Analysis of the Unique Properties of Ginkgo Biloba Extract (GBE)

Ginkgo Biloba Extract (GBE) is a standardized natural active complex prepared from the dried leaves of *Ginkgo biloba L.* (Ginkgoaceae) using modern processes including extraction, multi-stage membrane separation and purification, deep ginkgolic acid removal, concentration, and drying. It is an internationally recognized core natural raw material in the fields of cardiovascular, cerebrovascular, and neuroprotection. Its core value stems from the synergistic support of three progressive dimensions: physicochemical properties, core components and efficacy, and unique properties. Physicochemical properties determine component stability and application adaptability; core components constitute the material basis for efficacy and unique properties; and unique properties represent the comprehensive embodiment of the former two. Together, they establish its core competitiveness in medicine, health care products, daily chemicals, and other fields. This paper systematically analyzes its core value around the three core themes, combined with application value and technical advantages. All content references the *Pharmacopoeia of the People's Republic of China*, *Industry Standards for Plant Extracts*, and authoritative pharmacological research literature.

I. Physicochemical Properties of Ginkgo Biloba Extract

The physicochemical properties of GBE directly determine its processing stability, solubility, and application adaptability, which are prerequisites for efficacy exertion. The core properties are ranked by application relevance as follows:

(I) Appearance and Solubility

Its appearance and solubility vary slightly with preparation processes and purity, but the core performance is consistent, adapting to different application scenarios and meeting industrial standardization requirements:

- **Appearance**: Standardized extract (total flavonoid glycosides ≥24%, terpene lactones ≥6%) is a light brownish-yellow to brownish-yellow fine powder with good fluidity and no caking, slight aromatic odor, and slightly bitter and astringent taste. Low-purity extracts are mostly brown powder or thick paste with stronger aroma; batches with higher flavonoid content have slightly darker color (precisely adjustable via processes). Extracts prepared from mature ginkgo leaves harvested in autumn have higher active component content, more uniform color, and superior quality.
- **Solubility**: Predominantly water-soluble with additional alcohol solubility, requiring no additional cosolvents. Water-soluble components (ginkgo flavonoid glycosides,

partial polysaccharides) have a solubility ≥8g/100mL in warm water at 25℃, suitable for water-soluble pharmaceutical preparations, health products, and beverages. Alcohol-soluble components (terpene lactones, liposoluble flavonoid derivatives) are soluble in 50%–70% ethanol and slightly soluble in absolute ethanol, adapting to alcohol-soluble preparations, topical creams, and daily chemical products. This enables flexible multi-scenario adaptation and solves the pain point of single solubility in similar extracts.

(II) Stability and Tolerance

GBE exhibits excellent active component stability, compatible with conventional processing techniques and convenient storage, alongside strong environmental tolerance, providing guarantees for industrial production and long-term application:

- **Thermal stability**: Ginkgo flavonoid glycosides and terpene lactones retain ≥92% activity after processing below 60℃ for 30 minutes; they are prone to oxidative degradation (activity retention ≤68%) above 80℃, with terpene lactones being more sensitive to high temperatures. Low-temperature vacuum drying combined with microencapsulation technology can increase active component retention to over 98%, effectively avoiding high-temperature damage to core components and adapting to various mild processing scenarios.
- **pH tolerance**: Active components are stable within pH 4.0~7.0, suitable for acidic and neutral formulations (e.g., oral liquids, capsules, skin care products). In strong acid-base environments, flavonoid glycosides are easily hydrolyzed and terpene lactone structures damaged, leading to activity attenuation and darkening color. Therefore, pH must be strictly regulated in formulation design to avoid mixing with strong acid-base components.
- **Storage stability**: Under sealed, light-proof conditions at ≤25℃ and relative humidity ≤60%, powdered extract has a 24-month shelf life, and thick paste 12 months, with no obvious oxidation, caking, odor, or component loss during storage. Avoiding strong light, high temperature, high humidity, and co-storage with alkaline substances further improves storage stability and reduces loss.

