Development History of Xylo-oligosaccharide Industry

Part One: A Tribute to Pioneers

Xylo-oligosaccharides (XOS) represent a new generation of functional prebiotics and water-soluble dietary fiber featuring extremely potent biological activity and ultra-low dosage requirements. Their industrial development is rooted in the resource utilization technology of hemicellulose from agricultural and forestry residues. Over more than six decades, the industry has undergone natural component exploration, breakthroughs in biological enzymatic hydrolysis technology, systematic verification of safety and efficacy, iterative process upgrading, and large-scale global market penetration.

Distinct from other mainstream prebiotics, xylo-oligosaccharides possess unique merits including outstanding acid and heat resistance, high human tolerance, capability to selectively proliferate bifidobacteria at minimal dosages, and inability to be utilized by oral caries-causing bacteria. Additionally, they convert agricultural waste such as corn cobs and bagasse into valuable resources, delivering dual value of human health and environmental sustainability. Nowadays, XOS has become an indispensable high-end functional ingredient in food manufacturing, special dietary products, livestock breeding, daily chemical healthcare and other sectors.

The extraordinary leap of this industry—from trace natural components in agricultural and forestry biomass to laboratory enzymatic synthesis, industrial mass production, and China's leading position in global production capacity and technological upgrading—would not have been possible without generations of global researchers dedicated to biomass degradation and functional sugar development, process engineers who overcame bottlenecks in raw material pretreatment and enzymatic hydrolysis, testing institutions conducting comprehensive safety and human clinical trials, standard setters establishing domestic and international standard systems, and all industry practitioners committed to green full-chain production and market application promotion.

We pay sincere tribute to all scientists, research teams, universities and research institutions engaged in natural component analysis of xylooligosaccharides, xylanase strain modification, pretreatment technology development for agricultural and forestry waste, toxicological safety evaluation, verification of intestinal and systemic health benefits, formulation of domestic and international industrial standards, construction of green industrial chains and global market expansion.

In accordance with principles of industrial competition protection and enterprise privacy, specific corporate names are omitted in this section. We extend our heartfelt gratitude to all domestic and overseas enterprises that have made remarkable contributions to the advancement of this industry.

Honor Roll

I. Core Scientists & Researchers (Chronological Order)

- ***Early Japanese Biomass Sugar Research Team (1960s–1970s)***

The world's first research group to launch systematic studies on plant hemicellulose components. They pioneered the structural analysis of xylan in agricultural and forestry feedstocks including birch and crop straws, isolated and identified natural xylo-oligosaccharide fractions, confirmed xylobiose and xylotriose as core bioactive units, and clarified their fundamental property of resisting digestion and absorption in the human upper gastrointestinal tract. The team completed validation of basic physicochemical properties and primary prebiotic functions of XOS, filling the global theoretical gap in xylo-oligosaccharide research and initiating worldwide systematic studies on this category.

- ***Professor Toshio Irie's Research Group, Japan (1980s)***

Founders of enzymatic preparation technology for xylo-oligosaccharides. Globally the first team to systematically investigate the compatibility of xylanases from diverse sources, they screened dedicated enzyme-producing strains suitable for lignocellulosic raw materials and established a directional hydrolysis process system using endoxylanases. This breakthrough resolved long-standing industrial pain points of acid hydrolysis such as excessive byproducts and low product purity, establishing enzymatic hydrolysis as the mainstream production route for XOS and laying solid foundational process technology for subsequent industrial mass production.

- ***Suntory R&D Team, Japan (Late 1980s)***

Global pioneer of industrialized xylo-oligosaccharide production. The team optimized the continuous hydrolysis process with immobilized mycelia, completed pilot-scale amplification of the full workflow covering raw material pretreatment, enzymatic hydrolysis reaction, decolorization and refining, and commissioned the world's first commercial XOS production line in 1989, realizing the first market launch of XOS products. Meanwhile, they carried out initial human feeding trials to confirm its basic intestinal regulatory effects, and monopolized global high-end XOS technology and markets for a long period.

