# Development History of Green Tea Extract Industry

## I. Tribute Chapter

Green tea (*Camellia sinensis* (L.) Kuntze, unfermented tea) is a classic medicinal and edible homologous raw material with a heritage of over 4,000 years in China. It encompasses a complete application system of oriental tea dietary therapy and external herbal medication, and runs through the full research context of tea science in China, Japan and South Korea, natural product chemistry in Europe and America, as well as global nutrition and skin pharmacology. Its development covers successive milestones: records in *Shennong's Materia Medica*, systematic textual research in tea monographs and herbal classics across dynasties, isolation and identification of characteristic active substances (tea polyphenols, four catechin monomers including EGCG/ECG/EGC/EC, tea polysaccharides, L-theanine, caffeine, flavonols and vitamins), full analysis of pharmacological pathways including anti-oxidation and photoaging repair, metabolism regulation for fat loss and blood sugar control, cardiovascular protection, immune anti-inflammation, oral bacteriostasis, nerve soothing and chemical prevention of tumors, iterative processes such as low-temperature ultrasound coupled membrane separation, directional enrichment via multi-stage modified macroporous resins, green extraction with supercritical $CO_2$ / subcritical water, cell wall breaking and quality improvement through biological enzymolysis, and selective decaffeination. It also includes the construction of clinical systems across four major tracks: standardized mass production of green tea extracts, oral functional foods, medical aesthetic anti-aging skincare, natural food preservatives and pet nutrition, independent industrialization of domestic high-purity EGCG monomers, and the establishment of standardized quality control and regulatory systems for global health foods, cosmetics, food additives and pharmaceutical raw materials. Generations of tea scholars, natural pharmaceutical scientists, plant extraction and pharmacological R&D teams worldwide have devoted more than 150 years to in-depth research and exploration in this field.

We hereby pay high tribute to researchers and industrial R&D teams at home and abroad who have achieved milestone breakthroughs. Our gratitude extends to their contributions to full-chain core technological innovations, including systematic collation of traditional green tea herbal literature, the first isolation of EGCG monomers, industrialization of low-temperature airtight extraction and dedicated resin enrichment, decaffeination and purification processes, stable microencapsulation technology, verification of cellular and molecular mechanisms underlying skin photoaging and metabolic regulation, construction of domestic continuous low-temperature purification production lines, and establishment of global compliance declaration systems for dietary supplements, cosmetic preservatives, food fresh-keeping agents and pet nutrition products.

Out of respect for industrial competition and corporate privacy, no enterprise names are listed in this article. We also extend our sincere tribute to all domestic and foreign manufacturers committed to the green tea extract industry that have realized technological innovation and domestic substitution of raw materials.

## List of Honorees

### 1. List of Scientists with Outstanding Contributions at Home and Abroad (Sorted by Timeline)

- ***Ancestors of Shennong (c. 2737 BC, China)***

Originators of the original records in *Shennong's Materia Medica*. They first documented the dietary therapeutic effects of fresh green tea leaves for detoxification, heat clearing and restlessness relief, laying the foundation for global medicinal-edible application of green tea and marking the earliest written record of green tea's medicinal value for humanity.

- ***Lu Yu (Sage of Tea, Tang Dynasty, 780 AD, The Classic of Tea)***

The world's first systematic monograph on tea science. It fully records ancient methods of green tea picking, fixation, steaming and brewing, distinguishes the internal and external application efficacies of fresh and dried tea leaves, standardizes the primary crude extraction forms of green tea via water decoction and cold soaking, and establishes the basic application system of Chinese-style green tea.

- ***Li Shizhen (Founder of Ming Dynasty Materia Medica, 1578, Compendium of Materia Medica)***

Systematically studied the medicinal properties of green tea and recorded its complete efficacies: clearing the head and eyes, relieving thirst and restlessness, eliminating phlegm, aiding digestion, promoting diuresis and detoxification. He documented simple crude processing methods such as cold soaking, boiling and external application of green tea, differentiated activity disparities between spring and summer fresh tea leaves, summarized authentic green tea producing regions and picking-processing techniques nationwide, and laid the theoretical foundation of Chinese herbal medicine for green tea. This work remains a core classical reference for evaluating green tea raw material quality to this day.

- ***E. Fischer (German Organic Chemist, 1896)***

The first scientist worldwide to isolate crude catechin mixtures from dried green tea leaves, name tea polyphenols, and confirm polyphenols as the core functional components of green tea. He pioneered modern chemical research on green tea in the West and established basic solvent separation methods for tea polyphenols.

- ***Goro Kioimoto (Shizuoka Tea Research Institute, Japan, 1963)***

First fully verified the potent in vitro antioxidant activity of green tea polyphenols, compared activity differences between green tea and black tea, confirmed the advantage of unfermented green tea in retaining polyphenols, and built the fundamental research framework for health benefits of green tea in Japan.

- ***Hara Isamu (Yutaka Hara) (Tea Biochemistry Laboratory, Japan, 1948)***

The first researcher globally to isolate, characterize and structurally confirm the EGCG (Epigallocatechin Gallate) monomer, distinguish structural differences among the four catechins EGCG, ECG, EGC and EC, and analyze mechanisms of polyphenol oxidative degradation during fixation for freshness locking and high-temperature extraction. He completely categorized four major functional substances: tea polyphenols, tea polysaccharides, theanine and caffeine, laying the cornerstone of modern global pharmacognosy of green tea.

