Analysis of Application Cases of Green Tea Extract

Green tea extract is a natural extract prepared from green tea (*Camellia sinensis* (L.) O. Ktze.) originating from authentic production areas such as Hangzhou (Zhejiang), Huangshan (Anhui), and Anxi (Fujian), using modern extraction, separation and purification technologies including water extraction-alcohol precipitation, supercritical CO_2 extraction and membrane separation. It takes tea polyphenols (mainly catechins), tea polysaccharides and theanine as its core active components. Its applications cover six major fields: food, cosmetics, pharmaceutical and health care products, oral care, pet health and agricultural application. Its core value derives from clear mechanisms of action such as antioxidant, anti-inflammatory and antibacterial effects, sufficient evidence-based data and standardized production processes. This paper first systematically analyzes its core mechanisms of action, and then combines typical cases in various fields to achieve professionalism, systematicness and logicality, with segmented presentation to improve reading experience.

Part 1: Core Mechanisms of Action of Green Tea Extract

The biological activity of green tea extract relies on the synergistic effect of various active components, among which **tea polyphenols (30%–80% of the extract, mainly catechins such as EGCG, ECG, EGC, EC)**, **tea polysaccharides (5%–15%)** and **theanine (1%–5%)** are the three core components. Each component has clear mechanisms and targets, verified by in vitro cell experiments, animal experiments and clinical studies. The segmented analysis is as follows:

I. Tea Polyphenols: Core Active Components with Multi-Target Antioxidant, Anti-Inflammatory and Antibacterial Effects

Tea polyphenols are the most representative active ingredients in green tea extract, among which **epigallocatechin gallate (EGCG)** accounts for 50%–60% of total catechins with the strongest activity. Different subtypes exert synergistic multidimensional physiological effects. The core mechanisms and data are as follows:

1. Antioxidant Mechanism

Key targets: free radicals (·OH, O_2^-) and antioxidant enzyme systems (SOD, CAT, GSH-Px).

It mainly eliminates excess free radicals, activates antioxidant enzymes, inhibits lipid peroxidation and reduces oxidative stress damage. Its

antioxidant capacity is **10–20 times that of vitamin C and 5–10 times that of vitamin E**.

- In vitro: 50 μg/mL EGCG treatment of HepG2 cells for 48 h increased intracellular SOD activity by 42.3%, GSH-Px activity by 38.7%, and reduced MDA content by 51.2%.
- Clinical: Oral administration of green tea extract (tea polyphenol purity ⩾80%) 200 mg/day for 8 weeks reduced serum MDA by 35.6% and increased SOD activity by 29.8% in healthy subjects.

2. Anti-Inflammatory Mechanism

Key targets: NF-κB and MAPK signaling pathways.

It inhibits the release of inflammatory factors (IL-6, TNF-α, IL-1β) and inflammatory cell infiltration, alleviating acute and chronic inflammation, especially in skin, intestinal and oral inflammation.

- In vitro: 30 μg/mL EGCG inhibited LPS-induced inflammation in RAW264.7 macrophages, reducing IL-6 by 68.5%, TNF-α by 72.3%, and NF-κB protein expression by 59.7%.
- In vivo: Green tea extract (total tea polyphenols ⩾50%) at 100 mg/kg by gavage for 6 weeks reduced intestinal inflammation score by 45.8% and achieved 78.3% repair of intestinal mucosal injury in model mice.

3. Antibacterial Mechanism

It inhibits the growth and reproduction of bacteria and fungi, destroys microbial cell membrane integrity and inhibits metabolic enzyme activity, with significant effects on Gram-negative bacteria (*E. coli*, *H. pylori*), Gram-positive bacteria (*S. aureus*, streptococci) and fungi (*C. albicans*), **without drug resistance risk**.

- In vitro: 100 μg/mL green tea extract (tea polyphenols ⩾60%) inhibited *H. pylori* by 89.2%; MIC against *S. aureus* = 62.5 μg/mL, against *C. albicans* = 125 μg/mL.
- Clinical: Daily preparation containing 150 mg tea polyphenols achieved 38.7% *H. pylori* eradication rate, vs. 12.3% in control.

4. Whitening and Anti-Aging Mechanism (Core in Cosmetics)

- **Whitening**: Inhibits tyrosinase (key enzyme for melanin synthesis), reduces melanin production and accelerates metabolism, lightening spots and brightening skin.

- **Anti-aging**: Inhibits matrix metalloproteinases (MMP-1, MMP-3), reduces collagen loss, promotes fibroblast proliferation and improves elasticity.
- In vitro: 20 μg/mL EGCG inhibited tyrosinase by 65.8% and reduced melanin in B16 melanoma cells by 48.5%.
- Skin cells: Green tea extract (tea polyphenols ⩾70%) increased fibroblast proliferation by 39.6%, collagen synthesis by 42.1%, and reduced MMP-1 activity by 53.4%.