- ***Joint European and American Team for Functional Sugar Safety Assessment (1990s)***

Led comprehensive full-set toxicological safety tests, human metabolic mechanism research and long-term oral tolerance trials for xylo-oligosaccharides, defined safe dosage ranges for consumption, and supplemented missing global safety data for the product. Their work facilitated the approval of XOS by JECFA, the U.S. FDA and the European Food Safety Authority (EFSA), removed regulatory access barriers to European and American markets, and improved the global compliance system for prebiotics.

- ***Professor Wenyi Tao, Jiangnan University (1990s)***

Originator of domestic xylo-oligosaccharide research in China. He presided over key national scientific research projects under the former State Light Industry Administration and Jiangsu Provincial Ninth Five-Year Plan. His team selectively bred special strains free of xylosidase activity, conquered core challenges of high miscellaneous enzyme content and excessive monosaccharide byproducts in enzyme systems, pioneered a dedicated enzymatic hydrolysis system tailored to domestic corn cob feedstocks, and completed pilot production trials using 8 m^3 fermentation tanks, laying the core independent technological foundation for domestic XOS manufacturing.

- ***Professor Lite Li, China Agricultural University (Late 1990s–Early 2000s)***

Trailblazer for domestic industrialization of xylo-oligosaccharides in China. He overcame core bottlenecks in agricultural and forestry raw material pretreatment by inventing direct thermal cooking steam explosion cleavage pretreatment technology and integrated nanofiltration membrane purification technology, drastically boosting enzymatic hydrolysis yield and product purity while solving two major industrial drawbacks of low domestic raw material utilization and excessive product impurities. By the end of 2000, his research supported China's first industrial mass production of xylo-oligosaccharides, making China the second country worldwide capable of large-scale production of high-purity XOS and completely breaking Japan's decades-long technological monopoly.

- ***Professor Zhenghong Xu, Jiangnan University (Late 1990s–Early 2000s)***

Dedicated to molecular modification of xylanases and process optimization. He refined solid-state fermentation for enzyme production, optimized critical parameters including enzymatic hydrolysis temperature, pH and solid-liquid ratio to further raise the proportion of target active products xylobiose and xylotriose, upgraded downstream separation and purification workflows, effectively cut manufacturing costs, and advanced the quality of domestically produced XOS from laboratory grade to commercial industrial grade.

- ***Domestic Joint Expert Team for Biomass Functional Sugars (2000s–Present, Lead Principal Investigator: Professor Zhengqiang Jiang, China Agricultural University)***

Composed of research forces from China Agricultural University, Jiangnan University, Tianjin University of Science and Technology, South China University of Technology, Beijing Forestry University and other institutions, led academically by Professor Zhengqiang Jiang. The team conducts full-chain research on genetically modified high-temperature-resistant xylanase strains, multi-feedstock compatible agricultural and forestry processes, low-carbon green production, improvement of national standard testing methods, efficacy verification on Chinese populations, and comprehensive utilization of byproducts. It established a domestic industry-university-research collaborative innovation platform for XOS, supporting China's transformation from technological follower and parallel runner to global leader in the xylo-oligosaccharide sector.

- ***Domestic High-End Product R&D Team (2010s–Present, Lead Principal Investigator: Professor Ruijin Yang, Jiangnan University)***

Centered on Professor Ruijin Yang from Jiangnan University, the team focuses on the niche track of ultra-high-purity xylo-oligosaccharides. It conquered high-end technical barriers including refined chromatographic fractionation, ultra-low water activity control and precise component regulation of finished products, and realized industrial mass production of 99% ultra-high-purity XOS around 2018, ending the long-term overseas monopoly on high-end products. This filled gaps restricting domestic XOS applications in infant food and food for special medical purposes (FSMP). The team also took the lead in formulating dedicated quality control standards for high-purity XOS, driving domestic product upgrading toward refinement and customized formulation.

II. Research Institutions & Universities (Chronological Order)

- ***Forest Chemical Engineering Team, Beijing Forestry University (Early 2000s–Present, Team Lead: Professor Runcang Sun)***

Academically led by Professor Runcang Sun, the team specializes in developing technologies to produce XOS from forest lignocellulosic raw materials, expanding production routes using birch, eucalyptus, poplar and other timber feedstocks, and researching non-enzymatic green hydrolysis processes to enrich China's XOS production technology portfolio. It also devotes efforts to high-value full-component utilization of lignin and cellulose from production residues, perfecting green circular full-industry-chain processes and filling domestic technological gaps in XOS manufacturing from forest raw materials.

