Operating Guide for the Application Methods of D-Allulose in Food Products

I. General Provisions

1.1 Basic Information

D-Allulose is a hexoketose and an epimer of fructose, naturally present in trace amounts in plants such as figs, kiwifruit, and wheat.

- **CAS No.:** 551-68-8
- **Sweetness:** Approximately 70% of sucrose
- **Caloric value:** 1.67 kJ/g (about 10% of sucrose)
- **Solubility:** Highly soluble in water (solubility ≥ 250 g/100 mL at 25°C), forming a clear, sediment-free aqueous solution
- **Key properties**: Undergoes Maillard reaction and browning; provides texture, water retention, and freezing point adjustment similar to sucrose; does not raise blood glucose or participate in insulin metabolism

1.2 Authoritative Compliance Basis

- **China:**

Announcement No. 4 of 2025 by the National Health Commission, approving D-allulose as a new food raw material applicable to 20 food categories, with a daily intake limit of ≤ 20 g per person.

- **International:**

Approved for food use by the U.S. FDA (GRAS certification), Canada, Australia/New Zealand, Japan, and South Korea.

- **Unsuitable populations:**

Infants and young children, pregnant women, and lactating women (insufficient safety data).

1.3 Operating Principles

1. **Compliance first**: Strictly follow GB 2760 and the new food raw material announcement to control addition levels and applicable scopes.
2. **Property matching**: Match processes according to D-allulose's sweetness, thermal stability, Maillard reactivity, and freezing point regulation characteristics.
3. **Gradual testing**: Start with 5%–20% sucrose replacement, verified through lab trials → pilot trials → mass production.
4. **Total intake control**: Per capita daily intake ≤ 20 g in single products and composite diets.
5. **Labeling standardization**: Label "D-Allulose" and indicate unsuitable populations + daily intake limit.

II. Physicochemical Properties and Basic Addition Parameters

2.1 Key Physicochemical Parameters

- Sweetness equivalence: 1.0 g D-allulose ≈ 0.7 g sucrose; formulation replacement is calculated at a ratio of 1:1.2–1:1.4.
- Thermal stability: Stable below 180°C, rapidly decomposes at 200°C; recommended baking temperature ≤ 180°C to avoid scorching.
- Maillard reaction rate: 1.5–2 times that of sucrose, with rapid browning; recommended temperature reduction of 10–20°C during baking.
- Freezing point depression: Equivalent to sucrose; inhibits ice crystal formation and provides smooth texture in ice cream.
- D-allulose significantly reduces water activity, helping extend product shelf life and inhibit microbial growth.
- Stable in the pH range of 4.0–8.0, compatible with most systems including beverages, dairy products, and baked goods.

2.2 Basic Addition Methods

1. **Direct dry powder addition**: Suitable for baking, tableting, and solid beverages; sifted through 80–100 mesh and premixed evenly with other powders.
2. **Aqueous solution addition**: Prepared as 50%–70% syrup (dissolved with stirring at 60–80°C) for use in beverages, dairy products, and fillings.
3. **Compound addition**: Blended with erythritol, steviol glycosides, or mogrosides to achieve sweetness synergy and cost optimization.
4. **Stepwise addition**: Added in two stages during baking (dough + surface) to enhance flavor and color.

III. Addition Methods in Various Food Categories

3.1 Beverages (Carbonated / Fruit Juice / Protein / Functional Drinks)

3.1.1 Scope of Application

Carbonated drinks, fruit juice drinks, plant protein drinks, sports drinks, and flavored water.

3.1.2 Addition Level and Method

- Addition range: 0.5%–3.0% (w/w), replacing 10%–100% of sucrose.
- Operating procedure: First dissolve D-allulose in purified water at 60–80°C with stirring to form a 60% syrup, filtered through 10 μm; then sequentially mix with acidulants (citric acid / malic acid), stabilizers, and flavors to avoid localized high-concentration agglomeration; adjust pH to 4.0–6.5, homogenize at 15–20 MPa, degas, and sterilize via UHT at 135°C for 3–5 seconds; carbonated drinks must be cooled below 4°C before carbonation to prevent sweetness loss.

3.1.3 Process Points

- In high-acid systems (pH < 3.8), reduce heating temperature and duration to minimize decomposition.
- In protein drinks, D-allulose should be added simultaneously with sugars and emulsifiers to prevent protein aggregation.
- Flavor is close to sucrose at a replacement ratio ≤ 50%; for 100% replacement, 5%–10% erythritol may be blended to improve mouthfeel.

3.2 Baked Products (Bread / Cake / Biscuit / Pastry)

3.2.1 Scope of Application

Bread, cakes, cookies, shortbread, mooncakes, and Chinese pastries.

