Operation Guidelines for Spirulina Powder Addition Methods in Application Fields

1. General Provisions

1.1 Purpose

To standardize the **addition methods**, operating procedures, dosage standards and quality control requirements of **spirulina powder** in various foods, health foods, feeds and pet foods; to avoid problems such as active ingredient loss, uneven dispersion and abnormal color during production; to ensure stable finished product quality and compliance with standards; to meet production demands for nutritional fortification, natural coloring and functional upgrading of products; to unify standardized workshop operation procedures and reduce production quality risks.

1.2 Scope of Application

This guideline applies to edible spirulina powder raw materials derived from *Spirulina platensis* and *Spirulina maxima*. It covers the full range of production and processing scenarios including beverages, dairy products, baked foods, meat products, candies, frozen foods, condiments, health foods, feeds and pet foods. It is available for production operators, R&D technicians, quality inspectors and post training.

1.3 Referenced Standards

Formulated in accordance with **GB 2760-2024 National Food Safety Standard for Uses of Food Additives**, **GB/T 16919-2022 General Quality Standard for Edible Spirulina Powder**, *National Food Safety Standard for Health Food Raw Materials*, and **GB/T 17243-2025 Feed Spirulina Powder**. It is established by combining the physicochemical properties of spirulina powder and the production processes of various product categories.

2. Basic Properties of Spirulina Powder

The processing method, addition timing and maximum dosage of spirulina powder are determined by its own physicochemical and functional properties, which serve as the core prerequisite for standardized addition operations. The specific properties are as follows:

2.1 Physicochemical Properties

- **Solubility and Dispersibility**: Spirulina powder is slightly soluble in water and cannot be completely dissolved, only forming a uniform suspension. The dry powder

is fine and easy to disperse with excellent dry mixing compatibility; slight sedimentation may occur after long-term standing. Continuous low-speed stirring is required to maintain stability in liquid systems, making it suitable for processes such as dry powder blending, low-speed emulsification and low-temperature batching.

- **Thermal and Acid Stability**: It is heat-sensitive; temperatures above 60℃ easily cause inactivation of core nutrients such as phycocyanin and active polysaccharides, accompanied by darkening color. It has moderate acid resistance, maintaining good stability in neutral and weakly acidic systems at pH 4.0-7.5; flocculation, color precipitation and activity loss tend to occur in strongly acidic environments (pH < 4.0).
- **Basic Parameters**: High-grade edible spirulina powder contains **protein ≥55%**, **phycocyanin ≥5.0%**, and **moisture ≤7.0%**. The dry powder presents a dark blue-green color with no peculiar odor; its 1% aqueous solution forms a uniform blue-green suspension. Bulk density ranges from 0.35-0.55g/cm³ with moderate hygroscopicity, and it remains stable when sealed at room temperature.

2.2 Core Functional Properties

- **Nutritional Fortification**: Rich in high-quality plant protein, phycocyanin, multiple vitamins, minerals and algal polysaccharides. It can efficiently supplement dietary nutrition and meet product positioning and nutrition claim requirements for high protein and nutritional enhancement.
- **Natural Coloring**: As a natural plant colorant, it endows products with blue-green and dark green tones, replacing synthetic artificial pigments and conforming to the R&D trend of clean label and natural healthy products.
- **Bioactivity**: Possesses antioxidant effects, regulates body metabolism and optimizes intestinal flora. It can enhance product functionality and is widely applied in functional foods, health foods and high-end pet foods.
- **Process Adaptability**: Can be compounded with conventional raw materials such as starch, sugar alcohols, milk powder and dietary fiber. It is incompatible with high temperature, strong acid-alkali and high shear processes, and suitable for production scenarios including low-temperature processing, dry powder mixing and normal-temperature batching.

2.3 Safety and Compliance Requirements

Spirulina powder is an officially approved common food raw material, natural food colorant and feed raw material in China, complying with GB 2760-2024 and national standard specifications for raw material application. It can be added in appropriate amounts according to production needs for all common foods. Health foods, complementary foods for infants and feed products shall strictly follow the national standard limits for corresponding categories. The recommended daily human intake is 3-5g; health foods must clearly mark the daily intake limit to avoid excessive consumption.

