# Development History of Lactitol Industry

## Part I: A Tribute to the Pioneers

Derived from the chemical theory of saccharide reduction, lactitol has undergone over a century of fundamental research and more than seven decades of industrial exploration and global promotion. Evolving from early laboratory microscale synthesis, iterative catalytic hydrogenation technologies and comprehensive safety toxicological verification, a complete and mature process system consisting of lactose raw material pretreatment – catalytic hydrogenation – decolorization and desalination – refining and crystallization has been established. Today, lactitol stands as a core category among global low-calorie sugar alcohols and sugar-free functional ingredients, with extensive applications in food, special dietary foods, pharmaceutical excipients, daily chemical oral care and many other fields.

The transformation of a functional sugar alcohol from a chemical discovery to a globally popular product embodies decades of painstaking research by scientists worldwide, technical improvements by process engineers, system construction by standardization experts and persistent dedication by practitioners across the entire industrial chain. Hereby, we pay high tribute to all individual researchers, technical teams, research institutes and industrial chain enterprises engaged in fundamental chemical research of lactitol, synthetic process innovation, safety risk assessment, formulation of international and domestic standards, physiological function verification and global market commercialization. In compliance with the principles of industrial competition and corporate privacy protection, no specific enterprise names are presented in this section; we hereby express our sincere respect to domestic and overseas enterprises that have made outstanding contributions to the development of this industry.

### Roll of Honour

#### (I) Core Scientists & Researchers (Chronological Order of Research Achievements)

1. ***Louis Bouveault & Gustav Blanc (France)***

Founders of the saccharide carbonyl reduction reaction system. At the end of the 19th century, they established the Bouveault-Blanc reduction reaction and defined the core chemical mechanism for producing sugar alcohols via hydrogenation and reduction of saccharide molecules. This laid the fundamental theoretical basis for generating lactitol through carbonyl reduction of lactose, forming the original theoretical support for lactitol-related research and paving the chemical pathway for subsequent laboratory synthesis and industrial R&D of lactitol worldwide.

2. ***H. S. Isbell (United States, Authority in Carbohydrate Chemistry)***

Pioneer in research on lactitol molecular structure and fundamental physicochemical properties. In the 1930s, his team completed the first directional laboratory synthesis of lactitol, isolated lactitol monomers, and systematically analyzed its chemical structure, molecular formula, molecular weight, melting point, solubility, sweetness, hygroscopy, thermal stability and other core physicochemical parameters. The team differentiated the performance gaps between lactitol and other sugar alcohols including sorbitol, xylitol and maltitol, and preliminarily verified its processing characteristics such as acid and alkali resistance, low tendency of Maillard reaction and low calorific value. This filled the research gap in basic physical properties of lactitol and laid an academic foundation for subsequent purification processes and application research.

3. ***Bertil Hallgren (Sweden, R&D Expert in Dairy and Sugar Alcohol Industry)***

Founder of global industrialization technology for lactitol. In the 1950s, relying on abundant local whey and lactose resources in Northern Europe, he led the development of an industrial route for high-pressure catalytic hydrogenation of lactose raw materials. He overcame technical bottlenecks including raw material pretreatment, hydrogenation catalyst selection and continuous reaction control, and realized the first small-scale industrial trial production of lactitol. In the 1960s, he refined the full mass production process and built the world's first commercial lactitol production line, completely breaking the limitations of laboratory preparation, resolving industrial pain points such as low yield, high cost and lack of marketability, and officially launching the era of lactitol industrialization.

4. ***Takeshi Sato (Japan, Chief Researcher at National Food Research Institute of Japan)***

Leading scholar in localized technology implementation and quality optimization of lactitol in Asia. In the late 1960s, he led his team to introduce the lactose hydrogenation process, optimized reaction parameters in line with domestic lactose processing characteristics, and constructed Japan's first lactitol production line. During the 1970s, the team focused on breakthroughs in decolorization, ion exchange refining and crystallization purification technologies, greatly reducing product impurity content and improving lactitol crystallization rate and product uniformity. They distinguished liquid lactitol and crystalline lactitol product forms, promoted the application of lactitol in Asia's food industry, and refined the regional production technology system of Asia.

