Analysis of the Unique Properties of Elderberry Extract

Overview

Elderberry Extract is a natural plant extract obtained through standardized extraction and purification from the mature fruits of **Sambucus** plants in the Caprifoliaceae family (mainly *Sambucus nigra* L., *Sambucus racemosa* L., and *Sambucus canadensis* L.). Its core active components include **anthocyanins** (cyanidin-3-glucoside, delphinidin-3-glucoside), **flavonoids** (quercetin, rutin, kaempferol), and **phenolic acids** (chlorogenic acid, caffeic acid), supplemented by polysaccharides, amino acids, vitamins (vitamin C, vitamin E), minerals (iron, potassium, calcium), and other auxiliary components.

Its physicochemical characteristics are dominated by anthocyanin-derived color, oxidation sensitivity, and differential solubility of components. Functionally, it features **immunomodulation, anti-inflammation, and antioxidant activity** as the core effects, with multi-target activities including antiviral, metabolic regulation, and skin protection. Its unique properties are reflected in the **synergistic mechanism of anthocyanins and flavonoids, high bioavailability, scenario-adaptable functionality, and full-industry-chain standardization**. As a distinctive plant extract with medicinal value, health-care efficacy, and cosmetic application potential, it is known as the **"Natural Immunity Guardian"** and the **"Precious Antioxidant Berry"**.

I. Physicochemical Characteristics

The physicochemical properties of elderberry extract are determined by the chemical structures of its core active components and closely related to standardized quality control, raw material varieties, and preparation processes. The key attributes are as follows:

(I) Appearance and Organoleptic Properties

- **Product Forms**:

Dark purplish-red to purplish-black powder; high-purity anthocyanin extract is a fine, loose powder with good fluidity and no caking. Liquid extract is a clear dark purplish-red to purplish-brown liquid without obvious precipitation; slight flocculation may occur after long-term storage (normal, recoverable after shaking).

- **Odor and Taste**:

Characteristic elderberry fruity aroma, slightly sour and sweet taste; higher content of anthocyanins and phenolic acids leads to more obvious sourness, no off-odor or burnt taste.

- **Microscopic Characteristics**:

Fruit epidermal cells (polygonal, containing purplish-red pigment), pulp parenchyma cells (containing mucilage), occasional seed fragments (elliptical, smooth surface), no starch grains. Anthocyanin pigment crystals (acicular or flaky) visible under high magnification.

(II) Core Chemical Components and Content Standards

Core components are divided into three categories: **anthocyanins, flavonoids, and phenolic acids**.

1. Anthocyanins

- **Representatives**: Cyanidin-3-glucoside, delphinidin-3-glucoside, petunidin-3-glucoside.

Cyanidin-3-glucoside is the main active monomer, accounting for **>60%** of total anthocyanins.

- **Content Standards**:
  - Food grade: total anthocyanins (calculated as cyanidin-3-glucoside) ≥ 2.0%–5.0%
  - Health food grade: ≥ 5.0%–10.0%
  - High-purity grade: ≥ 25.0%
  - Cosmetic grade: ≥ 3.0% (with strict limits on heavy metals and harmful impurities)
- **Main Functions**: Antioxidation, immunomodulation, antivirus, skin pigment regulation; main source of color and bio-compatibility.

2. Flavonoids

- **Representatives**: Quercetin, rutin, kaempferol, isorhamnetin.

Quercetin and its glycosides are the dominant active monomers.

- **Content Standards**:
  - Commercial extract: total flavonoids (calculated as rutin) ≥ 1.0%–3.0%
  - Health food grade: ≥ 3.0%
  - Cosmetic grade: ≥ 1.5%
- **Main Functions**: Antioxidation, anti-inflammation, immune enhancement, cardiovascular protection; improves stability and reduces anthocyanin oxidation.

3. Phenolic Acids

- **Representatives**: Chlorogenic acid, caffeic acid, ferulic acid, gallic acid.

Chlorogenic acid is the major active component.

