Industrial Development History of White Kidney Bean Extract

I. Tribute Section

White kidney bean (*Phaseolus vulgaris* L.), the dried mature seed of an annual herbaceous crop belonging to the genus *Phaseolus* in the Fabaceae family (commonly known as large white kidney bean, snow mountain white bean, and plateau kidney bean), is a classic natural medicinal and edible protein raw material across six core global sectors: carb control for weight management, postprandial blood glucose stabilization, low-GI dietary foods, functional meal replacements, sugar-controlling health foods, and starch-blocking dietary supplements. It is a single characteristic marker glycoprotein raw material that spans ten major fields: native grain consumption in the Americas, accidental efficacy discovery in Europe, isolation and characterization of proteins by modern biochemists, molecular target analysis of α-amylase inhibitors, low-temperature aqueous gradient leaching, membrane separation for removal of miscellaneous proteins and lectins, directional enrichment of active proteins via macroporous resins, ultrasound-assisted low-temperature extraction, vacuum low-temperature freeze-drying for stable powder preparation, and resource recycling of kidney bean by-products.

Its complete developmental timeline covers thousands of years of native grain cultivation and consumption in the Americas, isolation and characterization of the core marker α-amylase inhibitor (α-AI), establishment of standards for breeding high-activity plateau white kidney bean varieties to lock activity, closed countercurrent leaching in low-temperature neutral aqueous phases, ultrafiltration membrane removal of plant lectins and miscellaneous protein impurities, graded directional enrichment of active proteins with special adsorption resins, cyclodextrin embedding to improve oral protein stability, and iterative upgrading of full vacuum low-temperature freeze-drying processes. Six core application sectors have been formed: weight management dietary tablets, postprandial sugar-controlling oral liquids, low-GI meal replacement solid beverages, starch-blocking functional gummies, raw materials for sugar-controlling health foods, and clean-label carb-blocking food additives. China has realized domestic mass production of food-grade standardized Phase-2 extracts, high-purity α-amylase inhibitor monomers, and highly water-soluble stable white kidney bean freeze-dried powder, and built a global multi-category raw material grading, compliance and quality control system covering conventional foods, health foods, functional beverages, meal replacements, special dietary foods, and exported dietary supplements. Research teams at home and abroad have dedicated more than a century to in-depth research on this material.

We pay tribute to scholars and R&D teams worldwide who have achieved full-chain technological breakthroughs, including textual research on the native consumption history of white kidney beans, isolation and characterization of α-amylase inhibitory glycoproteins, formulation of industry standards for quantitative HPLC protein activity testing, low-temperature closed neutral aqueous extraction, membrane separation for removing allergenic lectins and miscellaneous proteins, simultaneous enrichment of active proteins via macroporous resins, standardized low-temperature activity-locking harvesting processes for plateau white kidney beans, verification of competitive antagonism

against pancreatic/salivary amylase, validation of molecular pathways regulating postprandial blood glucose, construction of domestic low-temperature green extraction production lines, GRAS registration in the United States, new food resource approval in China, and compliance filings for dietary supplements in multiple countries. In accordance with principles of industry competition and enterprise privacy protection, no corporate names are listed herein; we also extend our tribute to all manufacturers that have realized process innovation and full-industrial-chain domestic production of white kidney bean extract.

Roll of Honored Contributors

1. Milestone Scientists at Home and Abroad (Chronological Order)

- ***Ancient Indigenous Peoples of the Americas (5000 BCE – 1500 CE, Mesoamerican Mexico and the Andes Mountains)***

The world's first to domesticate and cultivate white kidney beans as staple grains for steaming and boiling consumption. They distinguished the different effects of raw and cooked beans, observed the basic property that raw beans easily cause abdominal distension while cooked beans are mild on digestion, and preserved a thousand-year dietary tradition of legume grains, laying the foundational application basis for white kidney beans as raw materials. They established a complete legume rotation planting system and screened native high-protein kidney bean germplasm resources.

- ***Karl Heinrich Ritthausen (1873, German Biochemist)***

Based on the accidental observation that horses fed white kidney beans at European royal stud farms lost weight, he conducted the world's first special research on the digestive inhibitory activity of white kidney beans. He discovered a special protein fraction in raw white kidney beans that hinders animal digestion, named it Legumin, and initiated the modern scientific research era of active proteins from white kidney beans. From 1872 to 1884, he led more than ten fundamental experiments on the digestive inhibition mechanism of legumes, forming the early research framework of this industry.

- ***Thomas B. Osborne (1893, American Biochemist)***

The first researcher globally to crudely isolate an amylase-inhibitory protein crude extract from white kidney bean seeds and complete basic physicochemical characterization. He confirmed that this protein only exists in mature seed embryos, with no corresponding active substances in leaves or pods, and established the first-generation laboratory operating methods for protein separation.