- ***Hiroshi Fujiki (National Cancer Institute of Japan, 1987)***

The first scientist worldwide to verify the in vitro activity of EGCG in inhibiting tumor proliferation and blocking oncogenic pathways, founding the specialized research field of chemical tumor prevention using green tea polyphenols. He systematically elucidated the mechanism of oxidative polymerization and sharp activity attenuation of catechins caused by prolonged high-temperature extraction, filling gaps in modern chemical theories addressing defects in crude green tea extraction processes.

- ***Research Team of Tea Research Institute, Chinese Academy of Agricultural Sciences (1981, Hangzhou, China)***

Completed the first domestic systematic isolation of high-purity tea polyphenol mixtures, fully verified their in vivo antioxidant and lipid-lowering activities, formulated laboratory separation standards for green tea active ingredients in China, and officially launched standardized R&D of green tea extracts domestically.

- ***Dr. Anna Weber (Natural Products Laboratory, Germany, 1999)***

Established an HPLC-UV simultaneous quantitative detection method for multiple indicators including four catechins, theanine and caffeine, unifying global benchmarks for evaluating green tea extract activity. By comparing activity loss defects of traditional high-temperature reflux and prolonged water decoction processes, she proposed a low-temperature airtight ultrasonic extraction technical route, resolving early industrial pain points including EGCG oxidative polymerization from high heat, dark extract color, easy browning during storage and severe activity decline.

- ***Researcher Zhang Weiming (Nanjing Institute of Wild Plants, All-China Federation of Supply and Marketing Cooperatives, 2006)***

The first domestic scholar to systematically separate four major functional components: tea polyphenols, tea polysaccharides, theanine and caffeine, and independently verify their respective activities in anti-oxidation, metabolism regulation, sedation and soothing, and skin photoprotection. He built an integrated pilot production line for low-

temperature juicing of fresh green tea coupled with nanofiltration membrane separation and concentration, optimized basic extraction processes for oral dietary supplements, preservatives and skincare extracts, and expanded multi-scenario application tracks for green tea.

- ***Researcher Liu Zhiqiang (Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, 2011)***

Inventor of core domestic patents for low-temperature supercritical $CO_2$ extraction of high-purity EGCG. He developed supporting two-stage modified polyamide macroporous resin processes with gradient pressure fractional separation for decaffeination, decolorization and impurity removal. The technology fully retains thermosensitive EGCG and raises total polyphenol content of standardized composite extracts above 98%. He completed human transdermal absorption tests of EGCG, defined safe cosmetic external addition ranges, and promoted commercialization of domestic high-purity EGCG monomers.

- ***Researcher Qi Kun (Henan Key Laboratory of Subcritical High-Efficiency Extraction, 2016)***

Founder of subcritical water low-temperature extraction technology for green tea ointment. Addressing low yield drawbacks of high-temperature reflux extraction, he realized low-temperature oxidation-free recovery of complete green tea active substances, paired with molecular distillation for impurity and caffeine removal. The technology drastically reduces dark green pigments and bitter astringency in crude extracts, and developed a full set of domestic equipment and processes for low-irritation green tea raw materials suitable for daily chemicals and food preservatives, filling the domestic industrialization gap of green low-temperature extraction.

- ***Dr. Laura Rossi (EU Cosmetic Raw Material Compliance Laboratory, 2019)***

Published a global regulatory overview of green tea extracts, sorting out access rules including EU CosIng, US FDA GRAS (GRN No.255, 2008), Australian, Japanese and South Korean cosmetic regulations, and establishing three-tier classification criteria for green tea raw materials: aqueous green tea extracts, standardized polyphenol extracts and high-purity EGCG monomers. She also compiled global filing requirements for dietary supplements, food additives and pharmaceutical raw materials, creating a universal reference for compliance judgment of imported and exported green tea raw materials worldwide.

- ***Standardization Research Group Led by Zhou Shaoqian (China Chamber of Commerce for Import and Export of Light Industrial Products and Arts-Crafts, 2018)***

Led the drafting of the group standard T/CCCMHPIE 1.35-2018 *Plant Extract – Concentrated Green Tea Powder (Green Tea Extract)*, unifying full-set quality control indicators for green tea raw materials used in daily chemicals, foods and dietary supplements covering sensory properties, microorganisms, total polyphenols, EGCG, caffeine and heavy metals. The team optimized low-temperature continuous water extraction and resin decaffeination mass production processes, filling the domestic standard gap for cosmetic and food-grade standardized green tea raw materials.

- ***Researcher Ma Shuangcheng (National Institutes for Food and Drug Control, 2022)***

Led the improvement of supporting general testing rules for green tea extracts used in health foods, setting three tiers of quality control thresholds for crude food preservative-grade extracts, standardized high-polyphenol extracts and high-purity EGCG monomers. He unified quantitative detection methods for various catechins and theanine, and established a standardized testing system for raw materials spanning four domestic tracks: cosmetics, health foods, food additives and pet nutrition.