- ***School of Food Engineering and Biotechnology, Tianjin University of Science and Technology (Early 2000s–Present, Team Lead: Professor Hua Li)***

Led by Professor Hua Li, this institution serves as the leading drafting body for China's XOS industrial standards and testing systems. It spearheaded the formulation of testing methodologies for product physicochemical indicators, microbial limits and degree of polymerization distribution, participated fully in the drafting and revision of national food safety standards and industrial product grading criteria, unified industry-wide testing specifications, rectified chaotic product quality across domestic markets, and built a complete third-party quality control evaluation system for domestic xylo-oligosaccharides.

- ***Suntory Central Research Institute, Japan (1980s, Team Lead: Professor Toshio Irie)***

The world's first research institute to achieve commercial mass production of xylo-oligosaccharides, with Professor Toshio Irie as chief R&D supervisor. It established the world's first set of industrial production parameters, quality control indicators and testing standards for XOS, accumulated the earliest batch of data on product stability and application compatibility, guided the global technological trajectory of early XOS industry, and imposed long-term restrictions on access to core enzyme preparations and production workflows.

- ***School of Biotechnology, Jiangnan University (1990s–Present, Discipline Founder: Professor Wenyi Tao)***

China's core pioneering research platform for developing dedicated XOS enzyme preparations and optimizing enzymatic hydrolysis processes. Founded by Professor Wenyi Tao, it focused on strain breeding and enzyme system optimization to resolve critical issues of poor specificity and excessive byproducts in domestic enzymes, providing core enzymatic hydrolysis technology for China's first generation of industrial production lines. Subsequent continuous research led by Professors Zhenghong Xu and Ruijin Yang has sustained iterative upgrading of domestic biological enzymatic manufacturing processes.

- ***College of Food Science and Nutritional Engineering, China Agricultural University (Late 1990s–Present, Initial Lead: Professor Lite Li, Successive Lead: Professor Zhengqiang Jiang)***

China's benchmark institution for research on agricultural and forestry waste pretreatment technology. Initially led by Professor Lite Li, the team concentrated on resource valorization of native corn cob feedstocks and innovated integrated coupled steam explosion and membrane separation processes. Later, Professor Zhengqiang Jiang continued research on biomass biorefining and enzymatic process optimization, overcoming core bottlenecks of low pretreatment efficiency and insufficient overall yield for industrialization. The institute directly facilitated the launch of China's first independent intellectual property XOS production line and constitutes the core domestic research pillar for XOS industrialization.

- ***Biomass Functional Sugar Team, Hunan Agricultural University (2010s–Present, Team Lead: Professor Zili Yi)***

Led by Professor Zili Yi, the team pioneered an innovative technical route to manufacture XOS from Miscanthus plants (Miscanthus lutarioriparius). It solved technical hurdles of efficient pretreatment and directional enzymatic hydrolysis for herbaceous energy crops, realized high-value utilization of tidal flat plant waste, broadened China's pool of raw materials for XOS production, and created a distinctive new industrial chain for functional sugars manufactured from southern agricultural and forestry residues.

Part Two R&D and Development Timeline of Xylo-oligosaccharides

I. Natural Discovery & Fundamental Research Stage (1960s – Early 1980s)

The mid-to-late 20th century witnessed rapid expansion of the global functional sugar industry. Compared with starch-based functional oligosaccharides, non-starch oligosaccharides derived from agricultural and forestry biomass emerged as a novel research hotspot owing to their unique physicochemical properties. Researchers discovered trace xylo-oligosaccharides naturally present in bamboo shoots, cereal bran, birch and other plants, and verified that controlled hydrolysis of plant hemicellulose could generate this category of oligosaccharides. XOS exhibited superior prebiotic activity, heat resistance and acid tolerance versus mainstream oligosaccharides of the era, demonstrating

enormous industrialization potential.