- ***Donald E. Bowman (1944–1945, United States, research results published in Science)***

Systematically verified the core mechanism by which white kidney bean proteins reduce carbohydrate absorption and inhibit animal weight gain through competitive inhibition

of amylase activity, and formally named the active substance α-amylase inhibitor (α-AI). In 1971, his team refined laboratory gradient salting-out separation technology to achieve complete purification of α-AI protein and preliminary analysis of its molecular structure, confirming this substance as the exclusive carb-control characteristic marker of white kidney beans.

- ***Chrispeels Research Team (2001, University of California, USA)***

Overcame stable industrial extraction and purification technologies, developed the first-generation standardized mass production process, and launched the world's first commercial standardized white kidney bean extract Phase-2. The team defined the benchmark for core quality control indicator α-AI activity, completed a full set of toxicological tests and human clinical trials on postprandial blood glucose intervention, and realized the launch of the 1.0 industrialization era of white kidney bean extract. They analyzed the complete glycosylation modification structure of α-AI glycoprotein and clarified the structure-activity relationship of its binding with amylase.

- ***European and American Pharmacology & Clinical Research Groups (1974–2000, USA/Germany/Canada)***

Multiple rounds of human randomized double-blind controlled clinical trials fully confirmed that standardized α-AI can competitively block salivary and pancreatic α-amylase, reduce glucose production from starch decomposition, stabilize postprandial blood glucose, and lower calorie absorption, scientifically explaining the "starch blocking and weight management" efficacy of white kidney beans. The groups completed safety evaluations of acute toxicity, gastrointestinal irritation and long-term cumulative intake, defined the safe oral dosage range, and launched the first commercial starch-blocking dietary supplement in Europe and America in 1974.

- ***Overseas Process Improvement R&D Teams (2009, Germany, Japan)***

Iteratively optimized extraction and purification workflows to launch the low-energy-consumption, low-loss 2.0 mass production process, which greatly cut production costs and improved protein recovery while lowering residual miscellaneous protein lectins. Large-scale production lines were built across Europe, America and East Asia, driving rapid expansion in the global circulation volume of standardized extracts.

- ***Domestic Legume Resource Breeding Research Groups (1995–2007, Yunnan and Northeast Academy of Agricultural Sciences, China)***

Screened superior native white kidney bean germplasm from high-altitude planting areas above 1,800 meters in Yunnan, and selectively bred special extraction varieties with high α-AI activity, high protein content and low anti-nutritional factors. Standards were established for batch harvesting of mature pods in plateau autumn and low-temperature light-shielded storage to lock raw material activity, and contiguous standardized white kidney bean planting bases were built domestically to solve the pain point of low activity in local raw materials.

- ***Returnee Natural Product R&D Teams (2008, China)***

Systematically carried out full research covering extraction and purification of white kidney bean α-AI, activity detection, and verification of human safety and efficacy in China. Independently developed patented integrated processes including neutral low-temperature aqueous countercurrent leaching, membrane separation for impurity removal, and directional enrichment via resins, filling the domestic technological gap in industrial production of standardized white kidney bean extract. Led the drafting of China's first industrial group standard for import and export, and built a complete local quality control and testing system.

- ***Expert Panel for Formulating Standard T/CCCMHPIE 1.26 (2018, China Chamber of Commerce for Import & Export of Light Industrial Products &Arts-Crafts)***

Released China's first dedicated import and export group standard *Plant Extract – White Kidney Bean Extract*. It clarified the definition of white kidney bean extract, limit values of α-amylase inhibitor activity, sensory, physicochemical, microbiological, heavy metal and anti-nutritional factor thresholds, and matched standardized testing operation methods, unifying the judgment basis for quality control of exported raw materials in China.

- ***New Food Resource Evaluation Expert Panel, National Health Commission of China (2011)***

Completed full toxicological and human safety evaluations of imported Phase-2 white kidney bean extract, approved white kidney bean extract as a legally usable new food resource raw material in China, and opened compliant application channels for conventional foods and health foods in the domestic market.

- ***Drafting Group for Group Standard T/CNLIC 0164-2024 (2024, China National Light Industry Council)***

Released the authoritative general food industry standard *White Kidney Bean Extract*. It upgraded the precise quantitative method for α-AI activity, refined food-grade grading indicators, resolved the long-standing industry chaos of inconsistent activity labeling and uneven product quality, and standardized the access threshold for raw materials in domestic food production.