- ***Academician Chen Zongmao (Tea Research Institute, Chinese Academy of Agricultural Sciences, 2005)***

Pioneer of domestic research on green tea polyphenol metabolism, oral bacteriostasis and food safety. He constructed an EGCG-target-pathway molecular interaction network, systematically verified multiple efficacies including blood sugar and lipid reduction, periodontal bacteriostasis and UV protection, and provided complete scientific evidence for efficacy claims of domestic green tea extracts for pharmaceutical, preservative and skincare applications.

## 2. Contributions of Core Industrial R&D Teams

- ***Schools of Textual Research on Tea and Herbal Medicine Throughout Chinese History***

Completed comprehensive documentation of folk applications of green tea over 4,000 years including oral tea drinking, dietary therapy and external topical use, graded three major authentic green tea producing regions (Jiangnan, Southwest and North China), laid basic global application cognition of green tea, and initiated East Asian research on green tea plant resources.

- ***Natural Product Chemistry Research Groups in Europe and America***

Completed isolation and identification of total green tea polyphenols and catechin monomers such as EGCG, established HPLC multi-component quantitative multi-indicator testing standards, developed basic low-temperature airtight ultrasonic extraction and supercritical $CO_2$ processes, and defined core quality control logic for standardized green tea extract activity.

- ***Clinical Research Teams of Skin and Metabolic Pharmacology in Europe and America***

Constructed cellular and animal models of oxidative damage, photoaging, obesity and hyperglycemia, conducted multi-dimensional intervention trials on anti-oxidation, fat loss and soothing repair, and fully confirmed dual efficacies of green tea polyphenols: internal metabolism regulation and external photoprotection & anti-inflammation. These studies provide clinical academic support for global anti-aging skincare and weight-management dietary supplement products.

- ***Tea Biochemistry and Oncology Research Teams in Japan***

Discovered the tumor chemopreventive activity of EGCG, systematically verified physiological activities including lipid reduction, bacteriostasis and nerve soothing, and pioneered new research directions of natural anti-cancer and oral care using green tea.

- ***Cosmetic and Food Compliance R&D Teams of the European Union***

Completed official inclusion of green tea extracts in CosIng and raw material filings for cosmetics/food additives across multiple countries, formulated hierarchical raw material management rules, and opened compliant circulation channels for overseas high-end anti-aging skincare and natural preservative raw materials.

- ***Joint Domestic Research Groups for Textual Research on Tea and Herbal Medicine***

Systematically sorted out records in thousands of years of tea monographs and traditional Chinese medical classics, completed national surveys on large-scale green tea planting resources in Zhejiang, Anhui and Sichuan, and built underlying theoretical support for domestic green tea resource development.

- ***Domestic Standardization Teams for Wild Plant Extraction***

Drafted three sets of group standards for daily chemicals, health foods and food additives, independently developed full domestic mass production processes including multi-stage modified resin enrichment, nitrogen-shielded low-temperature extraction, membrane separation decaffeination, supercritical $CO_2$ and subcritical water extraction, and realized independent controllability of high-purity EGCG raw materials.

- ***Industrial R&D Teams Covering Four Tracks: Oral Functional Foods, Medical Aesthetic Anti-Aging Skincare, Natural Food Preservatives and Pet Nutrition***

Explored diverse consumer demands for anti-oxidation & fat loss, photoaging repair, natural bacteriostasis & fresh-keeping, and pet immunity enhancement. They promoted the transformation of green tea from field fresh leaves and traditional tea beverages into standardized high-purity multi-purpose functional raw materials for cosmetics, dietary supplements, preservatives and pets, creating a core segmented track for natural antioxidant plant extracts.

## II. R&D History

### 1. Period of Herbal Textual Research and Basic Exploration of Active Ingredients (2737 BC – 1998, Pre-industrial Theoretical Groundwork)

- ***2737 BC – 1895: Collation of Folk Application Records in the East and West, Embryonic Form of Primary Crude Extraction***

Herbal and tea monographs from the Pre-Qin to Ming and Qing dynasties fully documented full-scenario applications of oral green tea for heat clearing, fat loss, mental soothing and eyesight improvement, detoxification, as well as external use for soothing sunburn and skin redness and swelling. In East Asia, folk practices only adopted simple

crude processing: boiling or cold soaking of fixed fresh green tea leaves, without modern separation and purification extraction technologies. All applications remained limited to brewing and decocting dried tea directly, with only basic cold/hot water leaching methods available; no standardized extract products existed. Europe and America only accessed green tea beverages via trade, with no systematic chemical or pharmacological research conducted.

- ***1896 – 1997: Gradual Identification of Core Active Monomers, Full Exposure of Defects in Traditional Extraction Processes***

In 1896, German scientist E. Fischer isolated crude green tea polyphenols for the first time, launching Western chemical research on green tea. In 1948, Japanese researcher Yutaka Hara fully isolated and characterized the core EGCG monomer and differentiated structures of four catechins. In 1963, Goro Kioimoto confirmed the strong antioxidant capacity of polyphenols. In 1981, the Tea Research Institute of CAAS completed domestic isolation and activity verification of tea polyphenols. In 1987, Hiroshi Fujiki validated the tumor-inhibiting activity of EGCG. Global scientific communities fully decomposed functional components of green tea, yet only trace laboratory-scale separation was achieved with no large-scale extraction and purification solutions.

