Performance Analysis of Mulberry Leaf Extract

Mulberry Leaf Extract is a natural both medicinal and edible active complex prepared from dried leaves of *Morus alba* L. (Moraceae family) using modern processes including low-temperature pulverization, enzymatic-assisted extraction, and membrane separation and purification. Its core value is supported by the synergy of three dimensions: physicochemical properties, key components and efficacy, and unique performance, which are progressive: physicochemical properties determine component stability and application adaptability; key components serve as the material basis for efficacy and unique performance; and unique performance is the comprehensive embodiment of the above two, jointly establishing its core competitiveness in multiple fields. This paper systematically analyzes its core value around the three key themes, combined with application value and technical advantages.

I. Physicochemical Properties of Mulberry Leaf Extract

The physicochemical properties of mulberry leaf extract directly determine its processing stability, solubility and application adaptability, which are prerequisites for efficacy. The core properties are listed in order of application relevance as follows:

(Ⅰ) Appearance and Solubility

Its appearance and solubility vary slightly with preparation processes, but the core performance is consistent and adaptable to different application scenarios:

- **Appearance**: High-purity extract (≥90%) is a fine pale yellow to yellowish-green powder with good fluidity, no caking, and a light, characteristic mulberry leaf aroma. Low-purity extract is mostly a brownish-yellow to dark brown powder or thick paste with a richer aroma; batches with higher flavonoid content have a slightly darker color (controllable). Extract prepared from frost-picked mulberry leaves features lighter color, higher active component content and better quality.
- **Solubility**: Mainly water-soluble with partial alcohol solubility, requiring no cosolvents. Water-soluble components (polysaccharides, DNJ, γ-aminobutyric acid) have a solubility of ≥10 g/100 mL in warm water at 25 °C, suitable for water-based products. Alcohol-soluble components (flavonoids, phytosterols) are soluble in 50%–70% ethanol and slightly soluble in absolute ethanol, adaptable to alcohol-soluble preparations and daily chemical products, enabling multi-scenario application.

(II) Stability and Tolerance

The active components have good stability, compatible with conventional processing and convenient storage, as detailed below:

- **Thermal stability**: DNJ and flavonoids maintain ≥90% activity after processing at below 60 °C for 30 minutes, but are prone to degradation and oxidation (retention rate ≤70%) above 80 °C. Mulberry leaf polysaccharides remain stable under short-term processing at below 100 °C. With -15 °C supercritical CO_2 extraction combined with low-temperature microencapsulation, activity retention rate reaches ≥98.5%, avoiding thermal damage.
- **pH tolerance**: Stable at pH 4.0–7.0, suitable for acidic and neutral formulations. Under strong acid or alkaline conditions, polysaccharide chains tend to break, DNJ activity declines, and flavonoids oxidize and discolor, requiring pH adjustment in formulations.
- **Storage stability**: Under sealed, light-proof conditions at below 25 °C and relative humidity ≤60%, the powder has a shelf life of 24 months and the paste 12 months, with no obvious oxidation, caking or odor during storage. Stability can be improved by avoiding strong light, high temperature, high humidity and co-storage with alkaline substances.

(III) Other Key Physicochemical Properties

- **Optical rotation**: Specific rotation $[\alpha]_{20}^{D}$ = -10° ~ -20° (10 g/100 mL aqueous solution), a core indicator of purity. Higher purity and DNJ content correspond to more stable optical rotation and larger absolute value.
- **Safety**: 20% concentration causes no skin irritation; oral LD_{50} in mice >5000 mg/kg (practically non-toxic). Complies with both medicinal and edible standards, safe for oral and external use, with no obvious liver or kidney burden after long-term intake. Patients with deficient cold of the spleen and stomach require compatible conditioning.
- **Hygroscopicity**: Moisture absorption rate ≤12% at 25 °C and 60% RH, slightly higher than similar extracts. Powder tends to absorb moisture and cake (facilitating processing) and requires aluminum foil sealing for moisture protection.
- **Testing characteristics**: Common grades are classified by DNJ content: 1%, 2%, 5%; flavonoids (calculated as rutin) ≥2%–5%; polysaccharides ≥5%–10%. Test methods include HPLC, UV-Vis and phenol-sulfuric acid method. Complies with national standards, with RSD of component content ≤2.0% between batches, ensuring stable quality.

II. Key Components and Corresponding Efficacy of Mulberry Leaf Extract

Mulberry leaf extract contains more than 100 chemical components, with core active components (≥90%) divided into four categories, featuring clear efficacy and synergistic effects, providing material support for its unique performance.

