Development History of the Fructo-oligosaccharide (FOS) Industry

Part One: A Tribute to the Pioneers

As a classic prebiotic and water-soluble dietary fiber, fructooligosaccharides (FOS) have undergone more than half a century of scientific exploration, technological innovation, safety verification and market popularization. Starting from the analysis of natural substances and laboratory extraction and synthesis to breakthroughs in industrial production technology, FOS has now become one of the most widely applied and highly recognized functional food ingredients worldwide. The global popularity of this ingredient is inseparable from generations of domestic and overseas researchers dedicated to basic research, engineers refining manufacturing processes repeatedly, testing institutions conducting rigorous verifications, standard-setters formulating scientific specifications, as well as practitioners throughout the entire industrial chain committed to this sector. We hereby pay high tribute to all scientists, research teams, universities and research institutions engaged in fundamental theoretical research of FOS, natural component analysis, production process improvement, toxicological safety assessment, clinical efficacy demonstration, industrial standard formulation and global market promotion. In compliance with principles of industrial competition protection and corporate privacy, specific enterprise names are omitted in this section. Special recognition is extended to all domestic and overseas enterprises that have made outstanding contributions to the development of this industry.

Honor Roll of Tribute

I. Core Scientists and Researchers (Chronological Order)

1. ***Early Japanese Research Team on Natural Components (1950s–1960s)***

The world's first research team to conduct foundational studies on FOS. It took the lead in separating natural raw materials of FOS, analyzing molecular structures and verifying basic physicochemical properties, identified its core prebiotic characteristics, initiated systematic global research on FOS, and laid the original theoretical foundation for the industry.

2. ***Professor Sakai (Japan, 1970s)***

Founder of enzymatic industrialization of FOS. He developed a catalytic synthesis system using fructosyltransferase, breaking the industry bottlenecks of low efficiency and high cost of natural extraction processes. The enzymatic mainstream production technology established by him has been adopted globally to this day, propelling the industry into the industrial era.

3. ***Professor Tomomatsu (Japan, 1980s)***

Systematically verified the gut microbiota-regulating efficacy of FOS and established a standardized evaluation system for prebiotic functions. It defined the functional positioning of the product and provided core academic evidence for food applications and functional claims of FOS.

4. ***Joint European and American Nutritional Research Team (1980s–1990s)***

Led the completion of a full set of toxicological safety evaluations and human metabolic trials, defined the safe daily intake limits, facilitated the acquisition of authoritative global food safety certifications for the product, and removed barriers to international trade and market access for FOS.

5. ***Professor Takemoto (Japan, 1990s)***

Expanded research on diversified health benefits of FOS. He verified its additional values including promoting mineral absorption and stabilizing postprandial blood glucose, further broadening the application scope of the product in segmented fields such as special dietary foods and low-sugar foods.

6. ***Professor Wei Yuan'an (1990s)***

Pioneer of domestic FOS research in China. He took the lead in research on domestic sugar-enzyme catalytic technology, developed a continuous production process with immobilized enzymes, solved pain points including insufficient activity of domestic enzymes and uneven product composition, and filled the domestic gap in continuous production technology.

7. ***Professor Jiang Bo (Jiangnan University, Mid-to-Late 1990s)***

Core promoter of domestic industrialization of FOS. He conquered key challenges including process scale-up and domestic production of enzyme preparations, built China's first enzymatic production line with independent intellectual property rights, and completely broke the dual monopoly of overseas technology and products.

8. ***Professor Wang Zhengxiang (Tianjin University of Science and Technology, Early 2000s)***

Specialized in tackling the domestic production of core upstream enzyme preparations. He realized full domestic substitution of dedicated fructosyltransferase for FOS, optimized strain fermentation processes, greatly reduced industrial production costs, and accelerated domestic substitution of imported FOS products.

9. ***Professor Tong Qunyi (Jiangnan University, Early 2000s)***

Focused on product purification and optimization of end-use applications. He remedied drawbacks of domestic products such as excessive glucose by-products and poor food compatibility, improved separation and purification processes and multi-scenario application solutions, and supported domestic products to enter the high-end food market.

10. Joint Expert Team from Domestic Universities (1990s to Present)

Composed of research forces from Jiangnan University, South China University of Technology, Tianjin University of Science and Technology and other institutions. It has long collaborated on full-chain research covering strain modification, process optimization, national standard formulation and localized efficacy verification, enabling China's FOS industry to achieve a leap from technology import to global leadership.