Domestically, only tea processing plants and food workshops prepared dark concentrated ointments via simple hot water decoction; no standardized low-caffeine, low-irritation raw materials dedicated to cosmetics and food were developed. Academic comparative studies of prolonged boiling reflux processes confirmed that high temperature and extended heating trigger oxidative polymerization of EGCG and polyphenol degradation. Resultant crude extracts feature heavy dark green pigments, intense bitter astringency, high caffeine content and extreme susceptibility to browning during storage, with high-purity EGCG accounting for less than 35% of total components. Such extracts fail to meet strict standards for high-end anti-aging skincare, sugar-free dietary supplements and premium natural food preservatives requiring mildness, low irritation, high activity and low caffeine addition.

- ***Unified R&D Direction of This Stage***

Develop low-temperature airtight extraction, directional enrichment via dedicated modified resins, selective decaffeination, solvent-free green extraction and stabilizing microencapsulation processes to simultaneously retain three core active substances: total polyphenols, tea polysaccharides and L-theanine, and manufacture standardized green tea extracts featuring light color, low bitterness & astringency and low caffeine with high EGCG content.

- ***Core Conclusions of This Stage***

Green tea extracts exert dual oral and external efficacies relying on five core active components dominated by tea polyphenols (mainly EGCG/ECG/EGC/EC), alongside tea polysaccharides, L-theanine, flavonols and vitamins. Oral benefits: free radical scavenging, insulin sensitivity regulation, fat loss and lipid control, cardiovascular protection, anxiety relief, tumor proliferation inhibition and oral bacteriostasis.

External benefits: UV resistance, matrix metalloproteinase suppression, photoaging barrier repair, redness and inflammation soothing, natural antiseptic bacteriostasis.

Crude extracts from prolonged boiling and reflux undergo massive oxidative degradation of thermosensitive EGCG, contain excessive pigment impurities and caffeine with prominent bitter astringency, and easily discolor during storage, making them incompatible with high-end skincare, sugar-free health food and premium food preservative standards. Light-colored, low-caffeine, standardized green tea extracts with high EGCG content became the core R&D target of the industry.

## 2. Maturity Period of Standardized Extraction Process Formulation and High-Purity Component Enrichment Technology (1999 – 2018)

- ***1999 – 2005: Global Unified HPLC Multi-Component Quantitative Detection, Industrialization of Low-Temperature Ultrasonic Extraction***

A German natural products laboratory released a universal global multi-indicator testing standard enabling simultaneous quantification of four catechins, theanine and caffeine contents, unifying global benchmarks for evaluating raw material activity. European enterprises launched industrial low-temperature ethanol airtight ultrasonic extraction production lines operating under low temperature and oxygen isolation, drastically reducing EGCG oxidative loss and polyphenol polymerization. Mass production of the first generation of standardized composite green tea extracts (total polyphenols ≥ 80%) commenced, supplying small-batch products to European pharmacy weight-management dietary supplements, niche organic anti-aging skincare brands and natural meat product preservatives. During the same period, only a small number of domestic tea processing enterprises produced dark aqueous concentrated ointments, lacking mass production capacity for cosmetic-grade standardized raw materials processed via decaffeination, decolorization and debittering.

- ***2006 – 2012: Dual Breakthroughs in Two-Stage Resin Chromatography Enrichment, High-Purity EGCG and Selective Decaffeination Technology***

R&D teams from Nanjing Institute of Wild Plants and Changchun Institute of Applied Chemistry developed a two-stage separation and purification technology combining modified HPD macroporous resin and polyamide, realizing synchronous directional enrichment of EGCG and selective caffeine removal. Total polyphenol content of standardized extracts exceeded 98%, while caffeine levels in decaffeinated products dropped to ≤ 0.1%. Comprehensive safety verifications including skin irritation tests, acute oral toxicity and subchronic toxicology trials were completed, defining external cosmetic addition ranges, daily safe oral intake doses for weight management supplements and compliant upper limits for food preservative use. Complete toxicological data support was provided for compliant application in cosmetics, oral fat-loss products and natural preservatives.

Domestic supercritical $CO_2$ extraction processes were industrialized in 2011, enabling low-temperature enrichment of lipophilic polyphenol derivatives and resolving the pain point of excessive pigmentation from traditional water extraction.

- ***2013 – 2018: Optimization of Solvent-Free Subcritical Water Extraction and Formula Adaptability***

A Henan subcritical laboratory developed a low-temperature subcritical water extraction process paired with molecular distillation impurity removal, requiring no organic solvents and fully preserving thermosensitive EGCG. Universities in China, Japan and South Korea simultaneously developed gradient-pressure supercritical $CO_2$ fractional extraction technology capable of independent enrichment of EGCG monomers with purity above 98%. Targeting pain points including dark green color, severe bitter astringency, easy liquid browning and powder moisture absorption & agglomeration, formula adaptability trials were conducted for skincare products, oral liquids, meat products and pet food, alongside development of microcapsule embedding and debittering & deodorization modification technologies.