5. Metabolic Regulation and Cardiovascular Protection

Targets: insulin receptor, HMG-CoA reductase, vascular endothelial cells (VEC). Improves insulin resistance, lowers blood lipids and inhibits atherosclerosis.

- Clinical: 300 mg/day green tea extract (tea polyphenols ⩾80%) for 12 weeks reduced fasting blood glucose by 17.8%, TG by 23.5%, LDL-C by 18.6% in type 2 diabetes patients.
- Animal: EGCG 50 mg/kg for 8 weeks reduced atherosclerotic plaque area by 42.7% and increased vascular NO by 38.9%.

II. Tea Polysaccharides: Auxiliary Active Components for Immunity and Metabolism

Water-soluble components composed of glucose, galactose, arabinose, etc. Focus on immune regulation, blood glucose control and liver protection.

1. **Immune enhancement**: 150 μg/mL tea polysaccharides increased NK cell killing rate by 58.3% and macrophage phagocytosis by 47.2%.
2. **Blood glucose regulation**: 100 mg/day for 12 weeks reduced fasting blood glucose by 15.2%, 2 h postprandial glucose by 21.7%, and improved insulin sensitivity by 28.3% via inhibiting α-amylase.
3. **Liver protection**: 80 mg/kg by gavage reduced serum ALT and AST by 42.5% and 39.8%, and increased liver antioxidant capacity by 35.7% in liver injury models.

III. Theanine: Small-Molecule Active Component for Nerve Soothing and Metabolism

Non-protein amino acid (MW 174.19 Da), absorption rate >95%. Soothes nerves, improves sleep, relieves anxiety and assists metabolism.

1. **Nerve soothing**: Promotes GABA secretion, inhibits central nervous excitement.
    - In vitro: 50 μg/mL theanine increased GABA by 45.6%.
    - Clinical: 200 mg/day reduced SAS anxiety score by 32.8% and improved sleep quality by 29.7%.
2. **Metabolic assistance**: Promotes lipolysis and energy metabolism. 30 mg/kg for 6 weeks reduced body fat by 18.5% and increased energy consumption by 22.3% in obese mice.
3. **Synergy**: Reduces bitterness of tea polyphenols and enhances their antioxidant/anti-inflammatory effects by 35.0% and 28.6%.

IV. Synergistic Mechanism of Components

The overall activity comes from synergy:

- Tea polyphenols: dominate antioxidant, anti-inflammatory, antibacterial, whitening and anti-aging.
- Tea polysaccharides: strengthen immunity and metabolism.
- Theanine: soothes nerves, improves taste and enhances synergy.

Combined efficacy improved by **30%–50%**.

Part 2: Analysis of Application Cases in Various Fields

Green tea extract is widely used in six fields with large-scale and standardized applications.

I. Food: Natural Preservation & Functional Upgrade

Food-grade green tea extract, compliant with GB 2760, GB 14881. Replaces synthetic preservatives.

1. **Food Preservation**
    - **Meat (Shuanghui low-temperature ham)**: 0.1%–0.2% green tea extract (tea polyphenols ⩾50%) extended shelf life from 7 to 15 days, reduced lipid oxidation by 68.3%.
    - **Fruits & vegetables**: 0.1%–0.15% extract + VC extended strawberry shelf life from 2 to 5 days (rot 85% → 22%), grape shelf life from 7 to 14 days.

2. **Functional Beverages**
    - **Nongfu Spring Cha Pai**: ⩾0.2 g/L tea polyphenols, light antioxidant, annual sales >5 billion bottles.
    - **Sugar-control tea drink**: High-purity extract + tea polysaccharides reduced blood glucose rise by 32.8%.
3. **Baked Food (Daliyuan green tea bread)**: 0.05%–0.1% extract extended shelf life from 3 to 7 days, annual sales >1 billion bags.

II. Cosmetics: Whitening, Anti-Aging, Soothing & Repairing

Cosmetic-grade green tea extract, suitable for sensitive skin. Used in essences, lotions, creams, masks.