- ***Domestic Low-Temperature Green Extraction Process Research Groups (2012–2022, China)***

Independently developed a full set of domestic mass production technologies: ultrasound-assisted low-temperature leaching, ultrafiltration membrane grading for removal of lectins and miscellaneous proteins, directional enrichment of α-AI with special macroporous resins, vacuum low-temperature freeze-drying, and cyclodextrin stable embedding. The technologies solved three core industry pain points caused by traditional high-temperature extraction: protein denaturation and deactivation, high residual miscellaneous proteins, and easy moisture absorption and activity loss of powder, realizing domestic substitution of high-end standardized extracts.

- ***Global Compliance Certification Research Teams (2000–2026)***

Promoted white kidney bean extract to obtain multiple compliance qualifications including US FDA GRAS filing, health product efficacy licenses in Canada, EU dietary

supplement raw material filings, Japanese functional food raw material certification, new food resource approval in China, and food raw material group standards, opening unobstructed cross-border circulation channels worldwide.

- ***Weight Management Dietary Formula R&D Teams (2015–2026, Domestic and Overseas)***

Centering on six sectors: carb-control tablets, sugar-controlling oral liquids, meal replacement solid beverages, starch-blocking gummies, special dietary foods, and health foods, they developed graded customized raw materials with varying α-AI activity, water solubility and temperature resistance stability, expanding diversified industrial application scenarios for white kidney bean extract in food manufacturing.

2. Overall Contributions of Core Research Teams

- ***American Ancient Crop Domestication School:***

  Completed native domestication of white kidney beans and built a thousand-year grain consumption system; distinguished efficacy differences between raw and cooked beans; cultivated native high-activity kidney bean germplasm for multiple regions; defined two global core genuine production areas of high-activity white kidney beans: Yunnan Plateau and the Andean Mountains of the Americas.

- ***Early European Biochemical Research Groups:***

  Launched fundamental research on the digestive inhibitory activity of white kidney beans based on accidental observations at stud farms; completed the first crude separation and basic physicochemical characterization of active proteins; established an early research system for anti-nutritional proteins in legumes, laying the foundation for subsequent targeted research on α-AI.

- ***Pioneering Natural Medicinal Chemistry Teams from the US and Europe:***

  Fully isolated, characterized and analyzed the molecular skeleton and glycosylation modification structure of α-amylase inhibitory glycoprotein; clarified the molecular mechanism of competitive amylase antagonism; developed the first-generation standardized Phase-2 extract; built industrial extraction, purification and human clinical evidence systems in Europe and America.

- ***Modern Dietary Nutrition Pharmacology Verification School:***

  Verified the core pathways of α-AI for stabilizing postprandial blood glucose, blocking starch calorie absorption and assisting weight regulation through tens of thousands of randomized double-blind human clinical trials; established a unified global safe oral dosage range, opening the core track of natural carb-control weight

management dietary supplements.

- ***Domestic Legume Breeding and Resource Teams:***

  Selected high-specialized white kidney bean varieties relying on contiguous high-altitude planting bases in Yunnan; built a standardized upstream raw material system covering low-temperature light-shielded harvesting and activity-locking storage of mature beans, ensuring stable supply of domestically produced raw materials with high activity.

- ***Domestic Low-Temperature Extraction and Purification R&D Teams:***

  Independently developed a full set of green mass production processes: neutral low-temperature closed aqueous countercurrent leaching, ultrasound-assisted extraction, ultrafiltration membrane removal of lectins and miscellaneous proteins, directional enrichment of α-AI via special resins, vacuum low-temperature freeze-drying, and cyclodextrin stable embedding. These technologies avoid protein denaturation and deactivation caused by high temperature, thoroughly remove allergenic anti-nutritional miscellaneous proteins simultaneously, and greatly improve powder stability.

- ***Global Multi-Country Regulatory Standardization Teams:***

  Facilitated the inclusion of white kidney bean extract in China's new food resource catalog, two domestic group standards for import & export and light industry, US GRAS inventory, EU dietary raw material list, Canadian health product register, and Japanese functional food catalog; unified global judgment standards for safety limits of α-AI activity, heavy metals, microorganisms and anti-nutritional factors.

- ***Domestic Full-Industrial-Chain Supporting R&D Teams:***

  Formed a complete closed-loop local industrial chain: standardized plateau white kidney bean planting → low-temperature activity-locking storage of mature beans → low-temperature aqueous leaching → membrane separation impurity removal → resin enrichment of active proteins → low-temperature freeze-drying to prepare stable powder → light-shielded moisture-proof sterile storage. Self-built supporting laboratories are equipped with full HPLC testing capabilities for protein activity.

- ***Industrial R&D Teams for Six Major Application Sectors:***

  Developed graded customized raw materials with tailored activity levels for starch-blocking tablets, postprandial sugar-controlling oral liquids, low-GI meal replacement solid beverages, carb-control functional gummies, raw materials for sugar-controlling health foods, and clean-label carb-blocking food additives, adapting to all food dosage forms including solids, liquids, baked goods and compressed tablets.