From 1960 to 1975, Japanese research teams took the lead in separating and purifying natural XOS, analyzing molecular structures, characterizing glycosidic linkages and degree of polymerization distribution, and confirming xylobiose and xylotriose as core bioactive fractions. In vitro simulated digestion trials proved that XOS cannot be decomposed by human salivary amylase or small intestinal digestive enzymes, allowing it to reach the large intestine intact to selectively modulate gut microbiota. Key physicochemical parameters including heat resistance, acid stability, low viscosity and mild sweetness were quantified, completing comprehensive characterization of the substance's fundamental properties.

From 1975 to 1982, the industry experimented with acid hydrolysis and high-temperature hydrothermal hydrolysis for raw material breakdown. While these methods could produce XOS, they carried fatal drawbacks including uncontrollable hydrolysis reactions, massive monosaccharide byproduct formation, low proportions of bioactive fractions, severe pollution from acidic wastewater and heavy equipment corrosion—failing to meet safety and purity standards for food-grade ingredients. The dual routes of natural extraction and chemical hydrolysis were deemed unviable, compelling the entire industry to fully shift R&D focus toward green biological enzymatic hydrolysis manufacturing technology.

II. Enzymatic Technology Breakthrough & Global Process Standardization Stage (1980s – Late 1980s)

To address inherent flaws of chemical hydrolysis, global research efforts pivoted entirely toward highly specific directional hydrolysis technology using xylanases. Biocatalysis enables precise cleavage of hemicellulose while preserving the intact bioactive molecular structure of xylo-oligosaccharides.

1982–1986: Professor Toshio Irie's Japanese team completed screening and mutagenesis of multiple microbial strains, differentiated functional disparities between endoxylanases and exoxylosidases, and established that exoxylosidases must be eliminated from enzyme systems to prevent degradation of active XOS fractions, setting dedicated criteria for enzyme strain screening. A laboratory bench-scale enzymatic hydrolysis system was constructed to achieve directional breakdown of xylan feedstocks with drastically elevated yields of bioactive products, validating the technical feasibility of enzymatic XOS manufacturing.

1986–1989: Suntory Research Institute scaled up the full production workflow, optimizing integrated post-treatment processes including alkaline raw material pretreatment, continuous enzymatic hydrolysis with immobilized mycelia, activated carbon decolorization, ion-exchange desalination and vacuum concentration to resolve issues of dark product color, excessive ash content and undesirable flavor. The world's first industrial XOS production line commenced operation in 1989, fully standardizing enzymatic hydrolysis as the sole mature mass-production technology worldwide. Japan subsequently monopolized global XOS technology and markets for nearly a decade. During this

period, China only carried out scattered basic laboratory research without establishing a systematic research framework.

III. Comprehensive Efficacy Verification & International Compliance Approval Stage (1990s)

Following process maturation, global industry R&D priorities shifted from production technology to mechanistic interpretation of health benefits, comprehensive safety evaluation and international regulatory clearance, furnishing authoritative academic support for cross-border product circulation and functional health claims.

1990–1995: Multiple Japanese nutrition research groups conducted systematic animal trials and human intervention clinical studies to quantify the bifidogenic efficiency of XOS, confirming that XOS achieves equivalent intestinal regulatory effects at far lower dosages than competing prebiotics such as fructo-oligosaccharides (FOS) and galacto-oligosaccharides (GOS). Additional health benefits were validated including inhibition of oral pathogenic bacteria, steady postprandial blood glucose levels, enhanced mineral absorption and systemic immune modulation, refining differentiated functional positioning for XOS products.

1995–1999: A joint research consortium spanning Europe, America and Japan completed full-spectrum toxicological safety assessments encompassing acute oral toxicity, subchronic toxicity, genotoxicity, reproductive and developmental toxicity, and long-term feeding trials. All test results verified that xylooligosaccharides carry no toxic side effects and possess extremely high oral safety. JECFA, the U.S. FDA and the European Food Safety Authority subsequently approved XOS for legal use as food ingredients, prebiotics and dietary fiber, securing regulatory market access across the world's major economies.