3. General Specification for Addition Processes

The following general operation specifications shall be followed for adding spirulina powder to all product categories to prevent quality defects such as activity loss, uneven dispersion, abnormal color and sedimentation stratification.

3.1 Pretreatment and Dispersion Methods

● **Dry Powder Pre-mixing Method**:

Applicable to all solid products (solid beverages, meal replacement powder, baking powder materials, tablet candies, pellet feeds, etc.).

Operation Key Points: Pre-mix and dilute spirulina powder with carrier dry powder such as maltodextrin, flour, sugar alcohols and milk powder at a ratio of 1:5, stir at low speed for 5-10 minutes until fully dispersed without agglomeration, then add to the main material mixing process to completely solve dry powder agglomeration and uneven dispersion.

●**Normal-temperature Suspension Preparation Method**:

Applicable to liquid and emulsified products (beverages, dairy products, sauces, oral liquids, etc.).

Operation Key Points: Use normal-temperature softened water (20-35℃, hot water is strictly prohibited), feed raw materials and water at a ratio of 1:10-15, stir at low speed (300-500r/min) for 15-20 minutes to form a uniform and stable suspension without filtration. Put into production within 30 minutes after preparation to avoid sedimentation from prolonged standing.

●**Compounding Taboo Principle**:

Prioritize compounding with vitamins, dietary fiber and sugar alcohols to improve nutrition and stability. Direct mixing with strong oxidants, strong acid and strong alkali raw materials is strictly prohibited. All high-temperature processing procedures shall be completed before adding spirulina powder to retain active ingredients to the maximum extent.

3.2 General Key Points of Addition Procedures

●**Addition Timing**:

The core principle is **post-stage addition at low temperature** and avoiding prolonged heating at high temperature. For thermally processed products, add after cooling down to below 40℃ upon completion of sterilization, boiling, baking and steaming processes.

●**Stirring Requirements**:

Stir solid systems until no visible green agglomerated particles remain; maintain full-process low-speed stirring (300-800r/min) for liquid systems. High shear homogenization

is forbidden to prevent algal cell rupture, color darkening and activity loss.

●**Dosing Requirements**:

Use high-precision electronic scales and micro-dosing equipment for feeding. For micro-coloring products, accurately control the dosage to ensure consistent batch uniformity of product color and nutritional indicators.

3.3 General Quality Control Standards

●**Dispersibility**:

No green caking or local color difference in solid products; uniform suspension without obvious stratification, sediment or flocculent particles in liquid products.

●**Sensory Requirements**:

Finished products have no algal fishy odor or peculiar smell, uniform and natural color without blackening, yellowing or local color abnormality.

●**Nutrition Control**:

Indicators such as protein and phycocyanin of finished products comply with formula design and national standards; nutrition label labeling is true and compliant, and functional claims are well-founded.

4. Category-Specific Addition Process Guidance

Clarify the exclusive dosage, procedures, operation key points and functional objectives of spirulina powder based on the process characteristics and formula systems of various product categories, so as to realize standardized operational implementation.

4.1 Beverages (Liquid Beverages & Solid Beverages)

4.1.1 Applicable Products

Functional beverages, plant beverages, liquid meal replacement beverages, solid meal replacement powder, solid functional instant powder, fruit and vegetable beverages, etc.

4.1.2 Dosage：

●Liquid beverages: **0.1%-1.5%** (mainly for coloring), **1.5%-3%** (mainly for nutritional fortification);

●Solid beverages: **2%-8%** (based on total formula mass).

4.1.3 Addition Procedures & Operation Key Points

- **Liquid Beverages**:

Cool finished products down to below 35℃ and enter the post-batching stage. Pour the prepared spirulina suspension into the batching tank, mix slowly with auxiliary materials such as sweeteners, vitamins and fruit and vegetable juice for 10 minutes. Homogenization is unnecessary throughout the process. Conduct rapid low-temperature pasteurization (≤60℃) or aseptic filling after batching to prevent high temperature damage to activity and color. Adjust the system pH to above 4.0 in advance for acidic fruit and vegetable beverages to avoid flocculation and discoloration.