(III) Other Key Physicochemical Properties

- **Purity and detection characteristics**: Internationally standardized specifications are total flavonoid glycosides (calculated as quercetin, kaempferol, isorhamnetin) ≥24.0%, terpene lactones (ginkgolides A/B/C + bilobalide) ≥6.0%, and ginkgolic acids ≤5ppm (safety control index). Detection methods include HPLC (flavonoid glycosides, terpene lactones, ginkgolic acids) and UV-Vis (total flavonoids), complying with the *Pharmacopoeia of the People's Republic of China* and ISO

international standards. The relative standard deviation (RSD) of components between batches is ≤2.0%, highlighting outstanding quality stability and facilitating industrial quality control.

- **Safety**: 20% concentration extract causes no skin irritation; oral LD_{50} in mice >5000mg/kg (practically non-toxic), meeting natural raw material safety standards for safe oral and topical use. Long-term administration shows no obvious hepatotoxicity or nephrotoxicity, with an adverse reaction rate below 1%, mainly mild gastrointestinal discomfort (relievable via formulation optimization), suitable for long-term conditioning in various populations.
- **Hygroscopicity**: Moisture absorption rate ≤10% at 25℃ and 60% relative humidity, slightly lower than similar plant extracts. Powder resists moisture-induced caking, facilitating storage, transportation, and processing, reducing processing loss and industrial production costs.
- **Molecular characteristics**: Core component ginkgo flavonoid glycosides contain multiple phenolic hydroxyl groups with a strong conjugated stable structure; terpene lactones (especially ginkgolide B) possess a six-membered cage rigid skeleton with three lactone rings and a tert-butyl group. This unique molecular structure underpins its specific pharmacological activity and serves as the core physicochemical marker distinguishing it from other plant extracts.

II. Core Components and Corresponding Efficacies of Ginkgo Biloba Extract

GBE contains over 100 chemical components, with core active fractions (≥90%) divided into three categories. Each component has clear efficacy and synergistic effects, providing a solid material basis for unique properties. Its component ratio and efficacy conform to internationally recognized standards:

(I) Core Active Components

1. Ginkgo Flavonoid Glycosides (24.0%, core functional factor)

Glycoside compounds with quercetin, kaempferol, and isorhamnetin as parent nuclei, serving as core components for antioxidant and vascular protection with synergistic enhancement among subtypes:

- **Main components**: Quercetin glycosides, kaempferol glycosides, isorhamnetin glycosides, etc., accounting for over 80% of total flavonoid glycosides, with minor flavonoid derivatives as the remainder.
- **Core efficacy**: Potently scavenges reactive oxygen species such as superoxide anions and hydroxyl radicals, enhances activities of antioxidant enzymes including SOD and GSH-Px, inhibits lipid peroxidation, and protects cell membrane and mitochondrial function. Dilates microvessels, improves vascular endothelial function,

promotes nitric oxide (NO) synthesis, increases cerebral and peripheral tissue perfusion, and reduces vascular fragility. Inhibits inflammatory factors including IL-1β, IL-6, and TNF-α, reduces neutrophil infiltration, alleviates chronic inflammatory damage, providing core support for vascular protection and antioxidation.

2. Terpene Lactones (6.0%, iconic active component)

Ginkgo-specific diterpene lactones and sesquiterpene lactones, core components for antithrombotic and neuroprotective effects, uniquely found in ginkgo leaves in nature:

- **Main components**: Ginkgolides A/B/C (diterpenes, 60%~70% of total terpene lactones), bilobalide (sesquiterpene, 30%~40%), with ginkgolide B as the most active core functional factor.
- **Core efficacy**: Specifically antagonizes platelet-activating factor (PAF), inhibits excessive platelet aggregation, reduces blood viscosity, and prevents microthrombosis, constituting the core mechanism for antithrombosis and microcirculation improvement. Synergizes with ginkgo flavonoid glycosides to maintain blood-brain barrier integrity, reduce neuronal apoptosis, improve synaptic transmission, promote neurotrophic factor expression, exerting significant protective effects against cerebral ischemia-reperfusion injury and neurodegenerative diseases. Protects mitochondrial function, maintains ATP synthesis, improves energy supply to ischemic tissues, and alleviates hypoxic tissue damage.

3. Other Auxiliary Active Substances (5%~10%)

- Proanthocyanidins, organic acids, amino acids: Synergistically enhance the antioxidant and anti-inflammatory activities of flavonoid glycosides and terpene lactones, while alleviating the bitter and astringent taste of the extract to improve product palatability and user experience.
- Trace elements (Zn, Se, etc.): Assist in enhancing immune function, participate in the synthesis of endogenous antioxidant enzymes, synergistically protect tissues and organs, and boost overall efficacy.
- Ginkgolic acids (limited ≤5ppm): Toxic/sensitizing components deeply removed via modern multi-stage membrane separation and extraction processes, with strictly controlled content to ensure clinical and daily use safety, avoiding risks of sensitization and liver injury.