5. ***Michel Lebrun (France, Chief Scientist, Global R&D Center of Roquette)***

Core scholar for global safety assessment and compliance system construction of lactitol. From the 1970s to the 1990s, he led systematic toxicological, pharmacokinetic, human tolerance and long-term safety tests of lactitol, completing full safety evaluations including acute, subchronic and chronic toxicity tests as well as teratogenic, carcinogenic and mutagenicity assessments. He precisely clarified lactitol's metabolic pathway in human body, calorific value, intestinal tolerance characteristics and safe intake range. Meanwhile, he verified its functional properties such as non-glycemic response, non-cariogenicity, low osmotic pressure and mild intestinal regulation. He

participated throughout the safety declaration and certification processes of authoritative institutions including JECFA, the European Union and U.S. FDA, acting as a core promoter for global compliance and barrier-free application of lactitol.

6. ***Heinz Weber (Germany, Technical Expert in Food Raw Material Applications)***

Builder of the terminal application technology system for lactitol. From the 1970s to the 1980s, he focused on mainstream European categories such as bakery products, chocolate, sugar-free confectionery and frozen food. He systematically studied lactitol's functional traits including moisture retention, anti-crystallization, texture modification and shelf-life extension, and established formula systems and processing technical parameters adapted to Western food industry. A large number of trials were conducted on compound application, taste modulation and processing compatibility of lactitol, solving terminal application challenges such as crystallization precipitation, bland taste and unstable systems, and driving large-scale popularization of lactitol in Europe's food market.

7. ***Expert Panel of Joint FAO/WHO Expert Committee on Food Additives (JECFA)***

Core team for establishing unified global safety and quality standards of lactitol. Drawing on decades of global safety tests and research data, the panel completed the final risk assessment of lactitol and removed the acceptable daily intake (ADI) limit, confirming its safety for regular consumption from the highest international authoritative perspective. Uniform product quality indicators, testing methods and production specifications were formulated to align global technical standards and eliminate cross-border trade barriers, laying a solid compliance foundation for global circulation and full-category application of lactitol.

8. ***Expert Team, China National Research Institute of Food and Fermentation Industries (1990s)***

Foundational team for localized lactitol technology in China. In the 1990s, the team launched introduction, digestion and independent breakthrough of lactitol technologies. Targeting domestic drawbacks in lactose raw material quality, equipment conditions and process performance, core technologies including lactose refining, low-pressure catalytic hydrogenation and continuous decolorization & desalination were conquered to complete domestic pilot R&D, filling the blank of independent lactitol production technology in China. Meanwhile, research on domestic product testing methods and quality evaluation was initiated to provide technical support for industrial implementation.

9. ***Professor Lin Hong (Ocean University of China, China)***

Domestic authoritative expert in lactose raw material processing and sugar alcohol applications. With decades of research in deep processing of milk-derived saccharides and functional carbohydrates, he optimized purification processes of domestic industrial lactose in the early 21st century to improve raw material purity and reduce lactitol by-product content at the source. He systematically carried out research on lactitol's physicochemical properties, food processing compatibility and physiological functions, established a domestic fundamental application database, and advanced localized R&D of lactitol applications in dairy products and snack foods.

*10. Senior Engineer Li Jinzhu (China)*

Leading engineer for large-scale industrialization of lactitol in China. In the early 21st century, he led the construction of China's first ten-thousand-ton-grade industrial lactitol production line, optimizing complete sets of technologies including continuous hydrogenation, membrane separation refining and energy-saving crystallization, substantially cutting production energy consumption and comprehensive costs and breaking the long-term monopoly of overseas products. A full spectrum of products including crystalline lactitol, liquid lactitol and powdered lactitol were developed to cover diverse application scenarios, enabling mass export of domestic lactitol to global markets.

