Industrial Development History of Mulberry Leaf Extract

I. Tribute Chapter

Mulberry leaf (*Morus alba* L., the dried leaf of deciduous trees belonging to the genus *Morus* in the Moraceae family, commonly known as winter mulberry leaf, frost mulberry leaf or immortal herb) is a classic hypoglycemic medicinal and edible raw material for six core global sectors: postprandial blood glucose regulation, liver-clearing and eye-protection, antioxidant skincare, intestinal health, antibiotic replacement for livestock and poultry feed, and traditional Chinese medicine API. It is a multi-functional polyhydroxyalkaloid raw material covering ten major fields: pre-Qin folk herbal tea, official materia medica compiled in the Han and Tang dynasties, traditional dietary therapy in Japan and South Korea, separation and identification of alkaloids in modern times, mechanistic analysis of DNJ hypoglycemic targets, low-temperature water/ethanol fractional purification, ultrafiltration membrane removal of polysaccharide and protein impurities, directional enrichment of alkaloids via macroporous resin, stable embedding with nanocapsules, and circular resource utilization of the whole mulberry plant.

It has undergone more than 2,000 years of documented records on the harvesting and processing of medicinal herbs, isolation and characterization of core markers including 1-deoxynojirimycin (DNJ), total mulberry leaf flavonoids and mulberry leaf polysaccharides, establishment of harvesting standards for frost leaves rich in active ingredients, low-temperature closed countercurrent extraction, membrane separation for macromolecular impurity removal, directional enrichment of DNJ with special resins, improvement of oral bioavailability through cyclodextrin embedding, and full iterative processing technology of fixation and temperature control for activity retention. It has formed six core application sectors: blood sugar control health food, natural functional herbal tea, soothing and whitening cosmetics, antibiotic-free premix feed for livestock and poultry, TCM compound APIs for hypoglycemia, and clean-label food additives. China has realized domestic mass production of high-purity DNJ monomers, standardized freeze-dried mulberry leaf flavonoid powder and water-soluble mulberry leaf polysaccharides, and built a globally graded compliance quality control system for raw materials covering dietary supplements, beverages, cosmetics, feed and pharmaceuticals, with research teams at home and abroad conducting in-depth research for over two thousand years.

We pay tribute to scholars and R&D teams worldwide who have achieved full-chain technological breakthroughs, including textual research on mulberry leaf efficacy in ancient materia medica classics, separation and characterization of DNJ monomers, formulation of national standards for HPLC-DNJ quantitative detection, low-temperature closed countercurrent extraction, removal of polysaccharide and protein impurities via ultrafiltration membranes, enrichment of alkaloids with macroporous resins, standardized harvesting and activity-locking technology for frost mulberry leaves, verification of the molecular pathway for α-glucosidase inhibitory hypoglycemic activity,

construction of domestic solvent-free green extraction production lines, and compliance registration in multiple countries and regions across the globe. In accordance with the principles of industrial competition and corporate privacy protection, no enterprise names are listed in this text; we also extend our tribute to all manufacturers that have realized technological innovation and full domestic industrial chain localization of mulberry leaf extract.

Tribute List

1. Milestone Scientists at Home and Abroad (in chronological order)

- ***Ancestors engaged in sericulture in the Pre-Qin Period (1200 BC – 200 BC, Yellow River and Yangtze River Basins)***

Originators of China's mulberry and silkworm civilization. The ancestors discovered that decocted frost mulberry leaves taken as tea relieved polyphagia, easy hunger, dry mouth and thirst wasting symptoms; fresh mulberry leaves applied externally alleviated red swollen eyes and skin sores. Their practices constitute the earliest recorded human use of mulberry leaves for food and medicine, laying the foundation for dietary therapy applications in East Asia.

- ***Physicians who compiled Shennong's Classic of Materia Medica (Western Han Dynasty, 200 BC – 8 AD)***

Mulberry leaves were officially recorded in canonical texts for the first time, listed as a medium-grade medicinal herb under the entry of mulberry root bark. The text states that "the leaf dispels cold-heat and induces sweating", establishing the basic medicinal positioning of mulberry leaves for dispersing wind-heat and arresting sweating, marking the world's earliest written record of mulberry leaves for medicinal use.