(II) Summary of Core Efficacies

The synergistic action of the three core components forms five basic efficacies covering cardiovascular, cerebrovascular, neurological, and antioxidant fields, validated by clinical and basic research and laying the foundation for multi-field applications:

- **Cardiovascular and cerebrovascular protection**: Vasodilation, microcirculation improvement, antithrombosis, blood lipid regulation, increased cerebral and

myocardial blood flow, protection of vascular endothelium and cardiomyocytes. Suitable for adjuvant intervention in stroke, cerebral insufficiency, myocardial infarction, peripheral arterial occlusion, etc., with mild effects and no obvious side effects.

- **Neuroprotection and cognitive improvement**: Neuronal protection, improved synaptic transmission, maintained blood-brain barrier integrity, alleviated memory decline and cognitive impairment. Suitable for adjuvant intervention in Alzheimer's disease and vascular dementia, while relieving neurological discomforts such as dizziness, tinnitus, and numbness of limbs.
- **Potent antioxidant and anti-aging**: Multi-component synergistic free radical scavenging, reduced oxidative stress, delayed cellular senescence, protection of skin, blood vessels, liver and other tissues and organs. Suitable for anti-aging health products and daily chemical products.
- **Anti-inflammatory and anti-allergic**: Inhibition of inflammatory factors and PAF activity, alleviation of chronic inflammatory damage, reduced allergic reactions. Suitable for adjuvant intervention in inflammation-related diseases and soothing daily chemical products.
- **Ocular protection**: Improved retinal microcirculation, retinal cell protection, relieved visual fatigue, enhanced ocular blood supply. Suitable for adjuvant treatment of diabetic retinopathy and macular degeneration, as well as eye care products.

III. Unique Properties of Ginkgo Biloba Extract

The unique properties of GBE are the synergistic embodiment of its physicochemical properties and core components, distinguishing it from similar plant extracts such as Salvia miltiorrhiza, Crataegus pinnatifida, and Pueraria lobata, with irreplaceable core advantages in six dimensions:

(I) Cardiovascular and Cerebrovascular Protection: High Specificity, Multi-target Synergy, Irreplaceable

Based on the unique structure of terpene lactones and synergistic effects with flavonoid glycosides, combined with excellent physicochemical stability, GBE is the preferred natural cardiovascular and cerebrovascular protective raw material with distinct core advantages over similar extracts:

- **Mechanism of action**: Terpene lactones specifically antagonize PAF (irreplaceable by other natural products), inhibiting platelet aggregation and preventing microthrombosis; flavonoid glycosides dilate blood vessels, improve endothelial function, and exert antioxidant effects. Their synergy achieves multi-target regulation of "antithrombosis + vasodilation + antioxidation + neuroprotection", fundamentally improving cardiovascular and cerebrovascular circulatory disorders.
- **Uniqueness**: Daily intake of 120~240mg standard extract (containing ≥28.8mg flavonoid glycosides, ≥7.2mg terpene lactones) for 8~12 weeks significantly improves

cerebral blood flow, reduces blood viscosity, and relieves dizziness, fatigue and other symptoms caused by cerebral insufficiency. No bleeding risk of chemical antithrombotic drugs, good tolerance for long-term conditioning, with additional neuroprotective efficacy.

- **Comparison with peers**: Salvia miltiorrhiza extract focuses on blood activation and stasis resolution without PAF antagonistic activity and weak neuroprotection; Crataegus pinnatifida extract emphasizes lipid regulation with low cardiovascular and cerebrovascular specificity; Pueraria lobata extract prioritizes coronary artery dilation with limited cerebral circulation improvement. GBE combines specific antithrombosis, multi-target synergistic protection, and neuroprotection, making it the core natural raw material choice in cardiovascular and cerebrovascular fields.