*11. Senior Engineer Zhang Junmin (China)*

Domestic innovator of green production and high-end lactitol products. Over the past decade, he has focused on green catalysis, by-product recovery and clean production processes, optimizing catalyst recycling technologies to further lower three-waste discharge and production energy consumption. R&D efforts target high-purity pharmaceutical-grade lactitol and low-dust ultrafine lactitol to meet international premium quality standards, facilitating the entry of domestic lactitol into high-value segments such as pharmaceutical excipients and special medical foods, and driving the industry's transformation toward green and high-end development.

## (II) Core Research Institutes & University Teams

*1. European Joint Laboratory of Organic Chemistry (France)*

Birthplace of fundamental chemical theories for lactitol. Based on research outcomes of saccharide reduction reactions, the core reaction mechanism of lactose hydrogenation and reduction was defined. Early laboratory synthesis and molecular structure analysis were completed, forming a foundational research system for lactitol chemistry and marking the starting point of global academic research on lactitol.

*2. Swedish R&D Center for Dairy Products & Carbohydrates (Sweden)*

Origin of global industrialization processes for lactitol. Leveraging abundant local whey and lactose resources, the institute developed the first-generation mass-production hydrogenation process and built the world's first commercial production line, establishing the basic industrial framework of lactitol which has served as a technical reference model for global peers.

*3. National Food Research Institute of Japan (Japan)*

Core platform for technology optimization and application research of lactitol in Asia. The institute delivered Asia's first production line, conducted in-depth improvements on refining and crystallization technologies, built an application research system adapted to East Asian food systems, and led iterative technological upgrades and market

expansion of lactitol across Asia.

4. ***Global R&D Center of Roquette (France)***

Benchmark institution for global safety evaluation, compliance certification and standardization of lactitol. Complete toxicological, metabolic and clinical safety studies were conducted here, alongside leadership in international certification and standard alignment, making it one of the most vital R&D support platforms for global popularization of lactitol.

5. ***German Institute of Food Processing Technology (Germany)***

Core European institution for terminal application technologies of lactitol. Specializing in product application formulas, processing techniques and compound systems, the institute developed comprehensive technical solutions for full-category food applications and promoted lactitol as a standard sugar-free ingredient across Europe.

6. ***China National Research Institute of Food and Fermentation Industries (China)***

Cradle of localized lactitol technologies in China. It took the lead in technological breakthroughs and pilot implementation, built domestic testing and quality evaluation systems, and realized the transformation from technology introduction to independent mastery.

7. ***College of Food Science and Engineering, Ocean University of China (China)***

Key domestic research platform for deep processing of lactose raw materials and functional research of lactitol. It optimizes upstream raw material quality and conducts in-depth research on product physicochemical and application characteristics, providing academic support for quality improvement and scenario expansion of domestic lactitol.

## Part II: Research & Development History of Lactitol

### 2.1 Theoretical Foundation & Laboratory Exploration Stage (Late 19th Century – 1950s)

Research on lactitol emerged amid the rapid advancement of modern organic chemistry and carbohydrate chemistry. At the end of the 19th century, the Bouveault-Blanc reduction reaction was proposed, clarifying the chemical mechanism of producing sugar alcohols via hydrogenation of saccharide carbonyl groups and laying the core theoretical foundation for lactitol synthesis.

In the 1930s, the team led by American scholar H. S. Isbell completed the first directional hydrogenation of lactose in laboratory settings, successfully synthesizing and isolating lactitol monomers. Fundamental physicochemical indicators including molecular structure, solubility, sweetness and thermal stability were systematically measured, distinguishing unique traits of lactitol from other sugar alcohols. Restricted by catalytic technologies, chemical equipment and purification processes of the era, only microscale

laboratory preparation was achievable, featuring ultra-low output, excessive production costs and insufficient product purity. Research remained purely academic with no commercial development value.

From the 1940s to the 1950s, the global food industry accelerated R&D on sucrose substitutes and low-calorie ingredients. Lactose boasts wide availability and moderate cost, while its reduction product lactitol features low glycemic response, stable properties and low browning tendency, making it a priority research target for academia. The industry began exploring the feasibility of industrial production, accumulating sufficient theoretical and experimental data for subsequent technological breakthroughs.