- **Solid Beverages**:

  Add during the dry powder pre-mixing process. Pre-dilute spirulina powder with carriers such as maltodextrin, fructooligosaccharides and fruit/vegetable powder, then mix fully with other raw materials, followed by granulation, low-temperature drying (air inlet temperature ≤50℃) and packaging, ensuring uniform suspension without sediment or caking after reconstitution.

4.1.4 Functional Objectives & Notes

- **Functional Objectives**:

  Fortify nutritional components such as plant protein and phycocyanin, create natural green beverages, replace artificial pigments, enhance product functionality and clean label attributes, and enrich taste layers.

- **Notes**:

  For carbonated beverages, add at low temperature only after completion of aeration and sterilization to avoid bubble loss and color damage. Finished liquid beverages shall be stored away from light to prevent color fading and degradation of active ingredients caused by long-term light exposure.

4.2 Dairy Products (Liquid Milk, Yogurt, Milk Powder, Plant-based Milk)

4.2.1 Applicable Products

Flavored modified milk, low-temperature fermented yogurt, yogurt drinks, middle-aged and elderly nutritional milk powder, soybean plant-based milk, meal replacement milk powder, etc.

4.2.2 Dosage

0.2%-2.5% (based on total formula mass).

4.2.3 Addition Procedures & Operation Key Points

- **Liquid Milk / Plant-based Milk**:

  After milk source sterilization and homogenization, cool down to 30-40℃ for batching. Add the pre-mixed spirulina suspension, stir evenly at low speed and perform

aseptic filling to prevent phycocyanin inactivation and emulsion graying caused by high-temperature sterilization.

- **Fermented Yogurt**:

  Adopt unified **post-fermentation addition process**. Add spirulina suspension after yogurt fermentation maturation and cooling to below 35℃, stir gently for mixing. High-temperature feeding before fermentation is strictly prohibited to avoid inhibiting probiotic activity and affecting fermentation acidity and curd state.

- **Milk Powder Products**:

  Add via low-temperature dry mixing at the dry powder blending stage after spray drying. Pre-mix fully with milk powder and nutritional fortifiers under normal temperature operation throughout the process to protect heat-sensitive nutrients.

4.2.4 Functional Objectives & Notes

- **Functional Objectives**:

  Supplement high-quality plant protein and active polysaccharides, regulate intestinal metabolism synergistically with probiotics, endow dairy products with a natural cyan-green appearance, and improve nutritional added value and differentiated competitiveness.

- **Notes**:

  When the addition amount exceeds 2%, compound a small amount of pectin stabilizer to prevent slight stratification in the dairy system. Control the operating temperature ≤40℃ throughout the process to avoid slight algal fishy odor generated by high temperature.

4.3 Baked Foods (Bread, Pastries, Biscuits, Multigrain Pasta)

4.3.1 Applicable Products

Multigrain bread, soft pastries, crisp biscuits, steamed buns, dried noodles, baked meal replacement snacks, etc.

4.3.2 Dosage

0.3%-3.0% (based on total flour mass); can be increased to **3%-5%** for products focusing on nutritional fortification.

4.3.3 Addition Procedures & Operation Key Points

- **Bread / Pastries**:

  Add at the dry powder pretreatment stage. Pre-mix spirulina powder fully with flour, multigrain powder, yeast and other dry raw materials, then add water, egg liquid and oil for dough kneading with kneading temperature controlled ≤30℃. Maintain original fermentation and proofing processes; cool finished products naturally after baking to reduce continuous damage of high temperature to active ingredients.

- **Biscuits / Dried Noodles**:

  Add uniformly at the powder dry mixing stage. After even pre-mixing, proceed with dough kneading, tabletting, forming and drying. Control drying temperature ≤55℃ for dried noodles and cool biscuits rapidly after baking to retain nutrients to the maximum extent.