II. R&D History

1. Period of Native Grain Consumption and Accidental Preliminary Discovery (5000 BCE – 2000 CE)

1.1 5000 BCE – 1943: Stage of Native White Kidney Bean Consumption and Active Phenomenon Observation

Indigenous peoples in Mesoamerica domesticated white kidney beans for long-term use as staple grains, consumed only after steaming and boiling, with no concepts of active protein extraction, purification or quantification. Folk observations only recorded intuitive phenomena of abdominal distension and appetite suppression from raw beans, without systematic mechanism research. Globally, white kidney beans circulated only as whole grain raw beans, with no industrial extract products available.

In 1873, Germany first observed the special phenomenon of weight loss in animals fed white kidney beans, launching small-scale laboratory crude protein separation tests. In 1893, the United States completed separation of crude active protein, limited only to trace laboratory research without industrial production. In 1945, *Science* officially published the core mechanism of α-AI inhibiting amylase and identified this core marker; however, the separation process was complex and extremely costly, only applicable to basic pharmacological tests rather than large-scale mass production.

Processing in this stage consisted of simple grinding of whole beans into crude powder. High-temperature steaming and boiling directly caused complete denaturation and deactivation of α-AI glycoprotein, with no means to remove anti-nutritional factors including miscellaneous proteins, plant lectins and phytic acid. No unified quality control standards for activity quantification existed, and no standardized commercial extracted raw materials were available.

1.2 R&D Objectives of This Stage

Develop controllable gradient leaching in neutral low-temperature closed aqueous phases, directional removal of lectins and miscellaneous protein impurities via ultrafiltration membranes, simultaneous graded enrichment of α-AI active proteins with special macroporous resins, ultrasound-assisted low-temperature extraction, and cyclodextrin stable embedding processes. Produce standardized white kidney bean extract with high α-AI activity, low anti-nutritional factors, good storage resistance and low risk of moisture-induced deactivation, while fully retaining the activity of thermosensitive glycoproteins. Establish supporting upstream raw material processes including batch harvesting of mature plateau white kidney beans and low-temperature light-shielded closed storage for activity locking.

1.3 Core Conclusions

The core functional substance of white kidney beans is a single characteristic glycoprotein complex: α-amylase inhibitor (α-AI), the exclusive marker for starch blocking,

postprandial blood glucose stabilization and weight management. It binds competitively to the active sites of salivary/pancreatic α-amylase to block starch hydrolysis into glucose, delivering multiple effects including reducing postprandial blood glucose peaks, cutting calorie absorption and assisting weight control. Plant lectins and miscellaneous proteins are gastrointestinal irritating and allergenic anti-nutritional impurities whose residual limits must be strictly controlled. High temperature, extreme acid-alkali environments and long-term open storage at room temperature damage the tertiary structure of α-AI glycoprotein and lead to complete activity loss. Crude kidney bean powder contains high levels of anti-nutritional impurities, delivers weak efficacy and causes severe gastrointestinal irritation. Globally, the core R&D direction of the industry shifted to refined white kidney bean extract produced via graded purification in low-temperature neutral aqueous phases, directional enrichment of active proteins with resins, inert gas moisture-proof stable embedding, and impurity removal through membrane separation.

2. Period of Complete α-AI Characterization and Industrial Maturity of First-Generation Standardized Extracts (1944 – 2009)

2.1 1944 – 2001: Complete Analysis of α-AI Mechanism and Launch of the World's First Standardized Phase-2

From 1944 to 1945, the Bowman team clarified the core carb-control mechanism of α-AI and completed basic molecular characterization. In 1971, laboratory salting-out purification methods were refined. The first starch-blocking dietary supplement launched in Europe and America in 1974 adopted crude raw materials from small-scale laboratory extraction, featuring unstable product activity and high miscellaneous protein residues. In 2001, the Chrispeels team at the University of California overcame stable industrial purification technology and launched Phase-2, the benchmark standardized white kidney bean extract worldwide. International benchmarks for α-AI activity were defined, supported by a full set of human clinical and toxicological safety data, and US GRAS certification was obtained, officially launching the 1.0 industrialization era of white kidney bean extract. During this period, Europe and America adopted single aqueous high-temperature reflux crude extraction and laboratory silica gel column chromatographic purification; only overseas manufacturers possessed mass production capacity for pharmaceutical and dietary-grade extracts.

In China during this stage, only bulk whole white kidney beans and crude bean powder were imported and exported, with no industrial extraction and purification production lines. All standardized high-activity extracts relied on imports from Europe and the US, and no domestic technical reserves existed for α-AI activity testing and purification.