- **Content Standards**:
  - Commercial extract: total phenolic acids (calculated as chlorogenic acid) ≥ 0.5%–1.5%
  - High-purity grade: ≥ 2.0%
  - Pharmaceutical grade: precise content control for stable anti-inflammatory efficacy
- **Main Functions**: Anti-inflammation, antibacterial, antioxidant, gastrointestinal mucosal protection; enhances safety and reduces irritation.

(III) Key Physicochemical Parameters

1. **Solubility**:
   - Anthocyanins: soluble in water, hot water, 40%–60% ethanol, methanol; slightly soluble in acetone; insoluble in non-polar solvents.
   - Flavonoids: soluble in ethanol, methanol, DMSO; slightly soluble in water, soluble in alkaline aqueous solution.
   - Phenolic acids: soluble in water, ethanol; slightly soluble in non-polar solvents.
   - Polysaccharides: soluble in water; insoluble in organic solvents.
2. **Oxidation Sensitivity**:

Core components (especially anthocyanins and phenolic acids) are oxidation-sensitive. Fresh anthocyanins degrade under oxygen, light, and high temperature, fading from deep red to light red or brown.

Under UV 365 nm, characteristic purplish-red fluorescence (cyanidin-3-glucoside Rf ≈ 0.68). Storage requires **light protection, sealing, and oxygen isolation**.

3. **Stability**:
   - Dry powder: stable at ≤20 °C, RH ≤55%, sealed and light-protected; shelf life 1–2 years.
   - Aqueous solution: unstable; stored at 4 °C; shelf life extended to 2 months with antioxidants (vitamin C, tea polyphenols).
   - 50% ethanol solution: shelf life 3–4 months.

- Anthocyanins decompose above 70 °C; temperature strictly controlled during processing.

4. **pH Value**:

5% aqueous solution: pH 3.5–5.0 (weakly acidic), compatible with human intestinal tract and skin surface, low irritation.

5. **Chromatographic Characteristics**:
    - TLC: identifiable by characteristic purplish-red spots.
    - HPLC: quantitative analysis of cyanidin-3-glucoside, quercetin, chlorogenic acid.
    - IR: characteristic absorption peaks at 3350 cm^{-1} (-OH), 1620 cm^{-1} (C=O), 1520 cm^{-1} (benzene ring).

(IV) Correlation Between Raw Materials and Preparation

- **Raw Material Parts**:

Mature fruits have the highest active component content; peel and pulp > seeds.

- *Sambucus nigra*: highest anthocyanins, best for medicine and health food.
- *Sambucus racemosa*: better taste, suitable for food and beverages.
- *Sambucus canadensis*: high flavonoids, suitable for cosmetics.

- **Extraction Process**:

Mainstream: low-temperature water extraction or 40%–60% ethanol extraction, purification by macroporous resin (AB-8), ultrafiltration, spray drying (inlet ≤180 °C, outlet ≤80 °C).

High-purity anthocyanins: gel filtration chromatography, purity ≥25%.

Food/cosmetic grades: additional removal of heavy metals and pesticide residues.

Oral grades: optimized for improved bioavailability.

II. Core Components and Efficacy

Efficacy derives from the **synergistic action** of anthocyanins, flavonoids, phenolic acids, and auxiliary components, covering immunity, metabolism, skin, cardiovascular system, etc.

(I) Anthocyanins and Efficacy

- **Antioxidation & Anti-aging**: 20× stronger than vitamin C, 50× stronger than vitamin E; scavenges free radicals, protects cells, prevents chronic diseases.
- **Immunomodulation**: Activates macrophages, lymphocytes, NK cells; regulates cytokines; reduces respiratory infection risk.
- **Antiviral**: Inhibits adsorption, invasion, replication of influenza virus, RSV; blocks viral binding to host cells.
- **Skin Protection**: Penetrates epidermis, scavenges free radicals, inhibits tyrosinase, lightens spots, strengthens skin barrier.
- **Auxiliary Effects**: Improves intestinal microflora, assists glycemic control and weight management.

(II) Flavonoids and Efficacy

- **Anti-inflammatory & Antibacterial**: Inhibits NF-κB pathway, reduces pro-inflammatory factors; inhibits *Staphylococcus aureus*, *E. coli*, etc.
- **Immune & Antiviral Synergy**: Enhances immune cell activity and durability.
- **Cardiovascular Protection**: Dilates blood vessels, improves elasticity, lowers blood lipids, prevents atherosclerosis.
- **Skin Barrier Repair**: Promotes collagen synthesis, relieves redness and sensitivity.