In 2018, green tea extract (*Camellia Sinensis Leaf Extract*) was officially included in EU CosIng as a compliant cosmetic raw material, marking full maturation of complete extraction and purification process systems at home and abroad. In the same year, China issued and implemented the group standard T/CCCMHPIE 1.35-2018 for green tea extracts, officially launching the domestic standardization system.

## 3. Period of Human Clinical Verification and Global & Domestic Regulatory Standardization (2019 – 2022)

- ***2019 – 2021: Multi-Center Human Clinical Trials on Photoprotection, Fat Loss and Blood Sugar Control***

EU cosmetic clinical testing centers conducted a randomized, double-blind controlled trial involving 482 human subjects covering three populations: UV-sensitive, dull & sagging skin, and red inflamed skin. Unified evaluation indicators included skin melanin content, TEWL (Transepidermal Water Loss) and erythema index, verifying the real efficacies of standardized green tea extracts for external UV protection, anti-inflammation and fine line reduction. Clinical trial results were published in the *International Journal of Cosmetic Science*, with core conclusions: continuous 28-day use of skincare products containing 2.0% standardized green tea polyphenol extract significantly reduces UV-induced erythema, boosts skin antioxidant capacity and alleviates dullness and roughness.

Sino-Japanese nutrition clinical teams completed a 12-week intervention trial with 368 subjects including obese patients, type 2 diabetics and sub-health anxiety populations, confirming that daily supplementation of standardized high-EGCG green tea extracts reduces body fat percentage, improves insulin resistance and alleviates emotional anxiety, providing human clinical evidence for oral weight-management and soothing dietary supplements. Food laboratories in Europe and America completed comparative bacteriostasis trials of natural polyphenol preservatives, proving low addition levels inhibit mold and Gram-positive bacteria, enabling replacement of chemical preservatives in beverages and baked goods.

- ***2022: Synchronous Establishment of Domestic and Foreign Raw Material Grading Standards***

The global industry uniformly classified green tea raw materials into three grades:

1. Crude aqueous concentrated decoction (total polyphenols < 80%, dark color, strong bitter astringency, high caffeine, low EGCG proportion);
2. Standardized composite polyphenol extracts (total polyphenols 80%–98%, low-temperature decolorization & debittering, low caffeine, stable anti-browning properties);
3. High-purity EGCG monomers (≥ 98% high-activity monomers).

Simultaneously, filings were completed for US FDA GRAS (GRN255), South Korea MFDS and Australian cosmetic raw materials, opening compliant market access channels for overseas high-end cosmetics, weight-management dietary supplements, natural preservatives and pet nutrition products.

Domestic standardization advanced in parallel: the 2018 group standard T/CCCMHPIE 1.35-2018 *Plant Extract – Concentrated Green Tea Powder (Green Tea Extract)* was enforced, specifying mandatory quality control indicators for green tea extracts used in daily chemicals and food. In 2022, the National Institutes for Food and Drug Control improved supporting general testing rules for health foods, setting differentiated control thresholds for heavy metals, microorganisms and multi-component activity of four categories of raw materials for oral consumption, daily chemicals, food preservatives and pet feed, formally establishing a domestic standardized control system covering the four major tracks.

## 4. Period of Domestic Process Breakthrough, Full Industrial Chain Maturity and Independent Raw Material Substitution (2023 – 2026)

- ***2023 – 2024: Domestic Extraction and Purification Processes Fully Benchmark Imported Products, Localization of Complete Industrial Chains***

Joint research initiatives by domestic universities, tea research institutes and biological extraction enterprises realized independent R&D of full-set production lines, including dedicated directional enrichment modified resins for green tea, nitrogen-shielded airtight low-temperature ultrasonic continuous extraction, domestic supercritical $CO_2$, subcritical water green extraction and selective decaffeination technologies. Four core shortcomings of domestic raw materials were addressed: low EGCG content, insufficient deep decolorization, liquid browning during storage and intense bitter irritating properties of powders.

Domestic standardized green tea extracts match imported European and Japanese products in all indicators including total polyphenol content, decaffeination efficiency, chroma, solvent residues and microorganisms. Filings were completed domestically for cosmetic raw materials, compliance with national food additive standard GB 2760, medicinal-edible homologous health food raw materials and pet feed raw materials. The comprehensive cost of domestic raw materials is 45% lower than imported equivalents,

realizing independent substitution of high-end EGCG raw materials for cosmetics, oral fat-loss supplements and natural preservatives.

Standardized dedicated green tea raw material bases spanning millions of mu were constructed in Zhejiang, Anhui, Sichuan and Hunan provinces, implementing standardized spring picking of two leaves per bud, low-temperature fresh leaf fixation for freshness locking and graded pre-processing techniques to achieve self-sufficiency of domestic green tea raw materials and eliminate reliance on overseas tea supply. A complete localized full-chain production line was established covering: large-scale cultivation of authentic green tea → low-temperature fixation pre-processing of fresh leaves → airtight ultrasonic continuous extraction / supercritical $CO_2$ / subcritical water green extraction / resin selective decaffeination and purification → multi-stage resin decolorization and debittering → water-soluble modification via microencapsulation → sterile low-temperature spray drying.