- ***Tao Hongjing (Southern and Northern Dynasties, 456 – 536 AD, China)***

Annotations on Materia Medica Classics standardized mulberry leaf harvesting, raw use and honey-frying processing specifications, distinguished efficacy differences between spring leaves and frost leaves, clarified that frost mulberry leaves exert stronger effects in moistening dryness and improving eyesight, and perfected the compatibility system for oral administration and external application.

- ***Su Jing and the official materia medica compilation team of the Tang Dynasty (659 AD, Newly Revised Materia Medica)***

The official pharmacopoeia records that concentrated decoction of mulberry leaves treats beriberi and edema and unblocks bowel and urination, expanding the application direction of mulberry leaves in metabolic regulation and establishing unified national medicinal herb harvesting standards for the Tang Dynasty.

- ***Chen Cangqi (Tang Dynasty, 713 – 741 AD, Supplement to Materia Medica)***

Records that oral fresh mulberry leaf juice relieves cholera abdominal pain, while external application stops bleeding and treats sword wounds, broadening folk application

scenarios of mulberry leaves for emergency treatment and skin repair.

- ***Physicians who compiled Materia Medica of Ri Hua Zi (Five Dynasties and Ten Kingdoms Period)***

Systematically documented that mulberry leaves nourish the five internal organs, unblock joints, descend qi and dissipate blood stasis, and that mulberry leaf decoction mixed with wine treats general bi syndrome caused by wind, improving the compound system of mulberry leaves for metabolism and rheumatism regulation.

- ***Li Shizhen (1596 AD, Ming Dynasty, China)***

Compendium of Materia Medica systematically summarized the core efficacies of mulberry leaves for consumptive fever cough, improving eyesight, promoting hair growth and quenching thirst wasting. It confirmed optimal harvesting after frost, standardized traditional processing technologies including water decoction, honey-frying and baking for toxicity reduction and activity retention, laying the core theoretical basis for later applications of mulberry leaves in blood sugar control and eye care.

- ***Kampo Physicians of the Edo Period (1600 – 1868 AD, Japan)***

Introduced Chinese herbal formulas using mulberry leaves for thirst wasting, developed folk dietary therapy formulas of mulberry leaf herbal tea, forming a synchronized East Asian tradition of applying mulberry leaves for blood sugar regulation.

- ***Research Team led by M. Yagi (1976, Japan)***

For the first time globally isolated the natural polyhydroxyalkaloid DNJ from mulberry root bark and named it moranoline, ushering in the era of modern chemical research on mulberry-derived hypoglycemic alkaloids.

- ***Asano Research Group (1994, Japan)***

First separated and purified six characteristic alkaloids including DNJ, N-Me-DNJ and fagomine from mulberry leaves, fully analyzed the alkaloid component system of mulberry leaves, and identified DNJ as the core hypoglycemic marker of mulberry leaves.

- ***Pharmacology Team led by Kimura (1995, Japan)***

Animal experiments verified that DNJ strongly inhibits α-glucosidase activity and significantly reduces postprandial blood glucose peaks, scientifically validating the traditional efficacy of mulberry leaves for quenching thirst wasting and bridging empirical records in materia medica with modern molecular pharmacology.

- ***Natural Products Research Group led by Kato (1997, Japan)***

Fully resolved the chemical molecular structure of DNJ, established the primary thin-layer chromatography qualitative and ultraviolet quantitative detection methods, and built the basic quality control framework for mulberry leaf alkaloids.

- ***Evidence-Based Clinical Teams from Japan and South Korea (2000 – 2010)***

Completed randomized controlled clinical trials on populations with impaired glucose tolerance and type 2 diabetes, confirming that standardized DNJ-containing mulberry leaf extract gently flattens postprandial blood glucose and reduces glycated hemoglobin, perfecting the human evidence chain for oral blood sugar regulation.

- ***Domestic R&D Group for Forest Chemical Extraction Technology (2000 – 2010, China)***

Independently developed pilot-scale processes of low-temperature countercurrent water extraction, ethanol gradient extraction and ultrafiltration membrane impurity removal, solving three major pain points of traditional high-temperature extraction: DNJ degradation, excessive polysaccharide and protein impurities, and easy browning of extracts.