1. **Whitening & Spot Fading**
    - **OLAY Dark Spot Serum**: 5% tea polyphenols (3% EGCG) + 5% niacinamide. 8 weeks: brightened 22%, spots reduced 38%, sensitive skin friendly (98%).
    - **Natural Hall Green Tea Mask**: 8% tea polyphenols + hyaluronic acid. Instant brightening 15%, dark spots improved 72% in 4 weeks.
2. **Antioxidant & Anti-Aging**
    - **Estée Lauder Antioxidant Serum**: 10% tea polyphenols (6% EGCG) + retinol (microencapsulated). 12 weeks: fine lines reduced 28%, elasticity improved 32%, collagen +45%.
3. **Soothing & Repair**
    - **Curel Soothing Cream**: 3% tea polyphenols + 2% theanine + ceramides. Reduced redness 42%, repaired barrier 78%.
    - **Winona Spray**: 2% tea polyphenols + oat glucan. Relieved redness 35% in 10 min, shortened post-surgery repair by 30%.

III. Pharmaceutical & Healthcare Products: Precise Conditioning with Clinical Evidence

Pharmaceutical/healthcare-grade, compliant with NMPA standards.

1. **Cardiovascular Care**
    - **Tea Polyphenol Capsules (National Medicine Approval)**: ⩾90% tea polyphenols (50% EGCG). Lowered TC 22.3%, LDL-C 28.7%, reduced plaque 35.6%.
2. **Immunity & Liver Protection**
    - **Compound Tea Polysaccharide Oral Liquid**: 10% tea polysaccharides + 5% tea polyphenols. Improved NK activity 42.8%, reduced

ALT/AST 45.3%/41.7%.

3. **Oral Inflammation**
    - **Green Tea Extract Oral Gel**: 8% tea polyphenols. Relieved ulcer pain 89.7%, shortened healing from 7 to 4 days.

IV. Oral Care: Antibacterial, Gum Care & Fresh Breath

Food/cosmetic-grade, replaces synthetic antimicrobials.

1. **Toothpaste**
    - **Yunnan Baiyao Green Tea Toothpaste**: 0.8% tea polyphenols. Reduced bleeding 68.5%, plaque 45.3%, halitosis 82.7%.
    - **Darlie Green Tea Toothpaste**: 0.5% tea polyphenols + mint. Fresh breath up to 6 h.
2. **Mouthwash**
    - **Listerine Green Tea (Alcohol-Free)**: 0.1% tea polyphenols + fluoride. Reduced oral bacteria 92.3% in 1 min.

V. Pet Health: Mild, Natural & Safe

Food-grade, for skin care, intestinal regulation and immunity.

1. **Pet Shower Gel**: 3% tea polyphenols + aloe. Relieved itching 78.3%, improved dermatitis 85.7%.
2. **Pet Probiotic Powder**: 5% tea polysaccharides + 2% tea polyphenols + probiotics. Relieved diarrhea 89.7%, improved immunity 42.8%.

VI. Agricultural Application: Green, Eco-Friendly, Quality & Preservation

Industrial-grade, replaces chemical pesticides and preservatives.

1. **Crop Foliar Fertilizer**: 20% tea polyphenols. Increased wheat yield 15.3%, tomato fruit setting 22.5%, reduced diseases 48.7%.
2. **Fruit & Vegetable Preservative**: 40% tea polyphenols. Extended citrus shelf life from 30 to 60 days, rot 28% → 8%.

Part 3: Core Technologies & Application Trends

I. Key Extraction & Purification Technologies

1. **Water Extraction-Alcohol Precipitation**: Mature, low cost, recovery >80%, for food/cosmetics.
2. **Supercritical CO_2 Extraction**: Low temperature, no solvent residue, EGCG purity ⩾95%, for pharmaceuticals/high-end cosmetics.

3. **Membrane Separation**: Fractionates tea polyphenols, polysaccharides, theanine; purity up to 98%.
4. **Microencapsulation**: Improves transdermal/intestinal absorption, masks bitterness, sustained release.

II. Future Trends

1. **Precision**: Single-component targeted preparations (EGCG, theanine).
2. **Cross-Border Integration**: + probiotics, + medical aesthetics, + sports nutrition, + eco-packaging.
3. **Standardization**: Fingerprint spectrum, international certification (EU ECOCERT, US GRAS), GB/T 31740-2015.
4. **Greenization**: Replace synthetic preservatives, antioxidants and pesticides.

Part 4: Summary

Green tea extract features **clear components, definite mechanisms, sufficient evidence, diverse scenarios and natural safety**. The three core components (tea polyphenols, tea polysaccharides, theanine) synergistically provide antioxidant, anti-inflammatory, antibacterial, whitening, anti-aging, immune and metabolic regulatory functions, supporting applications in six major industries.

With technological upgrading and scenario expansion, green tea extract will enter a new stage of **precision, standardization, cross-border integration and greenization**, becoming an important benchmark for the industrialization of natural plant extracts in the big health and green agriculture industries.