(Ⅰ) Core Active Components

1. Alkaloids (0.5%–3.0%, core functional factors)

Centered on DNJ and its derivatives, they are the primary source of blood glucose regulation, with synergistic effects among subtypes:

- **1-Deoxynojirimycin (DNJ)**: Accounts for 60%–80% of total alkaloids, a potent reversible α-glucosidase inhibitor. It activates the AMPK signaling pathway to accelerate glucose uptake, inhibits intestinal glucose absorption, and smooths postprandial blood glucose. Continuous intake for 12 weeks reduces fasting blood glucose by 1.2–1.8 mmol/L. Suitable for pharmaceuticals and health products, with far less gastrointestinal irritation than synthetic hypoglycemic drugs.
- **Derivatives including N-methyl-DNJ and fagomine**: Account for 20%–40% of total alkaloids, assist in enhancing DNJ's hypoglycemic activity and stability, reduce degradation during processing and storage, and help improve glycolipid metabolism.

2. Flavonoids (1%–5.0%)

Both water-soluble and alcohol-soluble, mainly including rutin, quercetin and isoquercitrin, acting synergistically with polyphenols:

- **Rutin, quercetin, isoquercitrin**: Core efficacies include antioxidant, lipid-regulating and anti-inflammatory effects. They scavenge free radicals, inhibit lipid peroxidation, protect vascular endothelium and retina, reduce triglycerides via the PPARγ pathway, and inhibit LDL oxidation. Synergize with DNJ to improve glycolipid metabolism, suitable for health products and daily chemicals.
- **Polyphenols such as chlorogenic acid**: Enhance antioxidant and anti-inflammatory activity, relieve bitterness to improve palatability, and help protect intestinal mucosa.

3. Mulberry Leaf Polysaccharides (5%–15%)

Water-soluble heteropolysaccharides (molecular weight 10–30 kDa), odorless, an important supplement for immune regulation and auxiliary hypoglycemia:

- **Mulberry leaf polysaccharides**: Enhance immune cell activity and promote cytokine secretion; inhibit key enzymes in glucose metabolism (EC_{50} = 1.81 mg/mL and 2.91 mg/mL, respectively) to assist DNJ in lowering blood glucose; also exert antioxidant effects. Suitable for immunocompromised people, diabetics and high-end

health products.

- **Advantages**: Good water solubility, non-irritating, easy to compound. Can be used in infant supplements and sensitive-skin products to improve the stability of other components.

4. Other Active Substances (5%–10%)

- **γ-Aminobutyric acid (GABA)**: Content 0.1%–0.3%, relieves nerves, assists in blood pressure regulation and improves sleep. Synergizes with flavonoids to protect cardiovascular system, suitable for sleep-aiding health products and soothing daily chemicals.
- **Phytosterols (mainly β-sitosterol)**: Competitively inhibit cholesterol absorption, assist in lipid regulation, and have anti-inflammatory and skin-care effects, suitable for lipid-regulating health products and moisturizing cosmetics.
- **Auxiliary components**: Contain B vitamins, vitamin C, minerals (Ca, Fe, Zn) and dietary fiber, synergistically enhancing nutrition and efficacy.

(II) Summary of Core Efficacy

Synergy of the four core components forms five basic efficacies, laying a foundation for multi-field applications:

- **Precise blood glucose regulation**: DNJ, polysaccharides and flavonoids jointly delay glucose absorption and improve insulin sensitivity, reducing postprandial blood glucose peak by about 30%. Suitable for adjuvant management of prediabetes and type 2 diabetes, mild and non-irritating (not a replacement for hypoglycemic drugs).
- **Lipid regulation and weight management assistance**: Flavonoids and phytosterols inhibit cholesterol synthesis, promote bile acid excretion, reduce blood lipids and fat accumulation. Can be used as a core compound ingredient for weight loss, synergizing with lotus leaf extract.
- **Antioxidant and anti-inflammatory effects**: Flavonoids, polyphenols and polysaccharides scavenge free radicals, enhance antioxidant enzyme activity, downregulate inflammatory factors, and protect blood vessels, liver and retina. Suitable for anti-aging health products and cosmetics.
- **Immune regulation**: Polysaccharides and flavonoids achieve bidirectional immune regulation, enhancing immunity and balancing immune response. Suitable for all populations, with stable immune function after long-term use.
- **Liver-clearing, eyesight-improving and nerve-soothing effects**: Inherits the TCM efficacy of clearing liver and improving vision, improves ocular microcirculation and relieves eye fatigue. GABA synergistically soothes nerves and aids sleep, suitable for eye-care and sleep-aiding products.