- ***Expert Group for Formulating National Standard GB/T 40642 (2021, China)***

Formulated the national standard *Determination of 1-Deoxynojirimycin in Mulberry Leaf Extract – High Performance Liquid Chromatography*, unified national HPLC quantitative detection methods for DNJ, and filled the domestic gap in statutory detection of characteristic active components.

- ***R&D Team for Health Food Raw Material Standards (2024, China)***

Issued the group standard T/CNHFA 111.160—2024 *Raw Material Mulberry Leaf for Health Food*, specified minimum DNJ content limits for food-grade and health food-grade mulberry leaf extracts, and improved the domestic raw material grading and access system.

- ***Research Group for DNJ Purification via Macroporous Resin (2008 – 2016, China)***

Screened special neutral adsorption resins to realize directional enrichment of DNJ, raising the purity of crude DNJ from 0.2% to over 60%, and built large-scale mass production processes for resin purification.

- ***R&D Group for Supercritical CO_2 Extraction Technology (2010 – 2020, China)***

Realized industrial solvent-free low-temperature extraction of lipid-soluble flavonoids and plant sterols from mulberry leaves, suitable for raw material production of cosmetics and high-end oral preparations, and drastically reduced organic solvent residues.

- ***Expert Review Panel for EU Novel Food Ingredients (2018)***

Completed full toxicology, cumulative toxicity and human safety assessments of mulberry leaf extract, approved its filing as an EU novel food, and defined the safe daily oral dosage range for the EU market.

- ***Review Panel for Catalogue of Cosmetic Raw Materials in Use (2021, China)***

Included *Morus alba Leaf Extract* as an INCI cosmetic raw material, specified safe dosage limits for whitening and antioxidant skincare applications, and opened a compliance

channel for the cosmetics sector.

- ***Domestic R&D Team for Antibiotic Replacement in Feed (2018 – 2026, China)***

Developed low-irritation water-soluble premixes of mulberry leaf extract, completed full animal trials for livestock and poultry intestinal conditioning and stress reduction, matched national safety limit standards for feed raw materials, and expanded the antibiotic replacement sector for breeding.

- ***Research Team of Domestic Institute for Safety Evaluation of Natural Products (2026)***

Completed the formulation of full safety limit indicators for mulberry leaf extract used as raw materials in food, cosmetics, feed and pharmaceuticals, and established supporting national standard methods for simultaneous detection of DNJ, total flavonoids, heavy metals, microorganisms and solvent residues.

2. Overall Contributions of Core Research Teams

- ***Schools of Textual Research on Materia Medica across Chinese Dynasties:***

  Established a 2,000-year traditional processing system for frost mulberry leaves including harvesting, water decoction, honey-frying and baking; distinguished efficacy differences between spring leaves and frost leaves; preserved classic oral and external compound formulas for thirst wasting, eye disorders and skin sores; defined authentic mulberry production regions along the Yangtze River Basin, Sichuan, Zhejiang and Jiangsu provinces.

- ***R&D Communities for Traditional East Asian Dietary Therapy:***

  Developed mulberry leaf herbal tea and dietary preparations synchronously in China, Japan and South Korea, forming daily dietary therapy regimens tailored for Asian populations to regulate postprandial blood glucose and clear the liver for eye protection.

- ***Pioneering Teams of Natural Medicinal Chemistry in Japan:***

  First separated, characterized and resolved the molecular structure of DNJ, clarified the polyhydroxyalkaloid component system of mulberry leaves, and built primary basic technologies for alkaloid detection and purification.

- ***Schools of Modern Molecular Pharmacology Verification:***

  Gradually verified pathways of DNJ inhibiting α-glucosidase, flavonoids exerting antioxidant effects, and polysaccharides regulating intestinal flora via in vitro enzyme activity assays, animal models and multi-center human clinical trials, pioneering the core sector of natural postprandial blood glucose regulation.

- ***Domestic R&D Teams for Forest Chemical Extraction:***

  Independently developed full mass-production technologies including low-temperature closed countercurrent extraction, ultrafiltration membrane removal of polysaccharide and protein impurities, directional enrichment of DNJ via macroporous resin, supercritical solvent-free extraction, vacuum low-temperature freeze-drying and cyclodextrin stable embedding, solving industrial pain points of active ingredient degradation under high temperature, excessive impurities and storage browning.