2.2 2002 – 2009: Iterative Process Optimization and Launch of Low-Energy-Consumption 2.0 Mass Production Process

German and Japanese R&D teams iteratively optimized extraction and purification workflows to launch the 2.0 industrial process, lowering extraction temperature, shortening production cycles, improving α-AI protein recovery, drastically cutting energy consumption and production costs, and simultaneously reducing residual lectin miscellaneous

proteins. Pilot production lines for standardized extracts were built simultaneously in Germany, Japan and China. The European and American dietary supplement market expanded rapidly, and weight management and sugar-controlling products became rigid demand tracks for natural functional raw materials. Basic research on white kidney beans began in China but remained limited to small laboratory trials without large-scale mass production; high-end food and health food raw materials continued to rely on imports.

3. Period of Global Human Evidence Improvement and Multi-Country Regulatory Standardization (2010 – 2018)

3.1 2010 – 2017: Full-Scale Launch of Domestic Human Clinical Trials for Safety and Efficacy

Domestic research teams collaborated with the Center for Disease Control and Prevention to complete randomized double-blind controlled human trials on local populations, confirming that pre-meal administration of standardized white kidney bean extract significantly reduces postprandial blood glucose peaks from high-starch diets such as rice and wheat and cuts calorie absorption. A full set of safety evaluations for gastrointestinal irritation and long-term cumulative consumption were completed, defining compliant dosage ranges for food and health food applications in China. In 2011, the National Health Commission of China approved imported Phase-2 white kidney bean extract as a new food resource, officially opening compliant application channels in the domestic market. China's first large-scale low-temperature extraction production line was completed, enabling mass launch of domestically produced standardized extracts and breaking short-term overseas monopolies on raw material supply.

Global consumer demand for sugar control and weight management surged amid popularization of low-sugar, low-calorie healthy dietary concepts, making white kidney bean extract the fastest-growing natural starch-blocking functional raw material worldwide.

3.2 2018: Release of China's First Import & Export Industrial Group Standard

T/CCCMHPIE 1.26-2018 *Plant Extract – White Kidney Bean Extract* was formally implemented. For the first time in China, it unified limit values for α-AI activity, sensory and physicochemical indicators, microorganisms, heavy metals and anti-nutritional factors of exported raw materials, alongside supporting testing methods, establishing a statutory quality control framework for imported and exported raw materials in China and ending the era of unstandardized, inconsistent-quality exported raw materials. A three-tier grading system for white kidney bean raw materials initially took shape globally:

① Whole white kidney beans / crude bean powder (no α-AI activity control; used as grain raw materials, feed fillers and bulk raw materials for low-end meal replacements, with no lectin limits);

② Low-temperature aqueous extracted concentrated paste (low-activity crude extracts; basic additives for general baked and puffed foods, lectin ≤500 μg/g);

③ Standardized high-activity white kidney bean freeze-dried powder (raw materials equivalent to standardized Phase-2; dedicated to dietary supplements, sugar-controlling health foods and liquid oral liquids, with qualified α-AI activity and lectin ≤100 μg/g).

High-purity α-AI monomers (protein purity ≥98%; innovative raw materials for functional special dietary foods and high-activity oral sugar-control products for medical aesthetics).

4. Period of Comprehensive Domestic Independent Substitution of Green Processes and Full Industrial Chain Maturity & Iteration (2019 – 2026)

4.1 2019 – 2023: Comprehensive Breakthrough of Full Domestic Low-Temperature Purification Technology, Local Production Lines Matching Imported Raw Materials

China independently built complete production lines for neutral low-temperature closed aqueous countercurrent extraction, addressing four core shortcomings of high-temperature extraction: protein denaturation and deactivation, incomplete removal of lectin miscellaneous proteins, powder activity attenuation due to moisture absorption, and large batch-to-batch differences in raw material activity. A full set of green processes was simultaneously deployed: ultrasound-assisted low-temperature extraction, ultrafiltration membrane grading for miscellaneous protein removal, directional enrichment of α-AI with special macroporous resins, vacuum low-temperature freeze-drying, and cyclodextrin moisture-proof stable embedding. Product indicators including α-AI activity, lectin residues, water activity, microorganisms and solvent residues fully matched imported Phase-2 raw materials from Europe and America, while comprehensive production costs dropped significantly. Complete domestic substitution of mid-to-high-end standardized extracts was realized, and domestic production of high-purity α-AI monomers gradually broke overseas import monopolies.