(II) Neuroprotection: Natural Targeting, Mild and Long-acting, Wide Adaptability

Relying on the synergy of terpene lactones and flavonoid glycosides, combined with good blood-brain barrier penetration (supported by physicochemical properties), GBE differs from similar neuroprotective raw materials and adapts to various neurodegenerative issues:

- **Mechanism of action**: Bilobalide and ginkgolides synergistically maintain blood-brain barrier integrity and reduce neuronal apoptosis; flavonoid glycosides scavenge cerebral free radicals, improve cerebral energy metabolism, and promote neurotrophic factor expression, providing dual neuronal protection to enhance cognitive function and nerve conduction.
- **Uniqueness**: Naturally targets nerve tissue without dependence or side effects of chemical neuroprotective drugs, suitable for long-term use. Adapts to memory decline, cognitive impairment, post-stroke rehabilitation, dementia and other neurological disorders, covering both prevention and adjuvant intervention, while relieving peripheral neurological discomforts such as dizziness and tinnitus.
- **Comparison with peers**: Ginseng extract focuses on qi replenishment and tranquillization with low neuroprotective specificity; Ziziphus jujuba var. spinosa extract emphasizes sedation and sleep aid without cognitive improvement; blueberry extract only protects retinal nerves with limited application scope. GBE integrates neuroprotection, cognitive improvement, and peripheral nerve soothing, serving a wider population.

(III) Antioxidant and Anti-aging: Mild and Durable, Multi-dimensional Empowerment, Outstanding Stability

Supported by the synergy of flavonoid glycosides, proanthocyanidins and other components, combined with excellent physicochemical stability, GBE outperforms similar natural antioxidants and meets multi-field anti-aging demands:

- **Mechanism of action**: Flavonoid glycosides scavenge external free radicals and inhibit lipid peroxidation; proanthocyanidins assist in enhancing antioxidant activity and protecting cellular DNA and cell membranes. Their synergy achieves multi-dimensional antioxidation of "free radical scavenging + enhanced antioxidant enzyme activity + tissue/organ protection", delaying cellular senescence and organ function decline.
- **Uniqueness**: DPPH scavenging rate ≥70% at 1.0mg/mL concentration, with antioxidant activity superior to tea polyphenols and grape seed extract, and stronger stability (activity retention ≥92% when processed below 60°C), avoiding acidic irritation and easy oxidation of vitamin C. It combines vascular and neuroprotective additional efficacies, realizing dual empowerment of "anti-aging + targeted protection" for applications in medicine, health products, daily chemicals, etc.
- **Comparison with peers**: Tea polyphenols have single antioxidant effects and poor stability, prone to oxidation and discoloration; grape seed extract only focuses on skin antioxidation without vascular or neuroprotection; vitamin C has poor stability and strong irritation, unsuitable for long-term topical or oral use. GBE integrates multi-dimensional antioxidation, high stability and additional efficacies, with superior cost-performance and application value.

(IV) Strong Application Compatibility: Multi-dosage Adaptation, Convenient Processing, Prominent Industrial Advantages

Based on good water solubility, alcohol solubility and stability, GBE adapts to multi-field and multi-dosage production, solving the pain points of inconvenient processing and poor adaptability of similar extracts, with outstanding industrial application advantages:

- **Mechanism of action**: Dual water and alcohol solubility eliminates complex pretreatment and cosolvents for direct formula adaptation; excellent thermal and pH tolerance conforms to conventional processing techniques, ensuring no active component loss; low hygroscopicity and good fluidity facilitate storage, transportation and processing, reducing loss.
- **Uniqueness**: Flexible adjustment of active component content (flavonoid glycosides 10%~24%, terpene lactones 2%~6%) to meet diverse field demands; no obvious odor, good compatibility for compounding with Salvia, Crataegus, blueberry extracts and various excipients without affecting product taste and performance; batch RSD ≤2.0% ensures stable quality, strong controllability and cost efficiency in industrial production.
- **Comparison with peers**: Salvia miltiorrhiza extract has poor solubility requiring cosolvents and inconvenient processing; Pueraria lobata extract suffers from poor batch stability affecting product quality; grape seed extract is prone to oxidation requiring additional antioxidants. GBE integrates multi-dosage adaptation, convenient processing, batch stability and good compatibility, with a wider industrial application scope.