Research teams from Jiangnan University, South China University of Technology, Tianjin University of Science and Technology and other institutions have collaborated on comprehensive research involving strain modification, process optimization, standard formulation and localized efficacy verification, driving the domestic industry to shift from technology introduction to independent innovation and global leadership.

II. Research Institutions and Universities (Chronological Order)

1. Central Research Institute of Meiji Seika (Japan, 1970s–1980s)

The world's first research institution to complete pilot testing and commercial mass production of enzymatic FOS processes. It established the world's first generation of industrial production parameters and quality control standards, providing critical process references for the early development of the global industry.

2. School of Food Science and Technology, Jiangnan University (Since the 1990s)

China's earliest university platform engaged in R&D and industrialization of enzymatic FOS processes. It specializes in enzyme engineering and precise product separation technology, continuously iterates production processes, and leads domestic product quality improvement, cost reduction and upgrading.

3. College of Food Engineering and Biotechnology, Tianjin University of Science and Technology (Since the Late 1990s)

China's earliest research institution focusing on FOS detection technology and industrial standardization construction. It took the lead in establishing the product quality control system, fully participated in the compilation and revision of national and industrial standards, and standardized the overall development order of the industry.

4. School of Food Science and Engineering, South China University of Technology (Since the Early 2000s)

Focused on end-food applications and compound formula development of FOS. It optimized application solutions tailored to China's food industry scenarios, made up for deficiencies in end-product application, and promoted large-scale popularization of FOS in China's big health industry.

Part Two R&D and Development History of Fructooligosaccharides

I. Natural Discovery and Basic Research Stage (1950s – Early 1970s)

In the mid-to-late 20th century, the global food industry paid increasing attention to the development of dietary fiber and natural functional ingredients, with prebiotics and indigestible oligosaccharides becoming cutting-edge research directions. Researchers discovered a special type of fructan in natural plants such as chicory, Jerusalem artichoke, bananas and onions, whose physicochemical properties differ from conventional sucrose and glucose.

From 1950 to 1965, Japanese research teams completed the separation, purification and structural analysis of natural FOS, clarified its molecular structure, glycosidic bond types, degree of polymerization distribution and basic physicochemical properties. They verified that FOS can hardly be decomposed and absorbed by human salivary and small intestinal digestive enzymes, preliminarily explored its effects on intestinal microorganisms, and finished the basic characterization of the substance.

From 1965 to 1972, research entered the mechanism exploration phase. Researchers conducted in vitro digestion simulation tests, systematically measured the calorific value, solubility, thermal stability and acid resistance of FOS, and sorted out a complete set of basic physicochemical parameters. Meanwhile, scale-up trials of traditional natural extraction processes were carried out. However, restricted by low extraction rates, high costs and insufficient purity, large-scale industrial production could not be realized, forcing the industry to explore a brand-new artificial synthesis route.

II. Enzymatic Technology Breakthrough and Process Finalization Stage (1970s – Mid-1980s)

Deficiencies of natural extraction processes drove the industry to focus on R&D of bio-enzyme catalytic synthesis technology. In the 1970s, Professor Sakai's team in Japan successfully screened and cultured microbial strains with high fructosyltransferase yield, built an enzymatic reaction system using sucrose as raw material and fructosyltransferase as catalyst, and realized efficient conversion of FOS with qualitative leaps in conversion rate and production efficiency.

From 1972 to 1978, research teams continuously optimized core parameters including strain fermentation, enzyme production conditions, catalytic temperature, pH value and reaction duration, and finalized the optimal process for industrial production. Supporting post-treatment technologies including decolorization, desalination, concentration and purification were developed to resolve defects in product color, impurities and flavor, marking the official finalization of the enzymatic synthesis process. Featuring accessible raw materials, high conversion rates and controllable costs, this process has since become the mainstream universal production technology worldwide.

From 1978 to 1985, various research institutions completed process pilot tests and trial production, launching the first batch of enzymatically prepared FOS products. Preliminary toxicological and product stability tests were conducted simultaneously to accumulate core data for subsequent commercialization and safety certification.

III. Efficacy Verification and Global Compliance Stage (1980s – Late 1990s)

After production processes matured, the industry's R&D focus shifted to efficacy demonstration, safety assessment and regulatory market access. From 1980 to 1988, Professor Tomomatsu's Japanese team carried out systematic flora tests and human feeding trials, fully proving the prebiotic efficacy of FOS, establishing its core value in intestinal regulation and clarifying the functional positioning of the product.