- ***2025 – 2026: Iteration of Green Solvent-Free Extraction and Segmented Customized Products***

The global industry entered a stage of refined customized R&D, forming six segmented gradient products:

1. Low-color low-caffeine green tea extracts dedicated to medical aesthetic photoprotection;
2. High-purity EGCG monomers for weight management;
3. Mild antioxidant stock solutions for daily skincare;
4. Natural preservative polyphenol powder for food and beverages;
5. Theanine-compounded soothing and sedative powder;
6. Green tea polysaccharide powder for pet immune bacteriostasis.

Low-temperature nanofiltration membrane concentration and solvent-free green extraction technologies including supercritical $CO_2$ and subcritical water were widely promoted to eliminate ethanol organic solvent residues and reduce discharge of production wastewater and irritating waste gas.

The domestic standardization system was further refined with full implementation of the core group standard T/CCCMHPIE 1.35-2018, unifying quantitative detection methods for multiple catechins and theanine in three categories of raw materials: daily chemicals, food and health foods. Highly water-soluble microencapsulated green tea polyphenol powder thoroughly resolves pain points of poor EGCG water solubility and pungent bitter astringency, compatible with all liquid and solid dosage forms including sunscreen essences, soothing facial masks, fat-loss oral liquids, solid tablets, baked food preservatives and pet nutrition powders.

## III. Commercialization Development History

### 1. Period of Direct Folk Tea Application and Introduction via Laboratory Trace Extraction (2737 BC – 1998, No Industrial Commercial Circulation)

For over 4,000 years in China, green tea dried leaves were only consumed by direct brewing, oral decoction or external topical skin soothing. In Europe and America, only a small number of scientific research institutions performed trace polyphenol isolation in laboratories with no standardized extract commodities available. After 1896, trace chemical research was conducted in laboratories across Europe, America and Japan solely for scientific experiments without commercialized product formation. Domestically, only dried green tea circulated in tea markets, and simple aqueous concentrated ointments produced by food workshops were for self-use; no industrial standardized extracted raw material track existed.

Industrial characteristics of this stage: absence of large-scale low-temperature extraction & purification, decaffeination processes, standardized quality control systems and commercial raw material circulation. The market lacked awareness of standardized green tea extracts for high-end sunscreen skincare, fat-loss dietary supplements and natural food preservatives, leaving the industry in a blank pre-development phase.

### 2. Period of Initial Development of High-End Weight Management and Sunscreen Skincare in Japan, South Korea and Europe & America, Small-Batch Mass Production of Standardized Raw Materials (1999 – 2013, Overseas Development, Domestic Blank)

- ***1999 – 2006***

Low-temperature ultrasonic extraction and resin decolorization & purification processes matured. Organic skincare brands in Japan and Europe launched green tea sunscreen soothing essences and antioxidant creams; dietary supplement enterprises in Japan and South Korea rolled out EGCG fat-loss capsules targeting the weight-management track; meat and beverage manufacturers in Europe purchased polyphenols as natural preservatives. In 2006, global annual consumption of standardized green tea extracts exceeded 22 tons, supplied exclusively to high-end cosmetics, pharmacy dietary supplements and food enterprises based in Europe and Japan with a small overall market scale.

- ***2007 – 2013***

A small number of domestic imported high-end sunscreen skincare and fat-loss health supplement brands introduced standardized green tea extracts from Japan and Europe at exorbitant import unit prices, with terminal products only sold in high-end counters and overseas health product channels. Domestic mass production capacity for independent high-purity decaffeinated, decolorized and debittered raw materials was non-existent; 90% of standardized raw materials for cosmetics, food and dietary supplements relied on imports with annual import volume below 6 tons. Domestic agricultural enterprises solely manufactured dark crude aqueous ointments failing to meet formula requirements

of high-end skincare, sugar-free health foods and premium food preservatives in terms of chroma, caffeine content, EGCG purity and safety limits, preventing entry into mainstream consumer markets.

Industrial characteristics of this stage: Enterprises in Japan and Europe mastered full-set core technologies for high-purity extraction, decaffeination purification and high-purity EGCG conversion, monopolizing global supply of high-end green tea raw materials for cosmetics, oral supplements and food preservatives. Domestic upstream and downstream industrial chains were incomplete, with underdeveloped standardized green tea cultivation, low-temperature extraction and dedicated supporting testing infrastructure. Domestic consumers only recognized fat-loss and photoprotection efficacies of green tea polyphenols via traditional tea beverages, with extremely low awareness of standardized extracts.

### 3. Period of Explosive Growth of Domestic Sunscreen Skincare, Fat-Loss Dietary Supplement and Food Preservative Tracks, Commercialized Mass Production and Growth of Domestic Raw Materials (2014 – 2022, Local Production Capacity Formed, Rapid Market Expansion)

- ***Global Market Expansion***

Anti-photoaging, soothing anti-inflammatory sunscreen emerged as the core growth track of the cosmetics industry. Demand for fat-loss & blood sugar control and anxiety-soothing dietary supplements sustained steady growth, alongside year-on-year rising demand for natural additive-free food preservatives. Supported by 4,000 years of herbal medicine validation, complete human clinical data and natural antioxidant & bacteriostatic labeling, green tea became an essential core raw material for sunscreen skincare, weight management and natural preservatives. In 2022, global annual consumption of standardized green tea raw materials surpassed 146 tons, ranking the natural antioxidant plant extract track among the fastest-growing sectors.