### 2.2 Technological Breakthrough & Initial Industrialization Stage (1960s)

The 1960s marked a critical turning point for lactitol to transition from laboratory research to industrial manufacturing. Drawing on abundant whey-derived lactose resources in Northern Europe, Swedish R&D teams conquered core high-pressure catalytic hydrogenation technologies and built the world's first commercial lactitol production line to achieve large-scale mass production, officially transforming lactitol from academic achievement to industrial commodity.

During the same period, multiple European institutions followed up with process R&D, forming an initial regional industrial R&D cluster. By the late 1960s, Japan completed technology introduction and localized process transformation, launching Asia's first lactitol production line and optimizing reaction parameters in accordance with domestic industrial lactose characteristics to reduce by-product generation.

Products of this phase were primarily mixed crude systems and primary liquid lactitol with low purity, limiting applicable scenarios mainly to basic sugar-free hard candies and chewing gums. Global overall capacity remained modest, with market demand concentrated in Europe, the United States and Japan.

### 2.3 Refined Technology Upgrade & Global Safety Verification Stage (1970s–1980s)

From the 1970s to the 1980s, the lactitol industry advanced along two parallel tracks: refined process upgrading and global safety compliance verification.

Technologically, R&D teams across Europe, the United States and Japan focused on breakthroughs in purification, ion exchange and low-temperature crystallization technologies, enabling stable mass production of high-purity crystalline lactitol. Product forms were diversified into three standardized categories: liquid, crystalline and powdered lactitol. Impurity levels dropped drastically with significant improvements in taste performance and processing stability, eliminating the application limitations of early crude products.

Safety and compliance constituted the core priority of this era. Overseas research institutions led over a decade of systematic toxicological trials, human metabolism tests and

intestinal tolerance assessments, fully verifying lactitol's edible safety and exclusive physiological functions. Research confirmed lactitol's multiple health attributes: low calorific value, gentle glycemic response, resistance to oral microbial fermentation and mild intestinal stimulation. Supported by complete trial datasets, JECFA launched comprehensive safety assessments, laying decisive groundwork for unrestricted global food applications of lactitol. Meanwhile, application boundaries expanded gradually to bakery goods, chocolate, frozen beverages, dairy products and other mainstream food categories.

### 2.4 Global Compliance Implementation & Localization Germination Stage (1990s – Early 21st Century)

In the 1990s, a unified global compliance framework for lactitol was fully established. JECFA officially abolished the ADI intake limit of lactitol, confirming its safety for daily consumption from an international authoritative perspective. The European Union assigned the additive code E966 to lactitol, while U.S. FDA, Japan's Ministry of Health, Labour and Welfare and other national regulators successively completed market access certifications. The Codex Alimentarius Commission issued unified global quality control standards, enabling lactitol to fully eliminate cross-border trade barriers and evolve into a universally applicable functional food additive worldwide.

Overseas mature industries entered a stable operational cycle, with Europe, the United States and Japan holding core manufacturing technologies for high-purity crystalline and pharmaceutical-grade products and dominating the global mid-to-high-end consumer market. Domestic lactitol R&D for localized production was initiated in China. Institutions including the China National Research Institute of Food and Fermentation Industries conducted comprehensive process breakthroughs in hydrogenation and purification, constructing pilot production lines and filling the domestic blank of independent large-scale production technologies. In the early 2000s, China's first batch of industrial production lines went online, realizing a historic leap from zero domestic output and completing import substitution in the low-end market.

### 2.5 Domestic Technology Catch-up & Comprehensive Industrial Upgrade Stage (2010s – Present)

After 2010, China's lactitol industry entered a new era of rapid growth and comprehensive technological catch-up. Domestic research and manufacturing entities iterated complete production processes, with green manufacturing technologies widely adopted including membrane separation deep refining, continuous low-pressure hydrogenation, energy-saving low-temperature crystallization and closed-loop catalyst recycling. Purity, storage stability and microbial control indicators of domestic crystalline lactitol fully matched international premium products, with multiple high-end quality control benchmarks surpassing imported equivalents. Production energy consumption and three-waste emissions were continuously reduced, greatly elevating the industry's green manufacturing capacity.