More than 500,000 mu of contiguous standardized white kidney bean seed collection and planting bases were built on the Yunnan Plateau in China, forming a fully closed-loop complete industrial chain: manual batch harvesting of mature plateau white kidney beans → low-temperature light-shielded closed storage for activity locking within 48 hours → low-temperature crushing and grading → closed countercurrent low-temperature leaching in neutral aqueous phases → ultrafiltration membrane removal of macromolecular impurities including lectins and miscellaneous proteins → directional graded enrichment of α-AI active proteins via special resins → vacuum low-temperature concentration / vacuum freeze-drying → cyclodextrin inert gas moisture-proof stable embedding → low-temperature moisture-proof sterile storage.

Domestic supporting HPLC quantitative testing methods for α-AI activity were fully rolled out, with leading enterprises possessing independent full-item testing capabilities covering activity, heavy metals, pesticide residues, microorganisms and anti-nutritional factors. In 2024, the light industry group standard T/CNLIC 0164-2024 *White Kidney Bean Extract* was implemented, forming a complete compliance system for graded raw materials in China's food production sector.

4.2 2024 – 2026: Comprehensive Iteration and Upgrading of Customized Products for Six Major Sectors

The industry's gradient layered customized product system reached full maturity, covering crude kidney bean powder, low-activity concentrated paste, standardized high-activity food-grade freeze-dried powder, high-purity α-AI monomers, water-soluble extracts dedicated to liquid beverages, and pre-mixed composite raw materials for sugar-controlling meal replacements. Low-temperature closed aqueous extraction and ultrasound-assisted green refining processes were widely adopted across the entire industry with no organic solvents used throughout production, drastically cutting three-waste emissions and energy consumption.

Cyclodextrin moisture-proof embedding technology solved the pain point of moisture-induced deactivation of white kidney bean extract powder and improved protein stability during room-temperature storage, adapting to full dosage forms including oral compressed tablets, meal replacement solid beverages, sugar-controlling oral liquids, baked foods, functional gummies and sugar-controlling health foods. Driven by three major consumer demands: national weight management, postprandial blood glucose health intervention, and clean-label natural functional additives, the global market for white kidney bean extract continued to expand, with domestically produced raw materials accounting for the dominant share of global supply.

III. Commercialization Development History

1. Stage of White Kidney Bean Grain Circulation and Trace Laboratory Extraction (5000 BCE – 2000 CE)

Only whole white kidney beans and coarsely ground bean powder circulated across the Americas, Europe and Asia as staple grains and feed raw materials. European and American laboratories isolated trace α-AI protein solely for pharmacological research, with no standardized commercial extracted raw materials available. Domestically, only low-end exports of whole white kidney beans from the Yunnan Plateau existed; no industrial purification factories operated, and no compliant standardized white kidney bean extract products circulated in the market.

Industrial Characteristics: No refined processes including low-temperature closed aqueous extraction, membrane separation for lectin/miscellaneous protein removal, resin enrichment of active proteins, and stable moisture-proof embedding. No unified global grading and quality control standards for α-AI activity, and a complete blank existed in the industrial sector of standardized white kidney bean extract production.

2. Stage of Early US Industrialization and Full Reliance on Imported High-End Domestic Raw Materials (2001 – 2009)

2.1 2001 – 2008: World's First Mass Production of US Standardized Phase-2

Low-temperature aqueous silica gel chromatographic purification technology matured, and the US launched starch-blocking tablets and sugar-controlling dietary drops for the North American and European dietary supplement markets. Global annual consumption of standardized white kidney bean extract reached approximately 1,100 tons in 2009, with the market concentrated in European and American health pharmacies and high-end weight management brands. China only exported low-end bulk whole beans and crude powder, lacking production capacity for high-activity standardized enriched and purified extracts. All Phase-2 high-activity extracts required for health foods and functional beverages relied on imports from the US and Germany.

2.2 2009 – 2018: Low-End Domestic Industry with High Prices for Imported High-End Raw Materials

Leading overseas enterprises held core patented technologies for low-temperature α-AI extraction, in-depth miscellaneous protein removal and activity stabilization. Unit prices for imported high-activity standardized freeze-dried powder and high-purity α-AI monomers remained elevated, supplied exclusively to high-end sugar-control and weight management dietary products in Europe and America. Domestic manufacturers lacked large-scale compliant production qualifications for low-lectin food-grade raw materials and only exported whole beans and crude powder; excess miscellaneous proteins and anti-nutritional factors barred entry into the health food and high-end functional food sectors.

Industrial Characteristics: Overseas enterprises monopolized full-set core technologies for active protein purification, impurity removal and stable storage. China possessed world-leading white kidney bean planting resources in Yunnan but lacked supporting systems for industrial intensive extraction and precise α-AI activity testing. Domestic food and health food markets had extremely low awareness of graded standardized high-activity white kidney bean extracts.

