Analysis of the Unique Properties of D-Allulose

Overview

- D-Allulose (D-Psicose, CAS: 551-68-8) is a naturally occurring rare hexoketose and the C-3 epimer of D-fructose.
- Approved as a Novel Food Ingredient by the National Health Commission of China in July 2025, it has also obtained US FDA GRAS certification and regulatory recognition in Japan, South Korea and other countries.
- With a pure taste close to sucrose, extremely low calorie content, zero glycemic index (GI), high thermal stability, Maillard reaction activity and multiple physiological functions, it has become an ideal new-generation functional sucrose substitute, with overall performance superior to traditional sugar substitutes.

I. Physicochemical Properties

1. Basic Chemical Information

- Chinese Name: D-阿洛酮糖
- English Name: D-Allulose / D-Psicose
- Molecular Formula: $C_6H_{12}O_6$
- Molecular Weight: 180.16
- Structure: Hexoketose, C-3 epimer of D-fructose
- Source: Naturally present in trace amounts in plants such as figs, raisins, kiwifruit and wheat; industrially produced by enzymatic conversion (fructose catalyzed by D-allulose 3-epimerase) or microbial fermentation (Escherichia coli AS10).

2. Organoleptic and Physical Properties

- Appearance: White crystalline powder, odorless
- Sweetness: 70% (relative to sucrose at 100%)
- Sweetness Quality: Pure sucrose-like taste, no bitterness, metallic taste or after-astringency, with a mild and delicate mouthfeel
- Solubility: Very soluble in water (solubility ≥ 300 g/100 mL at 25 °C), clear and transparent aqueous solution
- Melting Point: Approximately 96 °C
- Caloric Value: ≤ 0.39 kcal/g (1.67 kJ/g), only about 1/10 that of sucrose (4 kcal/g)

3. Stability (Processing Compatibility)

- Thermal Stability: Stable at high temperatures (180 °C+), resistant to baking, cooking and sterilization
- pH Stability: Stable at pH 3–9, suitable for acidic beverages and neutral foods

- Maillard Reaction: Strong reactivity; undergoes browning with proteins/amino acids to produce rich caramel aroma and antioxidant products
- Caramelization: Capable of caramelization with strong coloring power and natural golden color
- Non-hygroscopic / Low-hygroscopic: Not prone to moisture absorption at room temperature, facilitating production of powdered foods and compressed candies

II. Functional Characteristics

1. Metabolic Properties: Zero Metabolic Burden, No Blood Glucose Elevation

- GI ≈ 0: Almost no increase in blood glucose and no stimulation of insulin secretion
- Absorption Mechanism: Small amount passively absorbed in the small intestine; over 90% is unmetabolized and excreted intact in urine
- No Conversion to Fat: Does not participate in fat synthesis pathways
- Non-cariogenic: Cannot be fermented and utilized by oral microorganisms, producing no acid and no erosion of tooth enamel

2. Physiological Functions

(1) Blood Glucose Regulation (Core Glycemic Control)

- Inhibits intestinal α-glucosidase, delaying carbohydrate breakdown and reducing glucose absorption
- Improves insulin sensitivity and lowers postprandial blood glucose peaks and fluctuations
- Suitable for safe long-term consumption by people with diabetes, impaired glucose tolerance and those on glycemic control diets

(2) Anti-obesity and Lipid Metabolism Regulation

- Inhibits hepatic fatty acid synthase (FAS), reducing visceral and hepatic fat accumulation
- Promotes fat oxidation and breakdown, lowering serum triglycerides and total cholesterol
- Animal and clinical studies show long-term intake reduces body weight and body fat percentage

(3) Strong Antioxidation and Free Radical Scavenging

- Efficiently scavenges hydroxyl radicals (·OH), superoxide anions ($O_2^{-}\cdot$) and reactive oxygen species (ROS)
- Inhibits lipid peroxidation and protects cell membranes and DNA from oxidative damage
- Maillard reaction products further enhance system antioxidation and extend food shelf life

(4) Intestinal and Organ Protection

- Better intestinal tolerance than sugar alcohols (lower risk of diarrhea or flatulence)
- Neuroprotection: Inhibits 6-hydroxydopamine-induced apoptosis
- Reduces expression of high glucose-induced inflammatory factor (MCP-1)

III. Unique Performance (Core Competitive Advantages)

1. Taste: Natural Sweetness Closest to Sucrose

- Pure, clean and free of off-flavors, perfectly replacing sucrose flavor
- Solves pain points such as after-bitterness, cooling sensation and off-notes of erythritol, stevia, sucralose and others

2. Processing: Full-Scenario Adaptation and Comprehensive Performance

- Heat-, acid- and alkali-resistant: Suitable for baking, beverages, confectionery, canned goods and sterilized foods
- Dual Maillard and Caramelization Activity: Imparts golden color, rich roasted aroma and caramel flavor to foods
- Structure and Texture: Provides sucrose-like volume, sweetness, moisture retention, crispness/softness
- Non-crystallizing and Non-hygroscopic: Superior to sugar alcohols (e.g., xylitol and erythritol tend to crystallize)

3. Health: Functional Sugar Substitute Beyond "Zero Calories"

- Actively controls blood glucose, reduces fat and provides antioxidation, not merely "calorie-free"
- Natural origin, high human compatibility, safety verified by multiple national authorities
- Does not affect intestinal flora, non-cariogenic and does not elevate uric acid

4. Regulation and Safety (Authoritative Recognition)

- China (2025): Novel Food Ingredient, purity ≥ 98%, recommended daily intake ≤ 20 g; not suitable for infants, pregnant women and lactating women
- United States (2011/2019): FDA GRAS (GRN 495, 696); labeling: not counted in "total sugars/added sugars", calories calculated at 0.4 kcal/g
- Japan: Ingredient for Foods for Specified Health Uses (FOSHU)
- JECFA/EFSA: No identified risks in safety assessments
- Toxicology: LD_{50} > 16.3 g/kg bw (practically non-toxic)

IV. Authoritative Basis and Data Sources

- Announcement on 5 New Food Ingredients Including D-Allulose (No. 4 of 2025) by the National Health Commission of China
- US FDA GRAS Notice (GRN) 495, 696
- Food additive standards of the Ministry of Health, Labour and Welfare of Japan and MFDS of South Korea
- Safety assessment reports from JECFA and EFSA
- SCI clinical and mechanism studies including *Food and Chemical Toxicology*, *Carbohydrate Polymers*
- Authoritative popular science from Science Popularization China and Chinese Nutrition Society

V. Summary

D-Allulose is a new-generation natural functional rare sugar that achieves an all-round breakthrough combining pure sucrose-like taste, extremely low calories, zero GI, high processing stability and multiple health functions. Its overall performance surpasses traditional sugar substitutes, making it the gold-standard sweetener in the fields of glycemic control, fat reduction and healthy foods.