4.3.4 Functional Objectives & Notes

- **Functional Objectives**:

  Optimize the nutritional structure of baked products, supplement plant protein and trace elements, endow products with a natural multigrain green appearance, enhance health attributes, and slightly improve dough water retention.

- **Notes**:

  Appropriately reduce the dosage when baking temperature exceeds 190℃ to avoid product blackening and slight peculiar odor caused by high temperature. Adjust formula water volume slightly for high-dosage products to prevent dry dough and poor moldability.

4.4 Meat Products (Sausages, Meat Balls, Prepared Fillings)

4.4.1 Applicable Products

Low-temperature steamed sausages, meat balls, quick-frozen prepared meat fillings, pre-made dish fillings, casual meat jerky, etc.

4.4.2 Dosage

0.5%-2.0% (based on total meat emulsion mass).

4.4.3 Addition Procedures & Operation Key Points

Add spirulina powder uniformly in the late stage of low-temperature chopping for meat products. After completion of basic chopping and system formation of meat emulsion, slowly add the normal-temperature prepared spirulina suspension into the chopper, conduct low-temperature (≤10℃) and low-speed chopping for 3-5 minutes to fully blend with meat emulsion, water retention agents and spices, followed by casing filling, forming and low-temperature steaming procedures.

4.4.4 Functional Objectives & Notes

- **Functional Objectives**:

  Optimize the nutritional ratio of meat products, balance the high-fat and high-protein structure of meat, slightly improve product water retention, enrich product categories, and develop functional prepared meat products.

- **Notes**:
  High-temperature chopping and early feeding during high-temperature steaming are strictly prohibited to prevent active ingredient failure and color darkening of meat products. Strictly control the dosage; excessive addition easily causes algal fishy odor and affects the original flavor of meat products.

4.5 Candies & Jellies (Gummy Candies, Hard Candies, Gel Jellies)

4.5.1 Applicable Products

Gel gummy candies, low-sugar hard candies, pectin jellies, functional meal replacement gummies, etc.

4.5.2 Dosage

Hard candies: **0.1%-0.8%**;

Gummy candies / Jellies: **0.5%-2.0%** (based on total formula mass).

4.5.3 Addition Procedures & Operation Key Points

Adopt unified low-temperature addition after sugar boiling and forming: After completion of sugar boiling and melting for hard candies and gummies, cool down to below 40℃, add spirulina suspension, stir evenly at low speed and cool rapidly for forming. For jellies, feed and mix after cooling to 35-40℃ upon completion of colloid boiling and sterilization, then conduct filling and condensation.

4.5.4 Functional Objectives & Notes

- **Functional Objectives**:
  Replace artificial pigments, endow candies and jellies with natural cyan-green color, strengthen nutritional attributes, and develop low-sugar, natural and functional leisure foods.
- **Notes**:
  Feeding during the high-temperature sugar boiling stage is strictly prohibited; high temperature will cause spirulina coking, color blackening and peculiar odor generation. Adjust the system pH ≥4.0 for acidic jellies to avoid flocculation stratification and uneven color.

4.6 Frozen Foods (Ice Cream, Frozen Pasta)

4.6.1 Applicable Products

Fancy ice cream, low-temperature ice products, frozen multigrain dough, quick-frozen snacks, etc.

4.6.2 Dosage

0.2%-1.5% (based on total formula mass).

4.6.3 Addition Procedures & Operation Key Points

- **Ice Cream / Ice Products**: After batching sterilization and homogenization, cool down to below 30℃, add spirulina suspension and stir evenly, then proceed with aging, freezing and filling under full low-temperature operation.
- **Frozen Pasta**: Add at the dry powder pre-mixing stage, mix evenly with powder materials for dough kneading and forming, then conduct rapid low-temperature freezing to reduce damage of ice crystals to nutritional ingredients.