(III) Phenolic Acids and Efficacy

- **Enhanced Anti-inflammation & Antibacterial**: Synergizes with flavonoids; inhibits *Helicobacter pylori*, *Cutibacterium acnes*.
- **Gastrointestinal Protection**: Forms mucosal protective layer; improves digestion, relieves gastric mucosa injury.
- **Antioxidation & Component Protection**: Stabilizes anthocyanins, reduces oxidation and color change.
- **Metabolic Assistance**: Helps regulate postprandial blood glucose and fat metabolism.

(IV) Multi-Component Synergistic Effects

- Anthocyanins: antioxidation, antivirus, skin pigment regulation
- Flavonoids: anti-inflammation, immunity, cardiovascular protection
- Phenolic acids: anti-inflammation, antibacterial, gastrointestinal protection
- Auxiliary components: nutrition, stability, bioactivity

Together they form a complete system:

Antioxidation + Immunomodulation + Anti-inflammation + Antibacterial

with extremely low irritation and high biocompatibility.

III. Unique Properties (Core Competitiveness & Differentiation Advantages)

(I) Dual-Core Synergistic Mechanism: Immunity + Antioxidation

- **Immune pathway**: activates immune cells and cytokines, improves non-specific and specific immunity.
- **Antioxidant pathway**: efficiently eliminates free radicals, protects cells and blood vessels.
- **Synergy**: Antioxidation protects immune cells; immunity enhances radical scavenging.
- Superior to blueberry/blackberry extracts in antioxidant capacity.

(II) Overall Synergy & High Safety Balance

- Multi-target, multi-layer synergistic system vs. single-target synthetic drugs.
- Natural plant-derived, low irritation, no obvious toxic side effects.
- Suitable for children, pregnant women (under medical advice), elderly.
- Flexible dosage forms: powder, liquid, capsules, tablets.

(III) Anthocyanin-Dependent Oxidation Responsiveness

- **Oxidation activation**: mild oxidation enhances activity for skin repair and anti-aging.
- **Scenario adaptation**:
  - Oral products: controlled oxidation to maintain efficacy.
  - Cosmetics: dynamic antioxidation based on skin oxidative stress.
  - Food: natural colorant with nutritional value.
- Unique deep purplish-red color for quality visualization.

(IV) Full-Scenario Cross-Border Adaptability

- **Pharmaceutical**: adjuvant treatment for influenza, respiratory infections, arthritis.
- **Health food**: immune regulation, antioxidation, antivirus, cardiovascular protection; daily ≤5 g (dry basis).
- **Cosmetics**: anti-aging, brightening, sensitive skin repair; natural colorant.
- **Food**: natural additive for beverages, confectionery, baked goods.
- **Animal husbandry**: natural immune enhancer, alternative to antibiotics.

(V) Full-Industry-Chain Standardization & Regulatory Compliance

- **China**: standards for food additives; approved as health food raw material.
- **International**: USP, EP HPLC methods; EU and US safety limits; FDA-approved as food supplement and colorant.
- **Industrial upgrading**: high-purity anthocyanin technology (≥25%); full-chain quality control.

IV. Summary

The core value of elderberry extract lies in **natural origin, multi-effect synergy, full-scenario adaptation, and standardized controllability**.

Its physicochemical characteristics, dual-core immunity-antioxidation mechanism, multi-component safety balance, oxidation responsiveness, cross-border adaptability, and full-chain standardization make it irreplaceable among berry extracts. It is honored as the **"Natural Immunity Guardian"** and one of the **most promising natural antioxidant raw materials of the 21st century**.

Future development will focus on:

- Precision extraction and stability modification
- In-depth mechanism research (antiviral, metabolic regulation)
- Scenario-based product development
- Full industrial chain upgrading

It will become a core raw material connecting **clinical adjuvant therapy, daily health management, and beauty care**, supporting the high-quality growth of the natural health industry.