- ***Global Standardization Teams for Pharmacopoeia and Regulations:***

  Promoted the inclusion of mulberry leaves in the Chinese Pharmacopoeia, Health Food Raw Material Catalogue, EU Novel Food Catalogue, Japanese Functional Food Raw Material List and Cosmetic Raw Material Catalogue, unblocking global import and export circulation channels.

- ***R&D Teams for Domestication of Native Mulberry Resources:***

  Relied on millions of mu of standardized mulberry orchards in Sichuan, Zhejiang and Guangxi provinces to breed superior protein mulberry cultivars with high DNJ content, and built a full industrial chain for standardized frost leaf harvesting, light-shielded and activity-locking storage and transportation.

- ***R&D Teams for National Standard Detection Systems:***

  Formulated the statutory HPLC DNJ detection national standard GB/T 40642 and group standards for health food raw materials, unifying grading, quality control and judgment criteria for mulberry leaf extract worldwide.

- ***Industrial R&D Teams for Six Major Sectors:***

  Developed graded customized raw materials targeting blood sugar control health food, natural herbal tea, whitening and antioxidant cosmetics, antibiotic-free feed for livestock and poultry, hypoglycemic TCM APIs and clean-label food additives, expanding diversified industrial application scenarios of mulberry leaf extract.

II. R&D History

1. Period of Primitive Traditional Folk Application and Basic Exploration (1200 BC – 1975)

1.1 1200 BC – 1975: Stage of crude processing and self-use via water decoction of fresh mulberry leaves

In China, Japan and South Korea, only wild mulberry leaves were harvested; frost leaves were picked, sun-dried, baked or honey-fried then decocted for herbal tea, while fresh leaves were mashed into juice for external application. Processing relied on manual sun-drying, open water boiling and simple natural sedimentation filtration, without

separation and purification or active ingredient stabilization technologies. The core hypoglycemic marker DNJ was prone to decomposition and loss during prolonged high-temperature decoction, and flavonoids underwent oxidative browning upon oxygen exposure. Macromolecular impurities including proteins, colloids and polysaccharides in mulberry leaves could not be removed. Only homemade mulberry leaf tea and decoctions circulated among the public; no standardized extracts were commercially available, and there existed no concept of quantitative quality control for active ingredients DNJ and total flavonoids. Physicians of successive dynasties accumulated basic safety insights: frost leaves possess superior quality, honey-fried leaves deliver milder effects, and prolonged decoction leads to attenuation of active ingredients.

1.2 R&D Objectives of This Stage

Develop fully closed controllable low-temperature countercurrent extraction, ultrafiltration membrane directional removal of macromolecular polysaccharide and protein impurities, graded directional enrichment of DNJ and flavonoids via special macroporous resins, supercritical solvent-free extraction of lipid-soluble components and cyclodextrin stable embedding technologies, to prepare standardized mulberry leaf extracts featuring high DNJ content, low impurities, storage resistance and anti-browning properties. Realize complete removal of macromolecular impurities while fully retaining heat-sensitive alkaloid and flavonoid activities; establish supporting front-end technologies including standardized harvesting of frost mulberry leaves and low-temperature closed transportation within 4 hours to lock active ingredients.

1.3 Core Conclusions

The core functional substance system of mulberry leaves consists of a ternary active complex: 1-deoxynojirimycin (DNJ, core marker for blood sugar control), total mulberry leaf flavonoids (markers for antioxidation, eye protection and skincare), and mulberry leaf polysaccharides (markers for intestinal conditioning and immune regulation). It exerts multiple effects including α-glucosidase inhibition, antioxidation, liver-clearing eyesight improvement, skin barrier repair and livestock intestinal regulation. High temperature, prolonged water extraction and open storage cause DNJ degradation and oxidative browning of flavonoids; crude products contain excessive impurities, poor storage stability and weak oral efficacy. Low-temperature closed fractional purification, directional resin enrichment and inert gas light-shielded stable embedding of mulberry leaf extracts have become core global R&D directions for the industry.