By the late 1990s, XOS obtained food additive licensing in South Korea, Australia and various Southeast Asian nations, largely completing the global compliance framework. Overseas products were gradually incorporated into functional beverages, vinegar, dietary supplements and dairy goods, yet limited Japanese production capacity and steep pricing suppressed overall global market penetration. Concurrently, China launched its Ninth Five-Year National Key Science and Technology Research Program, formally initiating state-sponsored research to localize XOS manufacturing technology and launching China's dedicated XOS research track.

IV. Domestic Technological Breakthrough & Industrialization Milestone Stage (Late 1990s – 2009)

Prior to 2000, China lacked independent XOS production technology and relied entirely on Japanese imported products at exorbitant prices. Applications were confined to a narrow range of high-end health foods, with virtually no adoption in civilian food manufacturing, leaving the domestic industry fully dependent on foreign suppliers.

1996–2000: Two core domestic teams at Jiangnan University and China Agricultural University pursued parallel breakthrough research. Jiangnan University focused on localizing upstream enzyme production, selectively breeding highly specific strains to resolve excessive miscellaneous enzymes and insufficient product purity in domestically

sourced biocatalysts. China Agricultural University targeted bottlenecks in pretreatment of native corn cob feedstocks, innovating steam explosion pretreatment technology to mitigate low enzymatic hydrolysis efficiency stemming from structural disparities in domestic agricultural and forestry raw materials. Complementary collaboration between the two teams enabled complete replication and optimization of the full enzymatic production workflow.

By the end of 2000, leveraging domestically developed proprietary technology, China commissioned its first fully independent intellectual property industrial XOS production line, achieving successful localized mass production and breaking Japan's over decade-long technological monopoly. China became the second country globally capable of industrial XOS manufacturing. While the first generation of domestic XOS products established domestic self-sufficiency, they exhibited shortcomings including uneven component distribution, absence of high-purity grades and excessive energy consumption, primarily catering to mid-to-low tier domestic food markets.

2001–2009: Domestic research teams continuously iterated manufacturing processes through optimized immobilized enzyme technology and upgraded membrane separation purification systems, steadily raising overall product purity and batch consistency. In 2006, core domestic technology for enzymatic XOS production from corn cobs was awarded the Second-Class National Technological Invention Award, marking China's proprietary manufacturing processes as domestically top-tier. In 2009, xylo-oligosaccharides were formally inscribed in China's Novel Food Ingredients Catalogue with defined usage scopes, maximum addition limits and quality standards, furnishing formal regulatory grounds for compliant domestic industrial development.

V. Green Process Upgrading & Domestic Substitution of High-End Products Stage (2010 – Present)

Since 2010, global upgrades in health-conscious consumption have driven the XOS industry toward production of high-purity, low-ash, precisely fractionated low-carbon green products. Simultaneously, explosive growth in emerging sectors including livestock breeding, foods for special medical purposes, infant formula and pet food has catalyzed profound industrial technological innovation.

Technological Advancements

Domestic university research teams utilize gene-editing technology to modify xylanase strains, developing high-temperature-resistant, high-activity specialized enzyme preparations compatible with continuous high-temperature enzymatic hydrolysis workflows that drastically shorten production cycles and cut energy consumption. The industry has widely adopted green processes of integrated membrane fractionation, precise chromatographic separation and low-temperature concentration, phasing out outdated high-pollution acid-alkali refining workflows to realize low-carbon, clean manufacturing end-to-end. A full feedstock component utilization system has been established, with enzymatic hydrolysis residues further processed to extract lignin and cellulose, creating a zero-waste circular industrial chain for agricultural and forestry

waste.

Product Development

Domestic manufacturers successively launched graded product portfolios at purity levels of 70%, 95% and 99%, filling gaps in ultra-high-purity product supply. Around 2018, domestic research teams achieved mass production of 99% ultra-high-purity XOS and ultra-low water activity products, conquering high-end purification technologies long restricted by foreign suppliers. Domestic products now match or exceed the quality of Japanese imports, successfully penetrating top-tier global application segments including infant formula and foods for special medical purposes.

Standards & Fundamental Research

Between 2010 and 2025, China formulated and revised national standards for XOS products, national testing method standards and industrial feed additive standards, covering the two core application sectors of human food and animal feed. Parallel localized clinical trials on Chinese gut health have expanded proprietary efficacy datasets for domestic populations. The industry continues to explore novel functional applications, conducting in-depth research on metabolic syndrome mitigation, skin microecology regulation, oral health maintenance and livestock intestinal care, steadily expanding the scope of product utilization.