From 1985 to 1995, multiple authoritative institutions across Europe, America and Japan jointly conducted comprehensive toxicological safety evaluations covering acute toxicity, subchronic toxicity, genotoxicity and reproductive toxicity tests. Results confirmed that FOS is safe for consumption with no side effects. JECFA, the U.S. FDA and the European Food Safety Authority successively completed safety assessments, approved FOS for legal use as food ingredients, dietary fiber and prebiotics, and granted market access qualifications.

From 1990 to 1999, FOS obtained compliance qualifications in dozens of countries and regions including South Korea, Australia and Southeast Asia, forming a basically complete global regulatory system. Overseas production capacity continued to expand, and products were widely applied in beverages, dairy products, candies, health foods and other sectors, with overseas markets reaching maturity. During the same period, domestic universities and research institutes followed up on FOS-related technologies, launching technology introduction and laboratory replication work, while China's first generation of researchers began tackling the domestic production of FOS.

IV. Technology Introduction and Independent Domestic Development Stage (Late 1990s – Early 2000s)

Before the 1990s, China relied entirely on imported FOS, whose high prices restricted industrial application. After 1990, universities including Jiangnan University, South China University of Technology and Tianjin University of Science and Technology took the lead in research on enzymatic processes, disassembled overseas technical routes, and completed strain breeding, laboratory and pilot tests, gradually forming China's core research teams.

From 1995 to 2002, leading domestic scientists led research breakthroughs, collaborated with industrial practitioners to introduce and absorb foreign technologies, and conquered core challenges including strain cultivation, enzyme activity regulation, catalytic reactions and preliminary purification. In 1997, China achieved its first industrial mass production, building the first batch of local FOS production lines, filling the domestic gap in industrial production and ending the long-term monopoly of foreign products.

From 2002 to 2009, supported by continuous technological iteration of domestic research teams, China gradually eliminated dependence on imported enzymes and realized independent mass production of strains and enzyme preparations, with steady improvements in product conversion rate and batch stability. Interim industrial standards were issued to standardize product indicators, and the application scope of FOS in China's food industry kept expanding. Around 2009, FOS was officially included in China's

catalog of food additives and new food raw materials, clarifying the compliance basis and driving rapid development of the domestic industry.

V. In-depth Technology Research and High-end Upgrading Stage (2010 – Present)

Since 2010, global consumption upgrading has driven FOS development toward high purity, low by-product content and customized component formulations. Beyond basic synthetic processes, the industry prioritized the development of deep purification technologies including multi-stage membrane separation, ion exchange, chromatographic purification and polymerization degree classification, launching diversified products such as low-glucose, ultra-high-purity, short-chain and long-chain FOS to meet stringent requirements of infant food, foods for special medical purposes and high-end health foods.

Domestic research institutes and top scientists carried out collaborative innovation, achieving comprehensive breakthroughs in strain genetic modification, continuous immobilized enzyme reactions and energy-saving production processes. Production energy consumption was further reduced, and core quality of domestic products fully matched international top-tier standards. From 2010 to 2025, China issued and revised multiple national and industrial standards, improved testing methods, quality grading systems and production specifications, shifting the industry from extensive capacity expansion to refined and high-end development.

Meanwhile, functional research continued to expand, with extensive new trials conducted around intestinal health, metabolic regulation, immunity enhancement and pet nutrition, continuously exploring new product values and broadening the application boundaries of FOS.

Part Three Commercialization History of Fructooligosaccharides

The commercialization process of FOS advanced alongside natural substance discovery, enzymatic technological innovation, improvement of global regulations, rise of domestic industries and upgrading of health consumption. It went through six major phases: overseas technological monopoly, global compliance popularization, domestic technological breakthrough, standard system establishment, Sino-foreign competitive coexistence, and China-led global development, evolving from laboratory research products into globally prevalent functional ingredients.

I. Overseas Production Launch and Initial Commercialization Stage (1980s)

The 1980s marked the starting point of FOS commercialization. Leveraging mature enzymatic processes, overseas research institutions took the lead in realizing global large-scale mass production and launched the first generation of commercial FOS product lines for food industrial use.

In the early stage of industrial development, FOS mainly served as sweeteners and texture modifiers while delivering basic dietary fiber functions, primarily applied in Japanese beverages, pastries and dairy products. Restricted by insufficient public awareness and high selling prices, the market scale was small with limited application scenarios. Nevertheless, its excellent performance won recognition from end manufacturers, laying a foundation for subsequent global promotion. During the same period, European research teams developed a natural extraction route from chicory, forming two parallel industrial technical routes: enzymatic synthesis and natural extraction.