2. Period of DNJ Monomer Isolation and Maturation of Primary Extraction Technologies (1976 – 1999)

2.1 1976 – 1994: First isolation of DNJ and complete analysis of mulberry leaf alkaloid system

In 1976, Japan's Yagi team isolated DNJ from mulberry root bark and completed its naming. In 1994, the Asano team separated six characteristic polyhydroxyalkaloids from mulberry leaves and confirmed DNJ as the unique high-activity hypoglycemic component of mulberry leaves. During the same period, Japanese laboratories produced small batches of mulberry leaf extract via open water decoction and ethanol reflux crude extraction, with limited supply for Kampo hypoglycemic preparations. In China, only crude processing of folk mulberry leaf tea existed, lacking standardized purification capacity; high-purity DNJ monomers were fully dependent on imports.

2.2 1995 – 1999: Verification of DNJ hypoglycemic pharmacology and launch of primary purification technologies

Animal experiments by the Kimura team confirmed the potent blood sugar control mechanism of DNJ. Ethanol gradient extraction replaced traditional single water decoction, boosting flavonoid extraction efficiency by over 35%. Basic acute toxicity and skin irritation safety tests were completed, defining safe dosage ranges for oral and external use. Japan launched standardized mulberry leaf extract dietary supplement capsules, forming an initial East Asian market for mulberry leaf raw materials for blood sugar regulation. China possessed abundant mulberry orchard resources but lacked supporting systems for intensive extraction and active ingredient detection; only low-grade mulberry leaf tea was exported.

3. Period of Global Clinical Evidence-Based Research and Multi-National Regulatory Standardization (2000 – 2014)

3.1 2000 – 2010: Full-scale rollout of multi-center human clinical trials verifying blood sugar regulation efficacy

Summary of randomized double-blind controlled trials conducted in Japan, South Korea, Europe and America confirmed that oral administration of standardized high-DNJ mulberry leaf extract with meals significantly flattens postprandial blood glucose peaks, reduces glycated hemoglobin and improves insulin resistance. Mulberry leaf flavonoids and polysaccharides were simultaneously verified to exert antioxidant, skin-soothing and intestinal flora-regulating effects. Supporting in vitro and animal trials for food antioxidant additives, skin soothing and livestock intestinal conditioning were completed concurrently. Driven by surging global demand for metabolic health, natural skincare and antibiotic-free breeding, mulberry leaf extract became an essential multi-functional natural functional raw material.

3.2 2011 – 2014: Formation of the initial global four-tier raw material regulatory standard framework

Four tiers of mulberry leaf raw materials were preliminarily unified worldwide:

① Crude processed mulberry leaf powder / mulberry leaf tea (DNJ: 0.05%–0.2%, applied in condiments, low-end feed and bulk herbal tea);

② Low-temperature water-extracted concentrated juice (DNJ: 0.2%–0.5%, applied in general functional beverages and food antioxidant additives);

③ Resin-enriched freeze-dried powder (DNJ: 0.5%–5%, applied in blood sugar control health food, mild skincare and pet intestinal care);

④ High-purity DNJ monomer API (DNJ ≥98%, applied in pharmaceuticals, high-end medical aesthetics and clinical dietary intervention).

Japan completed filing of mulberry leaves as functional food raw materials; China initiated R&D on DNJ quantitative detection methods to fill national standard gaps.

4. Period of Independent Domestic Technological Substitution and Maturation of the Full Industrial Chain (2015 – 2026)

4.1 2015 – 2022: Comprehensive breakthroughs in domestic green extraction technologies, with local production lines matching imported Japanese and Korean raw materials

China independently constructed complete production lines for low-temperature closed countercurrent extraction, addressing four major drawbacks: DNJ degradation under high temperature, incomplete removal of polysaccharide and protein impurities, easy browning of extracts and poor powder storage stability. Supporting full technologies including supercritical CO_2 solvent-free extraction, low-temperature impurity removal via ultrafiltration membranes, graded directional enrichment of DNJ with special macroporous resins and vacuum low-temperature freeze-drying were launched simultaneously. Domestic products matched imported Japanese and Korean raw materials in DNJ content, solvent residues, browning degree and microbial indicators, while overall production costs decreased significantly. Complete domestic substitution was realized for mid-to-low-end standardized extracts, and domestic manufacturers gradually broke the import monopoly of high-purity DNJ monomers.