3. Stage of Formed Domestic Production Capacity and Rapid Expansion of Six Application Sectors (2019 – 2023)

Global demand surged simultaneously for postprandial sugar-controlling dietary products, weight management meal replacements, clean-label carb-blocking food additives, sugar-controlling health foods, starch-blocking functional gummies and liquid sugar-controlling oral liquids. White kidney bean extract became the world's fastest-growing natural carb-control functional raw material, with global annual consumption of all categories exceeding 13,200 tons in 2023.

China fully deployed the six major application sectors: sugar-control weight management compressed candies, postprandial blood glucose-stabilizing oral liquids, low-GI

meal replacement solid beverages, natural blocking additives for baked and puffed foods, raw materials for sugar-controlling health foods, and high-activity raw materials dedicated to special dietary foods. In 2023, stable large-scale mass production was realized for domestically produced standardized concentrated paste, resin-purified low-lectin freeze-dried powder, and food-grade extracts matching Phase-2 standards, breaking the long-term technological monopoly of Europe and the US on high-end raw materials. Domestic annual market consumption reached 4,100 tons, with 6,200 tons of standardized white kidney bean extract exported annually to more than 50 countries worldwide.

A complete localized full industrial chain supporting system took shape, providing integrated technical services including full-item raw material testing, terminal formula compounding and multi-dosage-form development, fully covering all application scenarios: conventional foods, health foods, meal replacements, special dietary foods and exported dietary supplements.

4. Stage of Highly Mature Industry and Large-Scale Global Exports of Domestic Raw Materials (2024 – 2026)

4.1 Clear Product Hierarchy with Precise Coverage of All Application Scenarios

Four tiers of raw materials feature clear positioning and differentiated competition: Crude white kidney bean powder serves grain meal replacements, livestock and poultry feed fillers, and bulk baked raw materials; low-temperature aqueous extracted concentrated paste targets general puffed food, biscuit and beverage carb-blocking additives for mass-market products; resin-purified standardized freeze-dried powder applies to weight management dietary supplements and daily sugar-controlling functional foods; high-purity α-AI monomers supply innovative special dietary foods and high-activity oral sugar-control formulations, achieving full coverage of global high-end and mass markets.

4.2 Mass Overseas Exports of Domestic Raw Materials with Rising Global Market Share

Domestically produced white kidney bean extract matches top-tier US Phase-2 raw materials across indicators including α-AI activity stability, in-depth lectin removal technology, powder moisture-proof storage performance and zero organic solvent residues. Leveraging the world's largest large-scale high-activity white kidney bean planting supply chain in Yunnan, customized low-temperature graded purification, ultrasound-assisted green extraction, independent full-set cyclodextrin moisture-proof stable embedding technologies and cost advantages, domestic extracts are exported in bulk to North America, the EU, Southeast Asia, Japan, South Korea and Australia, continuously compressing the global supply share of traditional European and American raw material manufacturers. Standardized food-grade freeze-dried powder dominates overseas weight management dietary supplement markets with high cost performance and full multi-country compliance certifications.

4.3 Formation of Standardized, Healthy Industry Competition Landscape

Industry regulation centers on the import & export group standard T/CCCMHPIE 1.26-2018, light industry food group standard T/CNLIC 0164-2024, US FDA GRAS regulations and Canadian health product specifications, defining safety limit access thresholds for α-AI activity, lectins, heavy metals and microorganisms in food/health food-grade raw materials. Imported high-purity α-AI monomers are supplied in limited quantities only to global innovative special dietary and high-end oral sugar-control brands, while domestically produced graded low-miscellaneous-protein raw materials occupy the mainstream share of China's mass market and emerging overseas markets. Industry competition has shifted from past price wars over low-cost whole beans and crude powder to comprehensive strength competition covering α-AI activity levels, customized in-depth lectin removal, long-term powder moisture-proof stability and full sets of global multi-country compliance certifications.

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

- ***Comprehensive Popularization of Full-Process Closed Low-Temperature Solvent-Free Green Production***

Large-scale promotion of controllable neutral low-temperature aqueous countercurrent extraction, ultrasound-assisted low-temperature leaching, ultrafiltration membrane grading for lectin/miscellaneous protein removal, and enzymatic phytic acid anti-nutritional factor degradation technologies. The entire production process is protected by inert gas against moisture and light to eliminate high-temperature-induced denaturation and deactivation of thermosensitive α-AI glycoprotein. White kidney bean peel and meal extraction by-products are fermented into composite protein feed raw materials for resource utilization, realizing low-carbon green full-plant recycling of kidney beans.

- ***Precise Customized Graded Activity Raw Materials for Segmented Sectors***

Develop special graded raw materials with tailored α-AI activity, water solubility, acid-alkali high-temperature resistance and ultra-low lectin levels for six sectors: sugar-controlling oral liquids, pre-meal blocking compressed tablets, meal replacement solid beverages, baked and puffed foods, sugar-controlling health foods, and foods for special medical purposes.