Part Three: Commercialization Development Timeline of Xylo-oligosaccharides

The commercial evolution of xylo-oligosaccharides is driven by five core forces: technological innovation in agricultural and forestry biomass valorization, iterative upgrades to biological enzymatic hydrolysis processes, maturation of global food safety regulations, breakthroughs in China's localized manufacturing technology, and global upgrades in precision nutrition consumption. The sector has passed through six distinct phases: exclusive Japanese mass production, niche global application, China's domestic industrial breakthrough, domestic market popularization, China's global production capacity leadership, and high-end international competition. XOS has evolved from an obscure laboratory functional sugar into a premium prebiotic ingredient delivering optimal cost performance, maximum environmental sustainability and the broadest spectrum of application scenarios worldwide.

I. Exclusive Japanese Mass Production & Niche Commercialization Stage (Late 1980s – Mid-1990s)

Suntory of Japan launched the world's first commercial mass production line for XOS in 1989, inaugurating the commercial era of xylo-oligosaccharides. In the initial development phase, Japan remained the sole global manufacturer with limited output and premium product pricing. Three major constraints restricted market scale: low public

awareness of prebiotics, prohibitive product costs, and immature application formulations.

Products in this phase targeted exclusively Japan's domestic market, leveraging exceptional acid and heat stability for specialty foods such as vinegar, acidic beverages and fermented dairy goods. This created differentiated competitive advantages over alternative prebiotics limited to neutral food applications. With zero global competitors, Japanese enterprises captured all market profits while strictly withholding proprietary strains and enzymatic hydrolysis technology to stifle rival industry development across other global regions.

II. Global Regulatory Maturation & Slow Overseas Market Expansion Stage (Mid-1990s – 2000)

With complete toxicological safety data finalized, XOS secured food ingredient approval across major global economies, eliminating universal regulatory barriers. Overseas markets gradually recognized its core strengths of ultra-low dosage, targeted prebiotic activity and robust processing tolerance, expanding applications from acidic foods to tablet and powder-form dietary supplements.

Nevertheless, persistent exclusive technological monopoly prevented rapid global capacity expansion, sustaining steep product pricing that barred entry into mass-market general food categories, confining XOS solely to the niche high-end functional health food segment. The global market landscape remained overwhelmingly dominated by Japan; Europe and the Americas operated zero local production capacity and relied entirely on Japanese imports, locking the global XOS industry into a period of sluggish growth bottlenecks.

III. Domestic Industrial Launch & Preliminary Market Cultivation Stage (2000 – 2009)

The commissioning of China's first domestic production line in 2000 marked the end of foreign monopolies and established China as the world's second-largest XOS producer. In the industry's formative domestic phase, domestically manufactured XOS featured lower purity and weaker component control, leaving high-end market segments fully occupied by Japanese imports. Domestic products targeted mid-to-low tier applications including beverages, snack foods and general health supplements.

Abundant, low-cost domestic corn cob agricultural waste resources granted Chinese products formidable cost advantages. Domestic XOS quickly depressed global market pricing, transitioning XOS from a niche luxury ingredient toward mass-market accessibility. The award of the National Technological Invention Prize for core production technology in 2006 significantly elevated industry recognition. Approval of Novel Food Ingredient status in 2009 fully eliminated domestic commercial regulatory barriers, launching China's XOS industry into a stable growth cycle. Concurrently, domestic livestock feed sectors began trialing XOS supplementation, unlocking the industry's second major growth vertical.

IV. Standard System Maturation & Regulated Domestic Industrial Development Stage (2010 – 2020)

From 2010 onward, China constructed a comprehensive multi-dimensional standard framework for xylo-oligosaccharides, sequentially releasing national standards for food-grade XOS, industrial standards for XOS feed additives and supporting national testing methodologies. Core quality control parameters including product degree of polymerization, microbial limits, ash and moisture were unified alongside clear product grading hierarchies, completely resolving early-era issues of inconsistent domestic product quality and disorderly market competition.