China built over 12 million mu of standardized contiguous protein mulberry and fruit mulberry planting bases, forming a closed-loop full industrial chain:

Manual harvesting of mulberry leaves during frost season → low-temperature light-shielded closed transportation within 4 hours → fixation, temperature-controlled activity locking, crushing and grading → low-temperature countercurrent water extraction / gradient ethanol extraction / supercritical extraction → ultrafiltration membrane removal of macromolecular polysaccharide and protein impurities → graded directional enrichment of DNJ and flavonoids via macroporous resin → vacuum low-temperature concentration / freeze-drying → inert gas cyclodextrin stable embedding → light-shielded low-temperature sterile warehousing.

GB/T 40642 was formally implemented in 2021, unifying the statutory HPLC-DNJ quantitative detection standard nationwide and equipping domestic enterprises with

complete independent testing capabilities.

4.2 2023 – 2026: Comprehensive iterative upgrading of customized products for six segmented sectors

The industry formed gradient layered customized products: food-grade mulberry leaf concentrated juice, low-impurity mulberry leaf tea powder, high-DNJ freeze-dried powder for blood sugar control health food, high-purity pharmaceutical-grade DNJ monomers, skin-soothing whitening extract liquid and antibiotic replacement premix feed for livestock and poultry. Low-temperature closed extraction and supercritical solvent-free green technologies gained full industry-wide popularity, drastically cutting organic solvent usage and three-waste emissions. China formulated supporting national standard methods for simultaneous HPLC quantitative detection of DNJ and total flavonoids. Cyclodextrin embedding technology improved the oral bioavailability of DNJ and resolved powder oxidative browning issues, compatible with full dosage forms including compressed candy, oral liquid, functional beverages, whitening facial masks, washing and care products, livestock and poultry pellets, and hypoglycemic TCM compound preparations. Driven by dual factors of consumption upgrading in metabolic health and national antibiotic ban policies for breeding, the global market for mulberry leaf extract continued to expand.

III. Commercialization Development History

1. Stage of Crude Mulberry Leaf Tea Production and Laboratory Micro-Scale Extraction (1200 BC – 1975)

Indigenous populations in China, Japan and South Korea only sun-dried and baked frost mulberry leaves to make homemade herbal tea and external preparations for personal use. Japanese laboratories only isolated trace DNJ for pharmacological research, without standardized commercial extracted raw materials. In China, only crude processing of mulberry leaf tea existed, with no industrial purification factories; no compliant standardized mulberry leaf extract products circulated in the market.

Industrial Characteristics: Lack of low-temperature closed countercurrent extraction, ultrafiltration membrane impurity removal, resin-based DNJ enrichment and stable embedding technologies; absence of globally unified grading and quality control standards for DNJ; the industrial sector for standardized mulberry leaf extracts was entirely non-existent.

2. Stage of Early Japanese Industrialization and Full Import Dependence on High-End Raw Materials in China (1976 – 1999)

2.1 1976 – 1989: Small-scale mass production of standardized raw materials in Japan

Water decoction and ethanol reflux crude extraction technologies matured, and Japan launched mulberry leaf capsules for blood sugar control dietary supplements. In 1999, global annual consumption of standardized mulberry leaf extract reached approximately 860 tons, with the market concentrated in Japanese Kampo pharmacies and natural dietary supplement brands. China only exported small quantities of crude mulberry leaf tea, lacking purification capacity for high-purity DNJ; standardized enriched extracts required by health food and pharmaceutical industries were fully imported.

2.2 1990 – 1999: Low-end domestic industry with exorbitantly priced imported high-purity raw materials

Japanese enterprises monopolized core purification technologies for DNJ separation and low-temperature activity locking. Imported high-DNJ freeze-dried powder and high-purity monomers carried sky-high unit prices, supplied only to high-end East Asian blood sugar control dietary supplements and hospital-grade skin-soothing skincare products. Domestic manufacturers lacked compliance qualifications for high-purity health food/pharmaceutical-grade raw materials, exporting only low-grade mulberry leaf powder and bulk tea with excessive polysaccharide, protein and solvent residues, which disqualified them from entry into the health food and pharmaceutical sectors.

Industrial Characteristics: Overseas enterprises mastered full core technologies for active ingredient purification, impurity removal and stabilization. China ranked first globally in scaled mulberry planting resources but lacked supporting systems for intensive industrial extraction and multi-index detection; domestic market awareness of graded standardized mulberry leaf extracts remained extremely low.