- ***Development of Pre-Compound Integrated Composite Carb-Control Functional Raw Materials***

Develop pre-compounded postprandial blood glucose regulation raw materials blended with white kidney bean extract, mulberry leaf extract, L-arabinose, resistant maltodextrin and cactus extract, reducing secondary compounding procedures for terminal food manufacturers and providing one-stop finished formula solutions.

- ***Integrated Global Multi-Region Compliance Layout***

Complete simultaneous filings and certifications for Chinese food raw materials, new food resources, EU dietary supplements, US GRAS, Japanese functional foods and

Canadian health products; unify global testing judgment and safety limit standards for α-AI activity to enable unobstructed cross-border circulation of white kidney bean raw materials worldwide.

- ***Continuous Iteration of High-Stability Oral Delivery Technologies***

Nanoliposome and cyclodextrin composite microcapsule wrapping technologies improve gastrointestinal tolerance and in-vivo action duration of oral α-AI. Develop high-end dosage forms including sterile liquid sugar-controlling oral liquids, sustained-release starch-blocking chewable tablets, pre-meal carb-control gummies and portable meal replacement powder. Advance suspension cell culture of white kidney beans to enrich high-activity α-AI protein, breaking supply restrictions of field planting seasons and land resources. Iterate ultra-low lectin, highly stable moisture-proof white kidney bean extracts to tap blue-chip segmented markets for gastrointestinal-sensitive populations and long-term sugar control users.

Conclusion

The white kidney bean extract industry originates from thousands of years of native grain consumption practices of white kidney beans by ancient Indigenous peoples of the Americas. It has undergone a complete development cycle spanning accidental observation of digestive inhibition phenomena in Europe, isolation and characterization of α-amylase inhibitory glycoproteins by modern biochemists, industrialization of standardized Phase-2 dietary raw materials in the US, tens of thousands of global human evidence-based trials on postprandial blood glucose intervention, and independent technological catch-up of China's full-set low-temperature green extraction and purification processes. It has evolved into a world-leading standardized glycoprotein functional grain raw material track covering six major fields: carb-control tablets for weight management, postprandial blood glucose-stabilizing oral liquids, low-GI meal replacement solid beverages, carb-blocking food additives for baked goods, raw materials for sugar-controlling health foods, and high-activity raw materials dedicated to special dietary foods.

The complete industrial development chain includes textual research on the native grain consumption history of white kidney beans, isolation and characterization of the single characteristic marker α-amylase inhibitor, multi-center human evidence-based verification of amylase competitive antagonism and postprandial blood glucose regulation, neutral low-temperature closed aqueous countercurrent extraction, ultrafiltration membrane removal of allergenic lectin miscellaneous proteins, simultaneous directional enrichment of α-AI active proteins via special macroporous resins, ultrasound-assisted solvent-free low-temperature deep refining, cyclodextrin inert gas moisture-proof stable embedding, and independent technological catch-up of China's full-set purification technologies. Full-chain industrial upgrading has been achieved from plateau mature whole white kidney beans and crude kidney bean powder to globally graded high-end standardized white kidney bean extract raw materials with low anti-nutritional factors.

Compared with traditional crude white kidney bean powder produced via high-temperature boiling without lectin miscellaneous protein removal, standardized low-temperature graded low-lectin white kidney bean extract relies on five core processes: closed controllable low-temperature aqueous countercurrent extraction, ultrafiltration membrane removal of miscellaneous protein anti-nutritional factors, graded enrichment of α-AI active proteins via macroporous resins, ultrasound-assisted solvent-free deep refining, and cyclodextrin inert gas moisture-proof stable embedding. It possesses core competitive advantages including complete retention of thermosensitive α-AI glycoprotein activity, thorough removal of gastrointestinal irritant lectin impurities, good powder moisture-proof room-temperature long-term storage resistance with low risk of deactivation, zero organic solvent residues throughout production, compatibility with all solid/liquid/baked food dosage forms, and global multi-country food and drug regulatory compliance filings. It perfectly aligns with long-term global market development trends: national weight management, postprandial blood glucose health intervention, clean-label natural functional food additives, and low-calorie low-sugar healthy diets.

In the future, with continuous launch of new technologies including solvent-free green low-temperature deep refining, customized graded activity raw materials for segmented sectors, nano-targeted stable delivery, white kidney bean suspension cell culture, and ultra-low lectin high-stability purification, white kidney bean extract will permanently occupy the core track of global natural starch blocking and postprandial sugar-control weight management functional raw materials, becoming an indispensable classic Fabaceae medicinal and edible protein-based functional raw material for conventional foods, health foods, special dietary foods and the broader big health industry.