III. Unique Performance of Mulberry Leaf Extract (Core Competitive Advantages)

The unique performance of mulberry leaf extract reflects the synergy of its physicochemical properties and key components, distinguishing it from similar extracts. Core advantages cover six dimensions:

(Ⅰ) Blood Glucose Regulation: Natural, Mild, Multi-target (Core Uniqueness)

Based on the synergy of DNJ, flavonoids and polysaccharides and favorable physicochemical properties, it is a preferred natural raw material for auxiliary blood glucose control:

- **Mechanism**: DNJ inhibits intestinal glucose absorption; polysaccharides assist in inhibiting glycosidases; flavonoids improve insulin resistance. Multi-target dual regulation of "delayed absorption + enhanced sensitivity", especially suitable for people with rice- and flour-based diets.
- **Uniqueness**: Daily intake of 3–5 mg DNJ (300–500 mg of 1% extract) reduces fasting blood glucose by 1.2–1.8 mmol/L after 12 weeks, without gastrointestinal irritation of synthetic hypoglycemics. As a both medicinal and edible material, it supports long-term conditioning and prevention.
- **Comparison with similar products**: Bitter melon extract has single hypoglycemic effect and poor solubility; cassia seed extract focuses on eye protection with weak hypoglycemic activity. This product integrates multi-target action, mildness and dual regulation of glycolipid metabolism.

(Ⅱ) Liver-clearing & Eyesight-improving: Integration of Tradition and Modernity, Wide Adaptability (Differentiated Advantage)

Inherits TCM efficacy supported by modern pharmacology, distinct from other eye-care raw materials:

- **Mechanism**: Flavonoids and polyphenols protect retina; DNJ improves ocular microcirculation; polysaccharides enhance ocular immunity. Multi-component triple action: eye protection + anti-inflammation + antioxidation.
- **Uniqueness**: Combines Chinese and Western medicine, relieves eye fatigue for all groups without irritation or dependence. Can be compounded with blueberry extract and lutein for various eye-care products.
- **Comparison with similar products**: Blueberry extract only protects retina with single efficacy; lutein has poor solubility and low absorption. This product offers multiple efficacies and high cost performance for wider applications.

(Ⅲ) Antioxidation & Anti-aging: Mild, Long-lasting, Multi-target Synergy (Preferred Natural Antioxidant)

Supported by multi-component synergy and good stability, superior to other natural antioxidants:

- **Mechanism**: Flavonoids and polyphenols scavenge free radicals externally; polysaccharides enhance endogenous antioxidant enzyme activity. Multi-target delay of cell senescence and protection of multiple tissues and organs.
- **Uniqueness**: Provides triple antioxidant effects. DPPH scavenging rate ≥65% at 1.0 mg/mL, more stable than vitamin C and acid-free irritation, adaptable to anti-aging demands in multiple fields.
- **Comparison with similar products**: Tea polyphenols and grape seed extract have single function and poor stability; vitamin C is unstable and irritating. This product features multi-target action, high stability and additional efficacies.

(Ⅳ) Immune Regulation: Bidirectional, Mild & Non-irritating (Suitable for All Groups)

Synergy of polysaccharides and flavonoids enables mild adaptation to all populations, different from other immunoregulators:

- **Mechanism**: Polysaccharides enhance immune activity and cytokine secretion; flavonoids balance immune response, achieving dual effects of “immunity enhancement + homeostasis regulation”.
- **Uniqueness**: Suitable for all groups, free of side effects of immunosuppressants or excessive tonicity. Good water solubility and compounding ability, stabilizing immunity after long-term use.
- **Comparison with similar products**: Ganoderma and ginseng extracts are expensive with limited application; astragalus extract has weak immune targeting. This product integrates bidirectional regulation, cost-effectiveness and wide adaptability.

(Ⅴ) Strong Application Compatibility: Multi-dosage Adaptation, Convenient Processing (Outstanding Industrial Advantages)

Favorable physicochemical properties enable multi-field and multi-dosage production with significant industrial benefits:

- **Mechanism**: Mainly water-soluble with partial alcohol solubility, good stability and low irritation, requiring no complex pretreatment and ensuring active component retention.
- **Uniqueness**: Flexible adjustment of active component content, no obvious odor, good compounding performance, RSD ≤2.0% between batches, low industrial

application cost.

- **Comparison with similar products**: Bitter melon and cassia seed extracts have poor solubility and require cosolvents; hawthorn extract has strong odor. This product is adaptable to multiple dosages, easy to process and stable in batches.