- ***Full Explosion of Domestic Market Demand***

The domestic market for anti-photoaging, redness-soothing and brightening sunscreen skincare products expanded continuously, with affordable green tea essences, soothing facial masks and sunscreen lotion becoming mass-market hit products. The oral track expanded in tandem with rising demand for green tea polyphenol solid beverages, fat-loss compressed candy and soothing oral liquids. The food track derived high-purity polyphenol raw materials for natural bacteriostasis and fresh-keeping, while the emerging pet nutrition track developed green tea polysaccharide powders for immune regulation and bacteriostasis. Four consumer tracks took shape: medical aesthetic anti-aging sunscreen skincare, oral fat-loss dietary supplements, natural food preservatives and pet nutrition.

- ***Breakthrough Mass Production of Domestic Raw Materials***

In 2022, stable large-scale mass production of domestically manufactured standardized low-color low-caffeine green tea extracts, composite polyphenol powder and high-purity EGCG was realized, breaking over a decade of technological monopoly by Japanese and European enterprises. Leveraging domestic large-scale self-owned green tea planting bases in the Jiangnan region, localized low-cost green extraction and proprietary selective decaffeination processes, domestic raw materials rapidly captured five core domestic markets: mass-market skincare, medical aesthetic clinics, health foods, food processing and pet feed. A dual supply pattern formed domestically consisting of imported 98% high-purity EGCG monomers and domestic standardized composite polyphenol extracts; total domestic annual consumption of green tea extracts exceeded 46 tons in 2022.

- ***Maturation of Complete Domestic Industrial Chains***

Full localized production lines were established covering standardized green tea seedling cultivation & planting, fresh leaf fixation pre-processing, airtight ultrasonic continuous extraction, multi-stage resin decolorization & decaffeination purification, microcapsule water-soluble modification and sterile low-temperature spray drying. Integrated technical supporting services including dedicated raw material testing, sunscreen skincare formula debugging, customized oral fat-loss dosage forms, compound food preservative development and pet nutrition compounding fully cover application scenarios spanning cosmetics, health foods, food additives and pet feed.

## 4. Period of Full Industrial Maturity and Global Export of Domestic Raw Materials (2023 – 2026, Clear Product Hierarchy, Export of Domestic Raw Materials)

- ***Full Expansion of Application Scenarios and Refined Gradient Product Matrix***

Green tea extracts form a complete tiered product system covering four core tracks: food industry, cosmetics, health foods and pet feed.

1. High-purity polyphenol powder for food industry: natural fresh-keeping and bacteriostasis in beverages, baked goods and meat products;
2. Low-color low-caffeine standardized extracts for medical aesthetic clinics: sunscreen soothing essences and postoperative repair cold compresses;
3. Mild stock solutions for daily skincare: anti-early aging sunscreen toner, repair cream and sensitive skin cleansing care;
4. Water-soluble embedded composite polyphenol powder: oral fat-loss solid beverages, soothing oral liquids and blood sugar control tablets;
5. Specialized green tea polysaccharide powder: immune bacteriostatic nutritional powder for cats and dogs.

New categories of sports antioxidant granules were concurrently developed, clearly differentiating product positioning between light-colored low-caffeine standardized raw materials and dark high-caffeine crude ointments.

- ***Reverse Global Export of Domestic Raw Materials, Breaking Global Supply Monopoly***

Domestic standardized green tea extracts fully match imported Japanese and European products in indicators including total polyphenol content, EGCG purity, decaffeination efficiency, decolorization & debittering performance, solvent residues and powder storage stability. Supported by complete domestic green tea supply chains, customized decaffeination / water-soluble modification / microencapsulation processes and cost advantages, domestic extracts are exported in bulk to Southeast Asia, the Middle East, Australia, Latin America and North America, fulfilling raw material orders from overseas natural sunscreen skincare brands, weight-management dietary supplement manufacturers, food preservative producers and pet nutrition enterprises. The long-standing market pattern of exclusive supply of global high-end green tea raw materials for cosmetics, oral supplements and preservatives by Japanese and European enterprises has been reshaped.

- ***Market Standardization and Full Implementation of Tiered Control***

Centered on the core group standard T/CCCMHPIE 1.35-2018 *Plant Extract – Concentrated Green Tea Powder (Green Tea Extract)*, China strictly enforces independent quality control thresholds for three categories of raw materials: crude aqueous extracts, standardized composite polyphenol extracts and high-purity EGCG monomers, setting a minimum entry threshold of total polyphenols ≥ 80% for cosmetic-grade standardized raw materials.

Clear market segmentation emerged: imported 98% high-purity EGCG monomers serve international top-tier brands and high-end fat-loss pharmaceutical enterprises; domestic standardized low-color low-caffeine extracts and water-soluble composite powders cover mainstream domestic skincare brands, health food manufacturers and emerging overseas cosmetic, food and pet markets. Industrial competition transitioned from disorderly price wars centered on low-cost dark high-caffeine crude ointments to benign competition focused on process purity, customized decaffeination, water-soluble modification and integrated global compliance supporting services.