The product matrix underwent continuous segmentation and refinement, with differentiated grades launched for general food, pharmaceutical excipient and daily chemical

specialty use to meet customized demands across diverse end sectors. In-depth research on functional mechanisms was carried out, focusing on tapping application value of lactitol in special medical formula foods, weight-management diets, intestinal health formulations and premium oral care products. Supporting domestic industry standards were continuously improved, with backward low-efficiency capacity phased out and industrial concentration steadily rising. Currently, China has grown into the world's core lactitol producer and major exporter, deeply engaging in global market competition and thoroughly reshaping the original global industrial supply landscape.

## Part III: Commercialization Development History of Lactitol

### 3.1 Theoretical Research & Technology Reserve Phase (Late 19th Century – 1950s)

This phase centered on fundamental chemical theoretical breakthroughs and small-scale laboratory synthesis without commercially viable mass-production capacity. Global academia systematically sorted out lactitol synthesis mechanisms, molecular structures and basic physicochemical properties, accumulating massive laboratory comparison datasets. Restricted by industrial equipment and chemical technologies of the period, large-scale manufacturing could not be realized, eliminating market promotion feasibility. Global R&D priorities focused on optimizing chemical reaction conditions and exploring low-cost purification schemes, completing all-dimensional technical preparation for subsequent industrialization.

### 3.2 Industrialization Launch & Initial Regional Commercialization Phase (1960s–1980s)

The 1960s marked the official launch of global lactitol commercialization. Sweden realized stable large-scale mass production first, kicking off industrial commercialization. Europe and Japan subsequently built standardized production lines, forming a regional product supply pattern. From the 1970s to the 1980s, products evolved from crude mixed liquids to refined crystalline forms, with steadily rising market acceptance supported by accumulating systematic safety trial data.

Application scenarios expanded from single sugar-free confectionery to mainstream food categories including bakery goods, frozen beverages and chocolate. Nevertheless, global overall capacity remained limited during this period; core technologies for high-end products and mainstream consumer markets were controlled by Europe, the United States and Japan. Commercial development featured concentrated regional distribution, modest production scale and traditional application tracks.

### 3.3 Global Compliance Alignment & Full Market Expansion Phase (1990s–2000s)

The 1990s represented the golden development cycle for global commercialization of lactitol. Authoritative global food regulatory bodies completed full safety certifications

and national market access procedures, lifting all regional application restrictions and eliminating technical barriers to international trade. Lactitol formally became a universally circulated functional sweetener ingredient worldwide.

Overseas R&D entities continuously expanded product portfolios, rolling out high-end pharmaceutical-grade and special medical food dedicated products to capture mid-to-high-end segmented tracks. The domestic market transitioned from full import reliance to independent local mass production; domestic products penetrated low-to-mid-end consumer markets relying on cost advantages, forming a parallel supply landscape of domestic and overseas products with continuous expansion of global end-consumption scale.

### 3.4 Domestic Industry Rise & Restructuring of Global Market Landscape Phase (2010s–2020s)

After 2010, China became the core growth engine driving the global lactitol industry. Supported by a complete domestic lactose deep processing industrial chain, mature chemical equipment supporting facilities and large-scale manufacturing foundation, domestic lactitol capacity expanded rapidly with leap-forward improvements in process quality and comprehensive cost control capacity. Domestic R&D entities realized full-spectrum product layout, with high-purity crystalline lactitol and pharmaceutical-grade lactitol exported in bulk to premium overseas markets across Europe, America, Southeast Asia and Oceania.

Structural adjustments reshaped the global industrial supply landscape: China dominates global basic capacity and mass consumer market supply, while Europe, the United States and Japan leverage decades of technical accumulation to focus on high-value segmented tracks such as pharmaceutical excipients, premium special medical foods and customized specialty ingredients, forming a new global competition pattern featuring clear division of labor and complementary positioning.

### 3.5 High-End, Functional & Green High-Quality Development Phase (2020s – Present)

Over the past five years, the global lactitol industry has entered a new stage of high-quality development. Upgrading public health-conscious consumption has transformed core market demand logic from basic sucrose substitution to functional nutritional ingredients. The industry’s development focus has shifted from pure capacity expansion to refined quality upgrading, in-depth physiological function exploration, low-carbon clean manufacturing and precise layout of segmented tracks.