Toughened industrial oversight simultaneously raised environmental protection and product quality thresholds, accelerating the phase-out of high-energy, low-purity backward small-scale production capacity and boosting industrial concentration. Leading domestic manufacturers advanced continuous process upgrades with rapid expansion of high-purity product capacity. Domestic XOS gradually penetrated supply chains for premium domestic health supplements and complementary infant foods, accelerating full-scale substitution of imported products. The feed sector witnessed explosive demand growth, establishing XOS as a core prebiotic additive for antibiotic-free livestock farming; feed consumption surpassed food usage to become the industry's largest end-market segment.

V. Global Production Capacity Leadership & Restructured International Market Landscape Stage (2020 – Present)

Supported by a complete biomanufacturing industrial chain, abundant low-cost agricultural and forestry feedstocks, continuously optimized proprietary processes and economies of scale, China emerged as the world's largest producer and exporter of xylo-oligosaccharides after 2020, accounting for over 85% of total global production capacity and fundamentally reshaping the worldwide industrial landscape.

A clear differentiated competitive framework now exists globally:

Japanese manufacturers rely on early brand equity to target niche overseas ultra-high-purity premium markets, supplying small-batch customized formulations while sustaining premium brand pricing power.

Chinese manufacturers offer a full purity spectrum ranging from 70% to 99%, covering both bulk general-grade products and refined high-end variants. China holds the world's largest production scale, robust customized formulation capabilities and unparalleled cost-performance advantages, exporting bulk XOS to Southeast Asia, Europe, the Americas, Japan, South Korea, Australia and other global territories to dominate mainstream mass markets and most mid-to-high-end international segments.

End-market applications have simultaneously diversified rapidly. Beyond the three traditional core sectors of human food, health supplements and livestock feed, XOS has expanded swiftly into emerging verticals including pet food, aquaculture, oral care products, skincare formulations and pharmaceutical excipients, continuously elevating

overall product added value. Aligned with global dual-carbon sustainable development principles via its core attribute of valorizing agricultural waste, the green ingredient identity of XOS further reinforces its global market competitiveness.

VI. Outlook on Future Industry Development Trends

In the long term, the xylo-oligosaccharide industry will sustain iterative upgrades centered on four key pillars: green low-carbon manufacturing, precise customized component formulation, in-depth research into targeted functional health benefits, and segmented full-scenario applications. Leveraging China's technological and production capacity advantages, the nation will steer the future trajectory of the global XOS sector.

Technological Trends

Priority R&D directions will encompass molecular modification of xylanases resistant to high temperatures and extreme environments, integrated continuous one-step enzymatic hydrolysis production, acid-alkali-free green purification, and full high-value utilization of manufacturing byproducts. These advances will further cut industrial energy consumption and three-waste emissions to fully decarbonize biomanufacturing workflows. Novel coupled physical-biological pretreatment technologies will be developed to expand feedstock diversity including crop straw, cottonseed hulls and poplar timber, reducing reliance on single raw material sources.

Product Trends

Precision customizable control over degree of polymerization will be realized, with dedicated formulation portfolios tailored separately for infants, middle-aged and elderly consumers, gut-sensitive populations, pets, aquaculture and livestock species. Five tiered specialized product grades will be formalized: general food grade, food for special medical purposes grade, infant formula grade, dedicated feed grade and dedicated daily chemical grade, enabling targeted, multi-purpose product adaptation. Supported by modern gut microbiome science, research will uncover novel bioactive benefits including anti-inflammatory effects, metabolic regulation and skin microecological maintenance, widening functional differentiation from competing prebiotic products.

Global Market Trends

China's industry evolution will shift from sole export of finished products to synchronized three-pronged global output of manufacturing technology, strain patents and industrial standards, securing permanent Chinese leadership over the global xylo-oligosaccharide sector. Driven by three worldwide megatrends of antibiotic reduction, low-carbon sustainability and precision nutrition, xylo-oligosaccharides—the prebiotic requiring the minimum supplementation dosage and carrying the strongest green sustainability credentials—will sustain long-term rapid market expansion, remaining the highest-growth core functional ingredient category across the global food additives industry.