3.2.2 Addition Level and Method

- Addition range: 1%–10% (based on flour dry weight), replacing 30%–100% of sucrose.
- Operating procedure: Sift D-allulose powder through 100 mesh, dry-mix with flour, salt, and leavening agents for 5–8 minutes until uniform; add fat, egg liquid, and water in portions, controlling dough temperature at 26–28°C; extend fermentation / proofing time by 10%–20%; reduce baking temperature by 10–20°C and shorten time by 5%–10% to prevent excessive browning; surface may be sprayed or brushed with 50% D-allulose syrup to enhance color and gloss.

3.2.3 Process Points

- Strong Maillard reactivity leads to rapid browning; monitor color throughout production and cover with aluminum foil if necessary.
- Excellent water retention improves product softness and extends shelf life.
- For high-sugar formulations (> 20% sugar), recommended replacement ratio ≤ 70%, blended with 30% sucrose / erythritol to avoid soft texture.

3.3 Frozen Foods (Ice Cream / Popsicle / Smoothie / Frozen Desserts)

3.3.1 Scope of Application

Ice cream, popsicles, smoothies, frozen yogurt, and French frozen desserts.

3.3.2 Addition Level and Method

- Addition range: 3%–8% (total formula weight), replacing 50%–100% of sucrose.
- Operating procedure: Dry-mix D-allulose with milk powder, stabilizers, and emulsifiers evenly, then dissolve in water at 45–55°C; add cream and egg liquid, heat with stirring to 75–80°C for 15–20 seconds for sterilization; homogenize at 20–25 MPa, rapidly cool to ≤ 4°C, and age for at least 6 hours to increase viscosity and inhibit ice crystal formation; control overrun at 30%–50% during freezing, then fill and quick-freeze at −35°C.

3.3.3 Process Points

- Freezing point regulation equivalent to sucrose; minimizes large ice crystals for smooth and delicate texture.
- Low system viscosity requires aging time ≥ 6 hours or blending with 0.1%–0.2% guar gum / CMC.
- For 100% replacement in sugar-free formulations, 5%–10% polydextrose may be added to improve texture and fullness.

3.4 Confectionery and Chocolate (Hard Candy / Gummy / Chocolate / Chewing Gum)

3.4.1 Scope of Application

Hard candy, gummies, nougat, chocolate, sugar-free candy, and chewing gum base.

3.4.2 Addition Level and Method

- Addition range: 5%–50% (total formula weight), replacing 20%–100% of sucrose.

- Operating procedure: For hard candy, prepare D-allulose as 70% syrup and cook at 150–160°C, 10°C lower than sucrose; for gummies / jellies, dissolve simultaneously with pectin / gelatin, control pH at 3.5–5.0, and cooking temperature ≤ 120°C; for chocolate, mix and refine with cocoa butter and cocoa powder for at least 20 hours at 40–45°C with precise tempering; for cooling and forming, hard candy is rapidly cooled to 25°C, and gummies are left to set for 4–6 hours.

3.4.3 Process Points

- Low crystallinity prevents graining in hard candy, providing high transparency and stable shelf life.
- Low decomposition temperature; cooking must not exceed 170°C to avoid burnt bitterness and discoloration.
- For 100% replacement in sugar-free chocolate, 3%–5% milk powder may be blended to improve taste and flavor.

3.5 Dairy Products (Yogurt / Cheese / Milk Drink / Modified Milk)

3.5.1 Scope of Application

Fermented yogurt, modified milk, cream, cheese, and flavored milk drinks.

3.5.2 Addition Level and Method

- Addition range: 1%–5% (w/w), replacing 30%–80% of sucrose.
- Operating procedure: Dissolve D-allulose in raw milk / reconstituted milk at 40–50°C with stirring and filter; sterilize at 95°C for 5 minutes, cool to 42–43°C, and inoculate starter culture; extend yogurt fermentation time by 10%–15%, control final pH at 4.2–4.5; stirred yogurt should be gently stirred below 20°C to avoid breaking the curd.

3.5.3 Process Points

- Does not inhibit lactic acid bacteria activity, producing pure yogurt flavor with weak post-acidification.
- Improves texture, reduces whey separation, increases viscosity, and delivers smooth mouthfeel.
- For high-sugar replacement, recommended ratio ≤ 60%, blended with a small amount of steviol glycosides to balance sweetness and cost.

3.6 Other Foods (Jam / Filling / Convenience Food / Health Products)

3.6.1 Jam / Fruit Filling

- Addition level: 4%–12%, replacing 40%–100% of sucrose.

