal tissues, reduce mucosal congestion and edema, and assist in alleviating chronic inflammatory damage to the gastrointestinal tract and respiratory tract.

3. Immune Regulation and Defense Function

It activates the activity of macrophages, T lymphocytes and NK cells, improves the phagocytic capacity of immune cells and cytokine secretion, and enhances the body's ability to recognize and eliminate viruses, bacteria and tumor cells. Spirulina polysaccharides promote the synthesis of immunoglobulins (IgG, IgA), strengthen mucosal immunity (intestinal and respiratory tract) and reduce infection risks, suitable for people with low immunity and frequent colds. As the core ingredient for mucosal repair, chlorophyll repairs damaged mucosal barriers, reduces invasion channels for external pathogens, and builds the first line of immune defense for the human body.

4. Metabolic Regulation and Chronic Disease Intervention Function

● **Blood Sugar Regulation**:

Polysaccharides improve insulin sensitivity, promote GLUT4 glucose transport, reduce postprandial blood sugar, ameliorate insulin resistance, and assist in the management of type 2 diabetes.

● **Blood Lipid Regulation**:

GLA combined with phycocyanin inhibits cholesterol absorption and promotes bile acid excretion, reducing total cholesterol, triglycerides and Low-Density Lipoprotein Cholesterol (LDL-C), while elevating High-Density Lipoprotein Cholesterol (HDL-C), exerting anti-atherosclerotic effects. Chlorophyll assists in purifying blood, removing lipid metabolic waste in the blood, and maintaining smooth inner vascular walls.

● **Gastrointestinal Protection**:

Its weakly alkaline property neutralizes gastric acid, repairs gastrointestinal mucosa and promotes ulcer healing; dietary fiber proliferates intestinal probiotics, improves constipation and abdominal distension, and maintains intestinal microecological balance. Chlorophyll is the key active ingredient for gastrointestinal mucosal repair, which promotes the regeneration of mucosal epithelial cells, blocks the erosion of gastric acid and irritants on wound surfaces, and relieves discomfort caused by gastritis and gastric ulcers.

5. Detoxification and Anti-Radiation Function

Chlorophyll and phycocyanin jointly exert core detoxification effects, efficiently chelating and adsorbing heavy metals (lead, mercury, cadmium), radioactive substances (Strontium-90, Cesium-137) and metabolic toxins. They form stable non-toxic complexes after combination and are completely excreted through the intestinal tract, greatly

reducing the liver detoxification burden and improving the accumulation of toxins in the body.

Anti-Radiation Damage: It protects the hematopoietic system and bone marrow cells, reducing the risk of radiation-induced leukopenia and DNA mutation, suitable for crowds exposed to radiotherapy, nuclear radiation and electronic radiation. Meanwhile, chlorophyll repairs mucosal and cellular damage caused by radiation, alleviating physical inflammation and weakened hematopoietic function induced by radiation.

6. Exclusive Hematopoiesis and Qi-Blood Conditioning Function

The molecular structure of spirulina chlorophyll is highly homologous to human heme, differing only in central metal ions, making it a natural hematopoietic raw material. After entering the human body, it can rapidly participate in hemoglobin synthesis, enhance the oxygen-carrying capacity of red blood cells, and improve problems such as deficiency of qi and blood, dull complexion, physical hypoxia and fatigue. Combined with plant-based iron and vitamin B12 in spirulina, it forms a complete hematopoietic system of **raw material supply + synthesis assistance + cell repair**, with excellent conditioning effects on iron deficiency anemia, postoperative qi-blood loss and sub-health physical weakness, distinguishing it from ordinary single blood-nourishing nutrients.

7. Neuroprotection and Cognitive Improvement Function

Spirulina water-soluble chlorophyll possesses excellent blood-brain barrier crossing and neuroprotective capabilities. It can assist in penetrating the blood-brain barrier and target the central nervous system to realize cognitive empowerment through dual mechanisms of antioxidation and anti-inflammation. On the one hand, chlorophyll efficiently eliminates free radicals in brain tissue, inhibits neuronal lipid peroxidation damage, reduces neuronal apoptosis, stabilizes neuronal structure and activity, and delays brain nerve aging; on the other hand, it significantly inhibits the release of central inflammatory factors (TNF-α, IL-6), relieves chronic neuroinflammation, and avoids memory decline, slow thinking and inattention caused by inflammation.

Meanwhile, chlorophyll improves cerebral microcirculation and increases blood oxygen supply to brain tissue. Cooperating with spirulina B-complex vitamins and high-quality amino acids, it facilitates the synthesis and steady regulation of neurotransmitters such as dopamine and norepinephrine, effectively improving concentration, memory and thinking clarity. It can ameliorate sub-health brain fatigue and mental overdraw, and exert good auxiliary intervention effects on middle-aged and elderly cognitive decline and mild memory loss, serving as a natural active ingredient for brain and nerve maintenance.