II. Compliance Improvement and Overseas Market Expansion Stage (1990s)

The late 1980s to the 1990s represented a golden era for global layout of FOS. Supported by complete toxicological data and functional research reports, the product successively obtained authoritative safety certifications from the U.S. FDA, JECFA, the European Union and Japan's Ministry of Health, Labour and Welfare, acquiring legal food ingredient qualifications in major global countries and breaking regulatory barriers.

Overseas industrial practitioners continuously expanded production capacity and enriched product specifications, launching series products with varying polymerization degrees and purity levels. FOS applications rapidly expanded from traditional foods to high-end tracks including dietary supplements, functional health products and infant formula foods. As the prebiotic concept gained global popularity, FOS became the core raw material for intestinal health products. By the late 1990s, the global FOS market landscape basically took shape, with overseas industrial players dominating the global high-end market.

III. Domestic Industrialization and Market Cultivation Stage (Late 1990s – 2009)

At the end of the 1990s, relying on research breakthroughs by domestic scientists, domestic practitioners broke technical barriers and built China's first batch of production lines, completely eliminating China's full dependence on imported FOS. In the early development phase, domestic products lagged behind international competitors in enzyme activity control, purification processes and component uniformity, and mainly supplied the mid-to-low-end food market.

After 2000, domestic production processes underwent continuous iteration, annual output increased year by year, and market prices dropped sharply, promoting rapid penetration of FOS into domestic beverages, yogurts, snack foods and health foods. End consumers gradually built awareness of prebiotics and dietary fiber, forming an initial scale of China's health consumption market.

In 2009, FOS was officially approved as a new food raw material in China, with clear application scope, maximum addition limits and quality requirements defined. Backed by authoritative regulations, China's FOS industry entered a steady growth cycle.

IV. Standard System Establishment and Standardized Industrial Development Stage (2010–2020)

Starting in 2010, China accelerated the construction of the FOS standard system, successively releasing multiple national and industrial standards that unified physicochemical indicators, microbial limits, testing methods and production hygiene specifications, and established a product grading system, thoroughly resolving the problems of chaotic industrial indicators and uneven product quality.

FOS was continuously incorporated into food additive standards such as GB 2760, with its application scope further covering all types of ordinary foods and special dietary foods. The supervision, quality control and testing systems became increasingly complete, raising market access thresholds for the industry. Small-scale backward production capacity was gradually phased out, and industrial concentration kept rising.

During this phase, domestic practitioners simultaneously promoted the transformation of scientific research achievements, advanced process upgrading and product iteration, and launched mid-to-high-end products such as high-purity and low-glucose FOS. Domestic products gradually entered the supply chains of China's high-end foods and health foods, fully accelerating the process of domestic substitution for imports.

V. Capacity Expansion, Export Growth and Restructuring of the Global Market Landscape (2020 – Present)

Backed by a complete industrial chain, mature technologies, large-scale production capacity and cost-performance advantages, China has become the world's largest producer and exporter of FOS since 2020, with total production capacity of domestic industrial players accounting for more than half of the global total. Products are exported in large volumes to Southeast Asia, Europe, America, Japan, South Korea and other regions, deeply integrating into the global ingredient supply chain.

The current global industry features a clear division of labor and competitive landscape: mature overseas industrial players focus on natural extraction and ultra-high-purity customized products, dominating top segmented markets such as infant food and foods for special medical purposes while maintaining advantages in high-end supply. Domestic industrial players cover both general products and mid-to-high-end refined products, featuring large production scales, complete product categories and outstanding customization capabilities to cover all market tiers, ranking among the world's most competitive supplier echelons.

FOS applications show a diversified growth trend. Beyond traditional foods and health foods, they have rapidly expanded into emerging tracks including pet food, feed, meal replacements, weight management products and probiotic compound formulations, with steady growth in product added value.

VI. Outlook on Future Development Trends

In the long run, the FOS industry will continue to advance toward sophisticated processes, customized products, diversified functions and segmented applications. Technologically, immobilized enzymes, continuous production, green extraction and precise component separation will become mainstream R&D directions to further boost production efficiency, cut energy consumption and optimize product quality.

In terms of product development, dedicated formulas will be developed for different groups including infants, the elderly, people with sensitive stomachs and pets, continuously improving a differentiated product matrix covering short-chain, long-chain, high-purity and conventional-purity FOS. Functional research combining modern nutrition and microbiology will be carried out to explore brand-new benefits including immune regulation, metabolic health and skin care.

At the global market level, relying on advantages in production capacity, technology and standards, China will shift from simple product exports to synchronized exports of technology and standards, consolidating its core position in the global industry. As a classic prebiotic and water-soluble dietary fiber, the FOS market will maintain long-term stable growth and remain a mainstream global functional ingredient.