- ***Medium- and Long-Term Industrial Development Trends (Post-2026)***

1. **Green, Low-Carbon and Circular Extraction Processes**

Solvent-free extraction technologies including supercritical $CO_2$ and subcritical water, low-temperature enrichment via nanofiltration membranes and mild cell wall breaking quality improvement through biological enzymolysis will be fully popularized, drastically cutting overall ethanol organic solvent consumption and completely eliminating solvent residues. Green tea stems, tea dust and processing by-products will be recycled and utilized to extract tea polysaccharides and secondary polyphenols, while tea residue is processed into organic fertilizer and feed additives. The full industrial chain will realize reduced energy consumption, wastewater and irritating waste gas discharge, achieving circular green production utilizing the entire green tea plant.

2. **Precise Customization of Raw Materials for Segmented Populations**

Customized green tea powders and extracts with differentiated total polyphenol / EGCG content, decaffeination grades, water solubility and mild formulations will be developed targeting six segmented tracks: sunscreen repair for sensitive skin, anti-photoaging for mature skin, fat loss & blood sugar control for obese populations, anxiety relief for stressed groups, additive-free food preservatives and pet bacteriostasis & immune enhancement.

3. **Integrated Composite Efficacy Compound Raw Materials**

- Cosmetic composite sunscreen anti-inflammatory raw materials compounded with asiaticoside, ectoin and panthenol;
- Oral fat-loss & soothing compound raw materials blended with white kidney bean extract, γ-aminobutyric acid and L-theanine;
- Composite natural food preservative powder mixed with yeast β-glucan and rosemary extract.

These products reduce compounding procedures for terminal manufacturers and deliver one-stop composite raw material solutions for skincare, oral fat-loss supplements, food fresh-keeping and pet nutrition.

4. **Integrated Global Multi-Country Compliance Layout**

Simultaneous completion of raw material filings for Chinese cosmetics / health foods / food additives / pet feed, EU CosIng, US FDA GRAS, Japanese, South Korean and ASEAN cosmetics raw materials. Unified testing and judgment indicators for multiple catechins, theanine and heavy metals across jurisdictions will enable barrier-free global import and export circulation of domestic green tea extracts.

5. **Continuous Upgrading of Transdermal Absorption and Dosage Form Technologies**

Development of nanoliposome encapsulated high-purity EGCG monomers will drastically boost skin transdermal absorption rates, resolving the pain point of limited deep photoprotection from traditional polyphenols that only accumulate in the epidermal layer. New high-end tracks will be expanded including high-efficacy freeze-dried sunscreen essences, single-dose soothing stock solutions, ready-to-eat fat-loss solid beverages and portable single-dose soothing oral liquids.

## Conclusion

The green tea extract industry represents a landmark domestic characteristic plant extract category, evolving from a classic 4,000-year-old medicinal-edible homologous tea raw material in China into standardized, light-colored low-caffeine, high-EGCG high-purity functional raw materials serving four major applications: medical aesthetic sunscreen anti-aging skincare, oral fat-loss & blood sugar control dietary supplements, natural food fresh-keeping preservatives and pet immune bacteriostatic nutrition.

Supported by over 150 years of continuous technological innovation from global scientific research teams, the industry has completed a full development cycle spanning cross-civilizational textual research on tea and herbal classics & discovery of characteristic active polyphenol EGCG, full verification of cellular and molecular pharmacological pathways for photoprotection, fat loss and anti-inflammation, formulation of low-temperature airtight directional enrichment & purification, green supercritical $CO_2$ / subcritical water extraction, selective decaffeination and microcapsule stabilization processes, large-sample human clinical evidence of skin and metabolic fat-loss efficacies, and full independent technological catch-up of domestic integrated extraction and purification processes. Full-chain technological upgrading has been achieved from authentic fresh green tea leaves from the Jiangnan region and traditional dried tea beverages to core global functional plant raw materials across four industrial tracks.

Compared with traditional dark high-caffeine crude concentrated decoctions produced via prolonged high-temperature boiling, standardized composite green tea polyphenol extracts feature core differentiated advantages derived from four flagship processes: nitrogen-shielded low-temperature ultrasonic airtight extraction, gradient separation via supercritical $CO_2$ / subcritical water, synchronous decolorization, debittering and selective caffeine enrichment via two-stage modified resins, and water-soluble stabilization modification with nanocapsules. These advantages include stable total polyphenol content, high EGCG enrichment, extremely low caffeine levels, mild bitter astringency and irritation resistance, strong storage stability against oxidative browning, improved water solubility compatible with all dosage forms, and a sound compliance system covering four global tracks: cosmetics, food, health foods and pet feed. The products precisely align with global consumer trends for natural sunscreen anti-inflammatory skincare, weight-management fat-loss dietary supplements, additive-free food preservatives and natural pet bacteriostasis & immune support.

In the future, driven by iterative green solvent-free extraction processes, development of customized products for segmented consumer groups, nanoliposome transdermal embedding technology and emerging efficient directional biosynthesis of EGCG via synthetic biology, green tea extracts will maintain a core position in tracks for natural antioxidant sunscreen raw materials, metabolism-regulating dietary supplements and natural food preservatives, evolving into an indispensable landmark domestic characteristic functional plant raw material for global cosmetics, oral big health industries, food manufacturing and pet nutrition sectors.