III. Unique Performances

1. Evolutionary Uniqueness of Primitive Organisms

As a prokaryote with a 3.5-billion-year evolutionary history, it has no cell nucleus or complex organelles and an extremely simple cell structure. Nutrients are not blocked by cell walls with extreme bioavailability, making it the most primitive efficient nutritional carrier on Earth. It tolerates high alkalinity (pH 9~11), high temperature and strong light. Its adaptability to extreme environments endows it with strong stress resistance, keeping the internal chlorophyll structure highly stable with extremely low activity loss during processing and storage, far superior to chlorophyll from terrestrial plants.

2. Uniqueness of Nutrient Concentration

It ranks first in nutrient density per unit volume among natural ingredients: **1g of Spirulina Powder is equivalent to the total vitamins and minerals of 10kg of fruits and vegetables**. Only 3g can meet the daily basic micronutrient needs of adults, with irreplaceable attributes as a "natural nutrient concentrate". It achieves dual high enrichment of protein and active substances simultaneously, reaching a high-activity ratio of over 60% high protein, over 10% phycocyanin, over 2% polysaccharides and over 0.5% highly active chlorophyll, integrating multi-dimensional nutrition and functions, different from raw materials with single protein or single chlorophyll supplementation.

3. High-Efficiency Uniqueness of Digestion and Absorption

Without crude fiber cell walls, it can be directly absorbed without complex digestion, efficiently utilized by people with weak gastrointestinal function, the elderly and infants with zero digestive burden and rapid energy supply. Iron, calcium, zinc and other minerals exist in biological coordination binding state, avoiding gastrointestinal irritation and absorption antagonism of inorganic minerals, with absorption capacity increased by 3~5 times. Meanwhile, the exclusive water-soluble chlorophyll of spirulina breaks the shortcomings of terrestrial plant chlorophyll such as liposolubility, poor absorption and easy gastrointestinal irritation, which can be directly dissolved in body fluids for absorption and suitable for people of all age groups.

4. Systematic Uniqueness of Functional Synergy

It features six-dimensional synergy of **nutrition-immunity-antioxidation-metabolic regulation-detoxification & repair-neuroprotection**, rather than simple superposition of single functions: full nutrition lays a foundation; phycocyanin, SOD and chlorophyll exert triple antioxidation and anti-inflammation to repair cell damage; immune regulation strengthens body defense; metabolic regulation maintains physical homeostasis; chlorophyll specially supports mucosal repair, hematopoiesis & detoxification, neuroprotection and cognitive improvement, comprehensively upgrading physical health level.

All active substances coexist naturally and enhance each other’s efficacy, superior to artificially compounded nutritional supplements. It is natural and safe without side effects, causing no liver and kidney burden after long-term consumption, suitable for all age groups (infants, pregnant women, the elderly), different from synthetic nutrients and drugs.

5. Broad-Spectrum Uniqueness of Application Adaptability

- **Food Grade**:
  Nutritional fortification (grains, dairy products, beverages), functional foods (tablets, powder), natural pigments (compound natural coloring with phycocyanin and chlorophyll).
- **Feed Grade**:
  Aquaculture (shrimp, crab, fry), livestock and poultry breeding. Relying on the antioxidation and immunity-enhancing effects of chlorophyll, it promotes growth, improves immunity and optimizes meat color and luster.

- **Pharmaceutical Grade**:
  Preparations for adjuvant conditioning of anti-radiation, anemia, low immunity and chronic diseases. It utilizes the core efficacy of chlorophyll in hematopoiesis, detoxification and mucosal repair to strengthen clinical auxiliary conditioning value.
- **Daily Chemical Grade**:
  Raw materials for antioxidant, anti-inflammatory and whitening skin care products. Chlorophyll can eliminate skin free radicals, repair skin barriers and improve dullness and inflammation.

Ⅳ. Summary

The core value of **Spirulina Powder** lies in its uniqueness in four dimensions: efficient absorption brought by primitive biological structure, extreme concentration of full-nutrition spectrum, synergistic functions of multiple active substances, and broad-spectrum and safe application adaptability. As a landmark core active ingredient, natural water-soluble chlorophyll, with excellent efficacy in hematopoiesis and blood nourishment, detoxification and chelation, mucosal repair, antioxidation and anti-inflammation, neuroprotection and cognitive improvement, complements deeply with phycocyanin, spirulina polysaccharides and other components. It makes spirulina no longer a single nutritional supplement raw material, but a natural bioactive material integrating nutritional fortification, immunity enhancement, antioxidation, metabolic regulation, detoxification & anti-radiation, mucosal repair, qi-blood conditioning and brain maintenance, greatly enhancing its professional value and irreplaceability in the fields of big health, food innovation, biomedicine and daily chemicals.