(VI) Wide Source & High Cost-performance: Remarkable Industrialization Advantages (Strong Market Competitiveness)

Superior to similar extracts in cost performance with broad industrialization prospects:

- **Mechanism**: Leverages raw material advantages in major mulberry planting areas in China and mature processes for large-scale production, balancing environmental protection and economic benefits.
- **Uniqueness**: Stable year-round raw material supply (byproduct of sericulture with high resource utilization), mature processes with ≥90% activity retention, much lower price than high-end raw materials with multiple efficacies.
- **Comparison with similar products**: Blueberry and grape seed extracts rely on imports at high prices; bitter melon and cassia seed extracts have single efficacy. This product features stable raw materials, high cost-performance and multiple functions.

IV. Synergistic Relationship and Summary of the Three Core Themes

The three core themes of mulberry leaf extract form a logical closed loop of “basic support – material core – competitive advantage”, jointly constituting its core value:

- **Physicochemical properties as the foundation**: Water solubility, medium-low temperature stability and low irritation ensure component activity and application adaptability; optical rotation and safety guarantee quality control and safe use.
- **Key components and efficacy as the core**: Synergy of four components forms five basic efficacies, the material source of unique performance, in line with both medicinal and edible trends and chronic disease prevention demands.
- **Unique performance as the extension**: Favorable physicochemical properties and efficient components create differentiated advantages, solving pain points of similar raw materials and highlighting irreplaceability and multi-field value.

In summary, with “excellent physicochemical properties + efficiently synergistic components + unique core performance”, mulberry leaf extract is a versatile both medicinal and edible raw material focusing on “blood glucose regulation, liver-clearing & eyesight-improving, antioxidation & immune regulation”. It features remarkable efficacy,

flexible application and high cost-performance, with strong competitiveness and broad market prospects in multiple industries.

V. Application Value and Technical Advantages of Mulberry Leaf Extract

Based on the above properties and efficacies, mulberry leaf extract has significant application value in multiple fields. Modern preparation technology supports industrialization and further enhances core competitiveness:

(I) Core Application Value (Field-specific Precise Adaptation)

1. Pharmaceutical and Health Product Industry

With core efficacies, it serves as a key raw material for natural pharmaceuticals and health products adaptable to various forms:

- **Pharmaceutical preparations**: Used as adjuvant for blood glucose, blood lipid and eye-care products, low in side effects and high in safety, suitable for long-term use (diabetic nephropathy patients under medical guidance).
- **Health products**: Developed for blood glucose management, eye care, immune regulation and other products, suitable for multiple groups. Can be compounded with lotus leaf, salvia miltiorrhiza extracts for synergistic effects, meeting natural health demands.

2. Food Industry

Combines good water solubility, mild taste and multiple efficacies for “function + nutrition” in food processing:

- **Functional foods**: Used in blood glucose-friendly beverages, meal replacements for people with high blood glucose and obesity; added to infant and elderly foods for nutrition and immunity enhancement.
- **Common foods**: Applied in bakery products, dairy products at 0.5%–2.0% without affecting taste, providing additional functions and partially replacing chemical additives.

3. Cosmetic and Daily Chemical Industry

A preferred natural raw material for high-end skin care and daily chemicals with antioxidant and anti-inflammatory properties:

- **Skin care products**: Used in antioxidant, soothing and eye-care cosmetics, mild and non-irritating for sensitive skin, improving skin condition and protecting periorbital skin.

- **Daily chemicals**: Added to soothing toiletries to relieve sensitivity and inflammation; used in oral care to inhibit pathogenic bacteria, relieve gum sensitivity and freshen breath.

4. Other Fields

- **Feed additive**: Used in livestock and aquaculture feed to improve immunity, intestinal health and reduce antibiotic use, conforming to green breeding concepts.
- **External care**: Applied in soothing gels and eye drops, mild and non-irritating, relieving skin and eye discomfort with high safety.

(II) Core Technical Advantages (Supporting Application Implementation)

Modern preparation technologies improve product quality, adaptability and reduce costs, solving processing pain points:

- **Extraction and purification**: Enzymatic-assisted countercurrent extraction coupled with membrane separation achieves DNJ purity ≥5%, polysaccharide yield ≥10%, activity retention ≥90%. Dual-patent technology increases activity retention to over 98.5% and improves hygroscopicity.
- **Dosage optimization**: Produced as powder, paste, microcapsules and other forms. Microcapsules enhance stability and mask bitterness; powder with adjustable particle size suits various formulations.
- **Quality control**: Uses DNJ, flavonoids and polysaccharides as core indicators combined with physicochemical parameters, establishing a complete system with RSD ≤2.0% between batches, complying with national and export standards, with flexible component adjustment.
- **Industrial advantages**: Mature process for large-scale continuous production, recyclable solvents, stable raw material supply and high resource utilization. Customizable specifications and dosages for personalized demands.