3. Stage of Formed Domestic Production Capacity and Rapid Expansion of Six Application Sectors (2000 – 2022)

Global demand simultaneously surged for natural blood sugar control dietary supplements, whitening and antioxidant skincare, clean-label food preservatives, antibiotic-free livestock feed, hypoglycemic TCM APIs and functional herbal tea, establishing mulberry leaf extract as an essential multi-functional natural functional raw material. Global annual consumption of all categories of raw materials exceeded 9,800 tons in 2022.

China fully rolled out six domestic application sectors: health food for postprandial blood sugar regulation, natural antioxidant food additives, soothing herbal tea, skin-soothing whitening cosmetics, intestinal antibiotic replacement feed for livestock and poultry, and APIs for hypoglycemic TCM compounds. In 2022, domestic standardized concentrated juice, mid-to-low DNJ freeze-dried powder and resin-enriched extracts achieved stable large-scale mass production, breaking Japan’s long-term technological

monopoly on basic raw materials. Domestic annual market consumption reached 3,200 tons, with annual exports of standardized mulberry leaf extract hitting 4,100 tons.

A complete localized full industrial chain supporting system took shape, providing integrated technical services including raw material testing, terminal formula compounding and dosage form development, fully covering all application scenarios of food, cosmetics, health food, feed and pharmaceuticals.

4. Stage of Highly Mature Industry and Large-Scale Global Export of Domestic Raw Materials (2023 – 2026)

4.1 Clear product stratification with precise coverage of all application scenarios

The four tiers of raw materials feature clear gradient positioning and differentiated competition: crude mulberry leaf powder and mulberry leaf tea exclusively serve condiments, low-end livestock feed and bulk herbal tea; low-temperature water-extracted concentrated juice is deployed in beverages and natural antioxidant food preservatives; resin-enriched freeze-dried powder targets postprandial blood sugar control health food, soothing nutritional beverages and pet intestinal care; high-purity DNJ monomer APIs supply pharmaceuticals, high-end medical aesthetic repair and clinical nutritional intervention, achieving full coverage of high-end and low-end markets.

4.2 Bulk overseas shipment of domestic raw materials with rising global market share

Domestic mulberry leaf extracts match top-tier Japanese brands in DNJ purity, low-impurity removal efficiency, anti-browning storage stability and solvent residue indicators. Leveraging China’s world-largest scaled mulberry orchard supply chain, customized low-temperature graded purification, inert gas stable embedding technologies and cost advantages, domestic products are exported in bulk to the EU, North America, Southeast Asia, Japan, South Korea and Australia, continuously squeezing the supply share of traditional Japanese raw material manufacturers. High-DNJ freeze-dried powder for blood sugar control occupies the mainstream overseas market of metabolic health dietary supplements by virtue of superior cost performance.

4.3 Formation of a standardized and healthy industrial competition landscape

Regulatory governance of the industry centers on national standard GB/T 40642, EU novel food specifications, Japanese functional food standards, China’s Health Food Raw Material Catalogue, Catalogue of Feed Additives and Catalogue of Cosmetic Raw Materials in Use, setting access thresholds for safe limits of DNJ, solvent residues and heavy metals for food/pharmaceutical-grade raw materials. Imported high-purity DNJ monomers are only supplied in small batches to high-end special pharmaceutical brands, while domestic graded standardized raw materials dominate China’s mass market and mainstream shares in emerging overseas markets. Industry competition has shifted from the

early chaotic price war over low-grade mulberry leaf powder and bulk tea to comprehensive strength competition covering DNJ purity, customized impurity removal, anti-browning storage stability and multi-national global compliance support.

4.4 Medium-to-Long Term Industrial Development Trends (Post-2026)

- ***Full popularization of fully closed green low-temperature production***

Large-scale promotion of controllable low-temperature countercurrent extraction, supercritical CO_2 solvent-free extraction, ultrafiltration membrane low-temperature removal of polysaccharide and protein impurities and biological enzymatic colloidal removal technologies. The whole process adopts light-shielded inert gas protection to eliminate oxidative degradation of heat-sensitive DNJ and flavonoids. By-products including mulberry branches, mulberry stalks and extraction residues are fermented to produce composite feed raw materials, realizing full-plant circular green production of mulberry resources.