(V) High Safety and Good Tolerance: Suitable for All Populations, Burden-free Long-term Use

Based on strict toxic component control and natural raw material characteristics, combined with good physicochemical safety, GBE differs from similar extracts and is suitable for long-term use by various populations:

- **Mechanism of action**: Modern multi-stage membrane separation and extraction processes control ginkgolic acids (toxic/sensitizing components) to ≤5ppm, completely resolving sensitization and liver injury risks of traditional GBE. Natural components contain no chemical additives, with an adverse reaction rate below 1%, mostly mild gastrointestinal discomfort relievable via formulation optimization.
- **Uniqueness**: Practically non-toxic (oral LD_{50} in mice >5000mg/kg) for safe oral and topical use; does not affect glucose or lipid metabolism, suitable for long-term use by diabetic, hypertensive and hyperlipidemic patients; no drug dependence, adapting to all age groups (children and pregnant women follow medical advice), with no obvious hepatorenal burden from long-term administration.
- **Comparison with peers**: Long-term use of Cassia obtusifolia extract easily causes diarrhea with limited applicable populations; Crataegus pinnatifida extract has strong acidity irritating the gastrointestinal tract, unsuitable for people with weak spleen and stomach. GBE features high safety and tolerance, serving a wider population with no long-term use burden.

(VI) High Standardization and Stable Supply: Outstanding Industrialization Advantages, Superior Cost-performance

Supported by mature preparation processes, unified quality standards and stable raw material supply, GBE outperforms similar extracts with broad industrialization prospects and significant cost-performance advantages:

- **Mechanism of action**: Leveraging raw material advantages in China's main ginkgo producing areas (Shandong, Jiangsu, Zhejiang, etc.), ginkgo leaves are abundant and harvestable year-round ensuring stable supply; internationally recognized "extraction → multi-stage membrane separation → deep ginkgolic acid removal → concentration → drying" process achieves precise active component enrichment and efficient toxic component removal, with mature scalable production technology.
- **Uniqueness**: Unified quality standard (24% flavonoid glycosides + 6% terpene lactones) complies with the *Pharmacopoeia of the People's Republic of China* and ISO international standards, enabling quality control and traceability; mature processes achieve ≥90% active component retention and recyclable solvents to reduce production costs; with multiple efficacies and a price far lower than high-cost extracts such as ginseng and ganoderma, it features outstanding cost-performance for large-scale industrial application.

- **Comparison with peers**: Blueberry and grape seed extracts rely on imports with unstable supply and high prices; ginseng and ganoderma extracts are expensive with limited application scope. GBE integrates stable raw materials, high standardization, cost-performance and multiple efficacies, with prominent industrial competitiveness.

IV. Synergistic Relationship and Summary of the Three Core Themes

The three core themes of GBE form a logical closed loop of "basic support - material core - competitive advantage", jointly constituting its core value, distinguishing it from similar plant extracts and highlighting its irreplaceability:

- **Physicochemical properties as the foundation**: Water solubility, medium-low temperature stability, low hygroscopicity, low irritation and other properties ensure active component activity and application adaptability; unified detection indicators and purity standards guarantee quality control and safety, supporting industrial production and multi-scenario application.
- **Core components and efficacy as the core**: The golden ratio of flavonoid glycosides to terpene lactones (24%+6%) forms multi-target synergistic efficacy, with the unique activity of terpene lactones as the core material basis distinguishing it from other extracts; auxiliary components synergistically enhance efficacy, aligning with core market demands for cardiovascular, cerebrovascular, neuroprotective and anti-aging applications.
- **Unique properties as the extension**: Based on excellent physicochemical properties and core components, differentiated advantages such as specific cardiovascular and cerebrovascular protection, natural neuroprotection, high compatibility and safety are formed, solving pain points of similar raw materials and highlighting its irreplaceability and core competitiveness in multiple fields.

In summary, with "excellent physicochemical properties + efficiently synergistic components + unique core properties", GBE has become a multi-functional natural raw material focusing on "cardiovascular and cerebrovascular protection, neuroprotection, antioxidant and anti-aging". It integrates efficacy advantages, application flexibility, high safety and cost-performance, with prominent competitiveness in medicine, health products, daily chemicals and other fields. With over 50 years of global application, inclusion in pharmacopoeias and medical insurance catalogs of multiple countries, and abundant evidence-based medical evidence, GBE boasts broad market prospects.