4.6.4 Functional Objectives & Notes

- **Functional Objectives**: Enrich the color and nutrition of frozen foods, improve product taste, enhance natural health attributes, and align with the positioning of high-end low-temperature leisure foods.
- **Notes**: Store finished products at a constant temperature of -18℃ throughout the process; avoid repeated freezing and thawing leading to system stratification, color fading and nutrition loss.

4.7 Condiments (Sauces, Compound Soup Base)

4.7.1 Applicable Products

Compound salad dressing, fruit and vegetable condiment sauce, solid compound soup base, functional seasoning powder, etc.

4.7.2 Dosage

0.5%-2.5% (based on total formula mass).

4.7.3 Addition Procedures & Operation Key Points

For sauce products, feed after cooling to below 40℃ upon completion of emulsification and boiling, conduct low-speed emulsification stirring for 8-10 minutes to ensure uniform color. For solid soup base and seasoning powder, adopt dry powder pre-mixing process, mix fully with salt, spices and auxiliary materials evenly before packaging.

4.7.4 Functional Objectives & Notes

- **Functional Objectives**:

  Optimize the appearance and color of condiments, enrich nutritional dimensions, develop functional compound condiments, and enhance product differentiated advantages.

- **Notes**:
  Early feeding is prohibited for fermented condiments; only low-temperature addition at the finished product blending stage is allowed to avoid interfering with the microbial fermentation process.

4.8 Health Foods (Tablets, Instant Granules, Oral Liquids, Capsules)

4.8.1 Applicable Products

Spirulina nutritional tablets, dietary fiber instant granules, antioxidant oral liquids, intestinal care capsules and other health foods.

4.8.2 Dosage

5%-50% (based on total formula mass); the total daily human consumption of finished products is strictly controlled at 3-5g, with a maximum limit not exceeding 8g.

4.8.3 Addition Procedures & Operation Key Points

- **Tablets / Capsules**:
  Add at the dry powder pre-mixing stage. Pre-mix spirulina powder fully with auxiliary materials such as microcrystalline cellulose and magnesium stearate, conduct low-temperature granulation and drying (temperature ≤45℃), then complete tabletting and capsule filling to ensure qualified tablet moldability and disintegration time limit.
- **Instant Granules / Oral Liquids**:
  Follow the dry mixing process of solid beverages for instant granules; prepare oral liquids via low-temperature batching (≤35℃), conduct sterile filtration, low-speed homogenization and aseptic filling after suspension preparation to retain bioactivity to the maximum extent.

4.8.4 Functional Objectives & Notes

- **Functional Objectives**:
  Supplement high-quality plant protein, phycocyanin and trace elements, exert health benefits including antioxidation, intestinal regulation and auxiliary metabolism, and fit the positioning of dietary supplement and physical conditioning health foods.
- **Notes**:
  Strictly comply with national standard limits for health foods and accurately control feeding dosage and daily intake. Adopt full-process low-temperature operation for all procedures to prohibit high temperature damage to core health active ingredients; fully label nutritional components and intake limits on finished products.

4.9 Feeds & Pet Foods (Pellet Feeds, Pet Wet & Dry Food)

4.9.1 Applicable Products

Livestock and poultry breeding pellet feeds, aquatic feeds, pet dry food, pet wet food, functional pet snacks.

4.9.2 Dosage

1%-8% (based on total formula mass); can be increased to **8%-10%** for functional health feeds.

4.9.3 Addition Procedures & Operation Key Points

- **Pellet Feeds / Pet Dry Food**:
  Add at the dry powder pre-mixing stage, mix fully evenly with raw materials such as corn flour, soybean meal and nutritional additives, then proceed with extrusion puffing and low-temperature drying forming to improve pellet adhesion.
- **Pet Wet Food**:
  Add after batching cooling, mix spirulina suspension evenly with meat raw materials and fruit/vegetable auxiliary materials, then conduct low-temperature sterilization and filling sealing.