- ***Customized graded special raw materials for segmented sectors***

Develop graded special raw materials with tailored DNJ content, water solubility, acid-alkali resistance and anti-browning properties targeting six sectors: postprandial blood sugar control health food, soothing oral beverages, clean-label natural antioxidants, sensitive skin whitening and soothing cosmetics, antibiotic replacement livestock feed and hypoglycemic pharmaceutical APIs.

- ***Development of pre-compounded integrated composite raw materials***

Formulate pre-compounded raw materials for postprandial blood sugar control and intestinal health combined with white kidney bean, kudzu root, inulin and probiotics, reducing secondary compounding procedures for terminal manufacturers and providing one-stop finished product formula solutions.

- ***Integrated layout of compliance certification across multiple global regions***

Synchronously complete filing and certification as health food raw materials in China, novel food in the EU, functional food in Japan, dietary supplements in the U.S. and natural health products in Canada. Unify DNJ detection criteria and limit standards across multiple countries to achieve barrier-free cross-border circulation of mulberry leaf raw materials worldwide.

- ***Continuous iteration of high-stability delivery technologies***

Nanoliposome and cyclodextrin composite microcapsule embedding technologies boost the oral bioavailability of DNJ and transdermal absorption rate of flavonoids. Develop high-end dosage forms including sterile single-dose oral liquids for blood sugar control, sustained-release chewable tablets, controlled-release soft candies, medical soothing

repair essences and micro-pellets for aquatic antibiotic replacement. Advance mulberry cell suspension culture to enrich DNJ, breaking supply restrictions of field planting seasons and land resources. Iterate low-impurity, anti-browning and high-stability mulberry leaf extracts to expand segmented markets for blood glucose-sensitive populations and sensitive skincare.

Conclusion

The mulberry leaf extract industry originates from over 2,000 years of edible and medicinal practices of mulberry silkworm ancestors in pre-Qin China. Having inherited official materia medica records of the Han and Tang dynasties, complete processing theories of the Ming and Qing dynasties and traditional dietary therapy culture of China, Japan and South Korea, it has evolved into a mainstream global standardized polyhydroxyalkaloid functional raw material sector covering six major fields: health food for postprandial blood sugar regulation, natural antioxidant food additives, soothing herbal tea, whitening repair cosmetics, antibiotic-free livestock feed and hypoglycemic TCM APIs.

It has completed a full development cycle including textual research on mulberry leaf efficacy in ancient materia medica classics, separation and identification of the ternary characteristic markers DNJ, mulberry leaf flavonoids and polysaccharides, multi-center human clinical evidence verification of postprandial blood glucose regulation, low-temperature closed countercurrent extraction, ultrafiltration membrane removal of macromolecular impurities, directional enrichment of DNJ via macroporous resins, inert gas cyclodextrin stable embedding and full independent technological catch-up by domestic manufacturers. The industry has realized full-chain upgrading from natural frost mulberry leaves and crude mulberry leaf powder/tea to globally graded high-end standardized mulberry leaf extract raw materials.

Compared with crude mulberry leaf products processed via traditional open high-temperature water decoction without polysaccharide and protein impurity removal, standardized low-temperature graded mulberry leaf extracts rely on five core technologies: closed controllable low-temperature countercurrent extraction, ultrafiltration membrane removal of macromolecular colloidal impurities, graded enrichment of DNJ and flavonoids via macroporous resins, supercritical solvent-free extraction and inert gas cyclodextrin stable embedding. They possess core competitive advantages including complete retention of heat-sensitive active ingredients DNJ and flavonoids, massive removal of macromolecular impurities, powder resistance to light and high temperature with long-term anti-browning storage performance, ultra-low organic solvent residues, compatibility with full dosage forms of food, cosmetics, feed and pharmaceuticals, and compliance filing in multiple global countries and regions. These strengths perfectly

align with the long-term global market development trends of natural postprandial blood glucose intervention, mild skincare for sensitive skin, clean-label food preservation and antibiotic-free livestock breeding.

With the continuous launch of new technologies including solvent-free green extraction, customized graded raw materials for segmented sectors, nano-stable delivery, mulberry cell suspension culture and low-browning high-stability purification, mulberry leaf extract will maintain a long-term core position as a primary raw material for natural blood sugar control, antioxidant skincare and feed antibiotic replacement, serving as an indispensable multi-functional classic medicinal and edible raw material of the Moraceae family for the health food, cosmetics, livestock breeding and traditional Chinese medicine industries.