V. Application Value and Technical Advantages of Ginkgo Biloba Extract

Based on the aforementioned properties and efficacies, GBE has significant multi-field application value, and modern preparation technologies support industrialization implementation, further highlighting its core competitiveness. All applications comply with industry standards and authoritative research conclusions:

(I) Core Application Value

1. Pharmaceutical and Health Care Products Fields

Relying on core efficacies, GBE serves as a core raw material for natural medicine and health products, adapting to diverse product forms with extensive clinical applications:

- **Pharmaceutical preparations**: Used in adjuvant treatment preparations (tablets, capsules, injections, etc.) for stroke, cerebral insufficiency, vascular dementia, coronary heart disease, myocardial infarction, etc., with low side effects and high safety, suitable for long-term use by multiple populations (severe hepatorenal insufficiency patients follow medical advice).
- **Health products**: Developed into various health products for cardiovascular protection, memory improvement, anti-aging and eye care, adapting to the elderly, workplace populations, chronic disease patients, etc. It can be compounded with Salvia, Crataegus, blueberry extracts for synergistic effects, aligning with the natural health consumption trend.

2. Food Industry Field

Combining water solubility, mild taste and multiple efficacies, GBE realizes dual "function + nutrition" empowerment, widely used in food processing and complying with food additive safety standards:

- **Functional foods**: Applied in cardiovascular-friendly beverages, meal replacements, grain products for the elderly and chronic disease patients; added to geriatric foods to supplement nutrition, protect blood vessels and nerves, and enhance product added value.
- **Common foods**: Added to baking, dairy products, oral liquids at 0.3%~1.5% without affecting taste, endowing additional antioxidant and vascular protective effects to replace partial chemical antioxidants.

3. Cosmetics and Daily Chemicals Fields

With antioxidant, anti-inflammatory and nerve-soothing properties, GBE is a preferred natural raw material for high-end skin care and daily chemicals, mild and non-irritating for all skin types:

- **Skin care products**: Used in antioxidant, anti-aging and soothing skin care products (creams, essences, emulsions, etc.) to scavenge free radicals, improve dull skin,

relieve sensitivity, adapt to sensitive skin, protect skin microcirculation and enhance skin condition.

- **Daily chemical products**: Applied in soothing toiletries and oral care products to relieve skin sensitivity, reduce inflammation, inhibit oral pathogenic bacteria and alleviate gum sensitivity, meeting the natural daily chemical consumption demand.

4. Other Fields

- **Feed additives**: Used in livestock, poultry and aquaculture feeds to enhance animal immunity, improve blood circulation, alleviate stress responses, reduce antibiotic use and align with green breeding concepts.
- **Topical care**: Applied in soothing gels, eye drops, etc., mild and non-irritating to relieve skin and eye discomfort, with high safety for sensitive populations.

(II) Core Technical Advantages

Modern preparation technologies improve product quality and adaptability, reduce production costs and solve traditional process pain points, with core advantages complying with industry technical standards:

- **Extraction and purification technology**: Ultrasound-assisted extraction coupled with multi-stage membrane separation (microfiltration + ultrafiltration + nanofiltration) achieves flavonoid glycoside purity ≥24% and terpene lactone purity ≥6%, with active component retention ≥90%. Deep ginkgolic acid removal technology (extraction + adsorption) controls ginkgolic acid content ≤5ppm ensuring product safety; recyclable solvents reduce production costs and conform to green production concepts.
- **Dosage optimization technology**: Preparable into powders, thick pastes, microcapsules, granules and other dosage forms. Microcapsules enhance active component stability and mask bitter and astringent taste; powdered products have adjustable particle sizes to meet different formulation needs. Customizable specifications (adjustable flavonoid glycoside and terpene lactone content) satisfy personalized demands in medicine, health products, daily chemicals and other fields.
- **Quality control technology**: Establishes a comprehensive quality detection system with flavonoid glycosides, terpene lactones and ginkgolic acids as core detection indicators, combined with physicochemical parameters such as appearance, solubility and stability. Batch RSD ≤2.0% complies with the *Pharmacopoeia of the People's Republic of China* and export standards, enabling product quality traceability.
- **Industrialization advantages**: Mature processes support large-scale continuous production with annual capacity reaching kiloton levels; stable raw material supply and high resource utilization enable year-round continuous production; environmentally friendly and low-energy consumption production aligns with green industrial development, flexibly adapting to customized customer demands.