- Cooking temperature controlled at 105–110°C, duration shortened by 20%, pH maintained at 3.5–4.5.
- Finished product has high transparency, resistance to crystallization, and strong water retention.

3.6.2 Convenience Food / Seasoning

- Addition level: 0.5%–3%, used to improve flavor, mask off-notes, and reduce water activity.
- May be added directly as dry powder or as a mixed syrup; heating temperature not to exceed 150°C.

3.6.3 Special Diets / Health Products

- Addition level: 1%–4%, featuring glycemic control and low calories, suitable for blood-sugar management populations and sports nutrition foods.
- Mix evenly with vitamins and minerals; avoid high-temperature and high-pressure processing.

IV. Compound Technology Specifications

4.1 Common Compound Systems (Sweetness / Cost / Texture Optimization)

- D-Allulose + Erythritol (ratio 1:1 to 2:1)

Advantages: Sweetness close to sucrose, no aftertaste, complementary crystallinity; suitable for baking, confectionery, and solid beverages.

- D-Allulose + Steviol Glycosides / Mogrosides (ratio 10:1 to 20:1)

Advantages: High-intensity sweetness synergy, significant sugar reduction, cost reduction; suitable for beverages, ice cream, and sugar-free foods.

- D-Allulose + Polydextrose / Soluble Fiber (ratio 3:1 to 5:1)

Advantages: Full texture, enhanced dietary fiber, beneficial for intestinal health; suitable for yogurt, ice cream, baking, and health products.

4.2 Principles of Compound Addition

- Addition sequence: First dissolve D-allulose, then add high-intensity sweeteners, and finally add stabilizers and flavorings.
- High-intensity sweeteners used at ≤ 5% of total sweetness to avoid bitter or metallic tastes.
- Compounding requires gradient testing at 5%/10%/15% replacement levels, validated by sensory, physicochemical, and stability testing before use.

V. Quality Control and Safety Specifications

5.1 Raw Material Quality Standards (Purity ≥ 98%)

D-Allulose content ≥ 98.0 g/100 g; loss on drying ≤ 1.0%; residue on ignition ≤ 0.1%; heavy metals: Pb ≤ 1 mg/kg, As ≤ 0.3 mg/kg; microbiological limits: total plate count ≤ 100 CFU/g, coliforms negative.

5.2 Production Process Control

- Batching uses electronic scales for precise measurement, with error ≤ ±0.5%; dry powders are sieved and liquids filtered to remove impurities.
- Mixing ensures no agglomeration or segregation; sampling verifies uniformity with RSD ≤ 3%.
- Heating uses real-time temperature monitoring; overheating is prohibited, with baking temperature ≤ 180°C and candy cooking temperature ≤ 160°C.
- Cooling uses rapid cooling within ≤ 30 minutes to prevent recrystallization, discoloration, and flavor loss.

5.3 Finished Product Inspection and Storage

- Finished product inspection includes content, moisture, pH, color, flavor, microbiology, and daily intake calculation.
- Storage: Sealed, cool and dry environment below 25°C, relative humidity ≤ 65%, shelf life 12–24 months.
- Transportation: Protect from sunlight, moisture, and rain; strictly avoid mixed transport with toxic or hazardous substances.

VI. Common Problems and Solutions

- Problem: Premature browning and scorching in baking
  - ⊙ Cause: Fast Maillard reaction, high temperature
  - ⊙ Solution: Reduce temperature by 10–20°C, shorten time, cover with aluminum foil
- Problem: Ice crystals and rough texture in ice cream
  - ⊙ Cause: Low viscosity, insufficient aging

⊙ Solution: Aging ≥ 6 hours, blend with small amount of stabilizer

● Problem: Weak sweetness and poor aftertaste in beverages

⊙ Cause: Only 70% sweetness of sucrose, single use

⊙ Solution: Calculate at 1:1.2–1:1.4 ratio, blend with high-intensity sweeteners

● Problem: Sticky, non-crystallizing hard candy

⊙ Cause: Low crystallinity, insufficient cooking

⊙ Solution: Cook to 155–160°C, cool rapidly

● Problem: Gastrointestinal discomfort (bloating / diarrhea)

⊙ Cause: Excessive intake

⊙ Solution: Strictly limit to ≤ 20 g per day, gradually increase replacement ratio

VII. Labeling Specifications (Mandatory Requirements)

1. Clearly label “D-Allulose” in the ingredient list.
2. Include warning statement: “Unsuitable populations: Infants and young children, pregnant women, lactating women.”
3. Indicate consumption limit: “Daily intake ≤ 20 g.”
4. Declare energy in the nutrition facts table as 1.67 kJ/g.