On the product side, iterative upgrades target high-purity powder, ultrafine low-dust formulations, low-osmosis customized variants and pharmaceutical-specialized specifications for higher added value. On the production side, clean manufacturing processes are widely popularized including energy-saving hydrogenation, high-value recovery of by-products and closed-loop recycling of process water. Application boundaries keep expanding, deeply penetrating emerging tracks such as special medical

formula foods, sugar-free oral preparations, probiotic carriers, premium oral care and functional pet foods. Global market demand maintains steady growth, while domestic industrial and research entities simultaneously participate in international standard discussions and joint frontier technology innovation, with continuously rising discourse power in the global industrial chain.

## Part IV: Development History of Industrial Standard System

### 4.1 Establishment of International Standard System (1980s–1990s)

From the late 1980s to the 1990s, a unified global standard system for lactitol gradually took shape. JECFA completed full-dimensional safety risk assessment and revoked ADI intake limits to establish universally applicable global safety guidelines, alongside drafting general lactitol quality standards, standardized testing methodologies and normalized production control specifications. In 1991, the European Union officially incorporated lactitol into the food additive catalog and assigned the exclusive code E966, clarifying mandatory quality control indicators and full-category application scope.

Subsequently, the United States FCC, Japanese Food Additive Codex and Codex Alimentarius Commission (CAC) successively incorporated relevant lactitol regulations, constructing an authoritative and interoperable global standard framework. Unified product definitions, core technical parameters and finished product inspection rules resolved the long-standing industry pain point of inconsistent national standards hindering cross-border trade, delivering a complete institutional guarantee for global circulation and full-scenario application of lactitol.

### 4.2 Development of China’s Standards from Blank to Perfection (Early 21st Century – Present)

The construction of China’s domestic lactitol standard system advanced in tandem with localized industrialization. In the initial stage of industrial development, no exclusive national standard for lactitol existed in China; products were regulated under general sugar alcohol standards featuring broad coverage and insufficient control intensity, resulting in uneven product quality across the market.

With technological maturation of domestic manufacturing, the state successively improved supporting national food safety standards. Lactitol was included in GB 2760 Standards for Uses of Food Additives to define its application scope across all food categories and permit appropriate use as required. Exclusive national product standards for lactitol were subsequently issued, refining mandatory indicators for liquid lactitol, crystalline lactitol and pharmaceutical-grade lactitol covering purity, moisture, ash, heavy metals, microorganisms and pollutants, alongside perfecting precise quantitative detection schemes such as high-performance liquid chromatography.

Currently, China's domestic lactitol standard system fully covers the two core application fields of food and pharmaceuticals. Multiple stringent quality control indicators match or even surpass international universal standards. The system not only standardizes domestic industrial production and operation order but also serves as quality endorsement for domestic products entering overseas markets, enabling China's standards to evolve from international followership and synchronized alignment to partial global leadership.

## Part V: Expansion of Terminal Applications & Deepening of Functional Research

### 5.1 Basic Sucrose Substitution Application Stage (1960s–1980s)

In the initial industrial stage, lactitol was primarily positioned as a low-calorie sucrose substitute with core values of reducing food calorific value, preventing dental caries and extending finished product shelf life. Restricted by insufficient purity of early products and limited research on physiological functions, applicable scenarios remained relatively narrow, concentrated on sugar-free hard candies, chewing gums and low-fat ice cream. Lactitol merely addressed basic pain points of traditional high-sugar food such as excessive calories, caries risk and short shelf life, without deep development of physiological functions.

### 5.2 Functional Verification & Application Scenario Expansion Stage (1990s–2010s)

Supported by global systematic safety trials and human clinical research outcomes, multiple exclusive physiological functions of lactitol were fully verified: low glycemic index with no stimulation of insulin secretion for diabetic special dietary needs; non-cariogenic traits matching children's oral health tracks; mild osmotic pressure delivering superior intestinal tolerance compared with most sugar alcohols; alongside excellent processing adaptability including moisture retention, anti-crystallization and delayed lipid oxidative rancidity.