4.9.4 Functional Objectives & Notes

- **Functional Objectives**:
  Improve the nutritional level of livestock, poultry and pet feeds, enhance body antioxidant capacity, optimize intestinal digestion and absorption, reduce breeding stress response, and improve pet hair condition and body immunity.
- **Notes**:
  Control the puffing temperature of puffed feeds to avoid nutrition loss caused by high temperature. Strictly control the dosage; excessive addition easily affects the palatability of feeds and pet foods.

5. Common Problems and Solutions (Production Practical Guarantee)

Summarize high-frequency quality problems in the mass production of spirulina powder, accurately locate causes and provide standardized solutions to fully guarantee production stability.

Common Problems	Causes	Solutions
Dry powder agglomeration, uneven dispersion and local color difference of products	No pre-dilution in advance with direct feeding; excessively low stirring speed and insufficient stirring time	Pre-dilute all dry powder systems with carriers in advance; extend stirring time until no particle agglomeration in solid systems, and maintain full-process low-speed stabilizing stirring in liquid systems
Darkening, blackening and fading of finished product color	Excessively high feeding temperature, no cooling in the later stage of high-temperature procedures; finished products stored under light; unbalanced system pH	Strictly implement low-temperature post-stage feeding process with operating temperature ≤40℃; store finished products sealed away from light; adjust system pH to the stable range of 4.0-7.5
Stratification, sedimentation and flocculation of liquid products	Spirulina is only suspendable but not soluble in water; excessively long standing time; excessive acidity; no compound stabilizers	Conduct rapid filling after batching to shorten standing time; adjust system pH; compound stabilizers such as pectin and xanthan gum to improve suspension stability
Algal fishy odor and peculiar odor in finished products	Excessively high dosage; oxidative deterioration under high temperature; substandard raw material quality	Strictly control the standard dosage of each category; adopt full-process low-temperature operation to prevent oxidation; select high-quality edible spirulina powder complying with GB/T 16919-2022
Substandard nutritional indicators and inconsistent claims of finished products	Measurement deviation; active ingredient loss caused by high temperature; uneven feeding	Calibrate measuring equipment regularly for accurate feeding; unify low-temperature operation standards; strengthen pre-mixing process control to ensure mixing uniformity and test nutritional indicators before factory delivery

6. Storage and Transportation Requirements

6.1 Storage Requirements

- Store sealed spirulina powder raw materials in a cool, dry, dark and ventilated warehouse with storage temperature ≤25℃ and relative humidity ≤60%. Exposure to sunlight, high temperature and humid environments are strictly prohibited.
- Store raw materials independently and isolate from toxic, harmful, odorous and corrosive materials to avoid pollution and odor cross-contamination. Stacking height shall not exceed 8 layers to prevent extrusion caking and damage.
- The sealed shelf life of national standard high-quality spirulina powder is 24 months. Vacuum seal after opening and use up within 7 days; long-term open placement easily causes moisture absorption, oxidation and activity loss. Expired raw materials are prohibited from production application.

6.2 Transportation Requirements

- Keep away from light, rain and moisture during full transportation; prevent raw material moisture absorption caking and oxidative deterioration caused by damaged packaging.
- Transportation vehicles must be clean, dry, odorless and pollution-free; mixed transportation with toxic, harmful, corrosive and odorous goods is strictly prohibited.
- Handle loading and unloading gently to avoid violent impact and packaging extrusion. Damaged raw materials are prohibited from warehouse storage and production use.

7. Operation Safety Requirements

- Operators must wear work clothes, dust-proof masks, gloves and work caps on duty to prevent inhalation of spirulina dry powder dust and avoid long-term direct skin contact with dust.
- Maintain good workshop ventilation during batching and pre-mixing procedures to reduce dust flying and accumulation, and prevent potential dust static hazards.
- Strictly abide by equipment operation specifications when operating high-temperature equipment and filling equipment, and take protection against scalds and mechanical injuries.
- Dispose of production waste, expired raw materials and discarded packaging by classification in accordance with environmental protection regulations; random dumping is prohibited to avoid environmental pollution.
- Operators shall receive regular process and safety training. Stop production and report immediately in case of equipment failure, abnormal raw materials or unqualified finished product quality; illegal operation is forbidden.