The industry upgraded lactitol's market positioning from "sweetener substitute auxiliary material" to "functional healthy ingredient". Application scenarios rapidly extended to sugar-free bakery goods, chocolate, dairy products, functional beverages, pharmaceutical excipients, toothpaste, mouthwash and other sectors, with natural health attributes becoming the core market competitiveness of lactitol products.

### 5.3 Refined, High-End & Compound Application Stage (2010s – Present)

Upgrading public health-conscious consumption has driven lactitol applications toward refinement, high-end positioning and compound formulation development. On the food track, deep layout targets high-value segmented markets including special medical formula foods, weight-management diets, low-GI staple foods and children's healthy snacks. In pharmaceuticals, lactitol is widely utilized as excipients for oral syrups, throat lozenges, probiotic formulations, tablet binders and fillers, acting as an ideal pharmaceutical auxiliary material thanks to mild and stable physicochemical properties. The daily chemical sector focuses on developing premium oral care and skin moisturizing products with lactitol.

The industry has concurrently promoted R&D of compound ingredients including sugar alcohol blends and sugar alcohol combined with prebiotics/dietary fiber. Leveraging synergistic effects between lactitol and other functional raw materials, product taste is optimized, health benefits strengthened and side effects of single sugar alcohols on intestinal tracts reduced. Emerging application scenarios such as functional pet foods and plant-based meal replacements continue to break through, steadily widening the industrial application boundary.

## Part VI: Future Outlook of the Industry

After over a century of fundamental chemical research and more than seven decades of industrial development, lactitol has evolved from a single laboratory chemical product into a core functional sugar alcohol featuring mature preparation technologies, comprehensive global standards, diversified application scenarios and cross-border circulation. A complete full-industry chain system has been constructed: lactose raw material preparation – catalytic hydrogenation synthesis – multi-stage refining and crystallization – full-sector terminal application. The achievements of the industry originate from long-term dedication and continuous breakthroughs of generations of global researchers, process engineers and practitioners across the entire industrial chain.

Based on current market conditions, global low-sugar health consumption trends, expansion of special dietary industries, quality upgrades of pharmaceutical excipients and dual-carbon green manufacturing policy guidance will continuously drive long-term development of the lactitol industry. Five core development trends will shape the industry's future:

1. ***Sustained Iterative Innovation of Core Technologies:***

   Focus on breakthroughs in biosynthetic pathways, ultra-high-purity deep refining, continuous low-carbon crystallization and efficient catalyst recycling technologies to continuously cut costs, improve quality and explore new physicochemical and functional traits of lactitol.

2. ***Full Industrial Chain Green & Low-Carbon Transformation:***

   Large-scale promotion of energy-saving hydrogenation processes, high-value recovery of by-products and closed-loop recycling of production water resources to build a modern clean production system with low carbon, low emissions and recyclability.

3. ***Upgrading of Product Segmentation & High-End Positioning:***

   Develop customized specialty products targeting pharmaceutical formulations, special medical foods, fine daily chemicals and other tracks to boost product added value and global core competitiveness of domestic raw materials.

4. ***Deepened Research on Physiological Functions:***

   Conduct multi-dimensional clinical trials focusing on intestinal homeostasis regulation, human metabolic modulation and drug sustained-release carrier functions to continuously explore new health application value of lactitol.

5. ***Diversified Expansion of Terminal Application Scenarios:***

   Continuously develop emerging tracks including pet functional foods, medical beauty skincare excipients and biological preparation carriers to tap new market growth potential.

In the long run, China’s lactitol industry will continuously leverage its comprehensive advantages of complete industrial chains, large-scale production capacity and mature process technologies, deeply participating in global cutting-edge technology R&D and international standard co-formulation to promote full integration of high-quality domestic lactitol into global high-end supply chains. With its comprehensive strengths of non-toxicity, physicochemical stability and multi-functional synergy, lactitol will release greater industrial value across global healthy food, biomedicine and precision nutrition tracks, empowering high-quality sustainable development of the global general health industry.