DOI 10.15302/J-SSCAE-2021.05.007

Development Strategy of Microbial Industry in China

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Abstract: The microbial industry is a strategic emerging industry and an important field for developing new growth drivers and creating new global competitive advantages. Given the opportunity to promote Healthy China's construction, the development of the microbial industry is significant for regional scientific and technological innovation, high-quality industrial development, and improvement of people's welfare in China. This study expounds the macro-demand for the development of the microbial industry. It analyzes the development status of the global microbial industry regarding industrial layout and technological progress. The study further outlines the development trend of the microbial industry in China based on the industrial policy environment, and industrial-scale. It investigates the development status of segmentation directions, including microbial safety, health, manufacturing, and medicine, and dissects the challenges in the development of the industry. Our findings indicate that structuring systematic big scientific facilities, developing a series of industrialized technologies, and promoting the industrial application of microbial resources are key initiatives for accelerating the development of the microbial industry in China. Therefore, we propose strengthening the research and development of the high-tech microbial sector, promoting an industrial policy system for collaborative innovation and development, and building industrial clusters centered around microbial innovation platforms. All these will greatly improve the development level of the microbial industry in China.

Keywords: microbial industry; microbial safety; microbial health; microbial medicine; microbial manufacturing; big scientific facilities; industrial application

1 Introduction

The microbial industry is a national strategic emerging industry [1], and biotechnology was listed as the focus of the scientific and technological development strategy in the *Outline of the National Medium- and Long-term Science and Technology Development Plan (2006–2020)*. Furthermore, the *Special Plan for Biotechnology Innovation during 13th Five-Year Period* (2017) proposes expanding industry development space, improving development quality and efficiency, and supporting the development of emerging biotechnology industries. Therefore, China has created a relatively complete microbial industry system, including microbial technology industries, such as microbial medicine, manufacturing, and agriculture.

Microbial technology products are mainly used in agriculture, forestry, medicine and health, manufacturing, and other fields and have great potential for future development. A market research organization, BCC research predicts

Received date: July 18, 2021**; Revised date:** September 09, 2021

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Funding program: CAE Advisory Project "Research on the Development Strategy of China's Microbial Safety and Health Industry" (2020-ZD-05)

Chinese version: Strategic Study of CAE 2021, 23(5): 051–058

Cited item: Du Juan et al. Development Strategy of Microbial Industry in China. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2021.05.007

that the market scale of microbial products will increase from 186.3 billion USD in 2018 to 302.4 billion USD in 2023 globally, with a compound annual growth rate of 10.2% [2]. Furthermore, with the cross-integration development of omics, synthetic biology and other technologies, technological innovation and industrial transformation in microbiology have entered a new stage of vigorous growth. This will play an important role in promoting the transformation and upgrading of regional industries and producing new technologies, products, formats, and new models [3–5].

Given the great opportunity to promote the Healthy China' construction, the microbial industry should actively plan for high-quality development and give play to the deserved effect. As an academic display of the project's achievements "Research on the Development Strategy of Microbial Safety and Health Industry in China," this study systematically investigated the overall situation of the industry. Furthermore, it analyzed the industrial development direction. It summarized the countermeasures for developing the microbial industry in China from the four aspects of microbial safety, health, medicine, and manufacturing, providing a reference for macro-industrial layout and the development of fundamental technologies.

2 Analysis of the development needs of the microbial industry

2.1 Protecting people's lives and health

Microorganisms are key factors that affect human health and disease occurrence. The human genome and microbiome coordinate and maintain human health. With the progress of technology, microbial health products have been widely used and have played important roles in intestinal flora and nutritional balance. First, as an important maintainer of the host immune response, resistance to pathogens, digestion and absorption, material and energy metabolism, and promotion of growth and development, human microorganisms directly or indirectly regulate the functions of multiple systems. Second, the imbalance in human microhabitat is closely related to many diseases, such as intestinal diseases [6,7]. Third, human microhabitat is an "intermediate station" of drug metabolism, constantly changing with human aging and lifespan. Microbial detection is an essential means of ensuring human life and health. With improvements in living standards, people are paying more attention to health. As a disposable medical consumer product, the market demand for microbial testing products will steadily and continuously grow. Microbial drugs are widely used as regulators of the human immune system for infections, inflammation, diabetes, cancer, nutrition, and health care. Because of their advantages of good safety, short production cycle, and rich sources, microbial drugs have great potential for development in the future.

2.2 Promoting the upgrading of traditional industries

Microbial technology has great application potential in new materials and energy and is significant for sustainable industrial development. Compared to the traditional petrochemical and coal chemical industries, fermentation production using bio-based raw materials has strong renewability, high safety, and environmental friendliness, and microorganisms are the core resources in the relevant production process. The basic elements of biomass raw materials are C, H, and O, almost free of S. Therefore, sulfide is not produced in biological fermentation, and pollutant emissions will be significantly reduced in the production process. Through degradation, bio-based raw materials are transformed into CO_2 and H_2O and returned to nature, fundamentally preventing environmental pollution. For example, compared with chemical synthesis, the production of adipic acid by biological synthesis can reduce greenhouse gas emissions by 85%.

2.3 Supporting ecological and environmental protection

Microorganisms can be used to purify domestic and toxic industrial sewage, monitor environmental pollution, and provide important ecological and environmental protection. With economic and societal development, refractory organic pollutants in the environments have become diversified, complicated, and persistent. In response to environmental and ecological problems caused by environmental pollution, the research and development (R&D) of new methods and technologies of the microbiomes and their functions will help understand the interdependence of different forms of life in the ecosystem. This provides unique solutions for improving the ecological environment. The relationship between microorganisms and environments is not limited to the natural environment but can be extended to the social environments, such as the indoor environment. Particularly regarding biosafety, the importance of microbiological monitoring and intervention in the "small environment" has been confirmed through the practice of prevention and control of the novel coronavirus pneumonia (COVID-19) epidemic.

DOI 10.15302/J-SSCAE-2021.05.007

2.4 Facilitating the innovation of agricultural production

China is the largest global consumer of fertilizer. Excessive fertilization is prominent, increasing the cost of agricultural production, consuming excessively, and causing serious soil and groundwater pollution [8]. Microorganisms are indispensable for improving soil fertility, promoting grain production, controlling grain diseases and insect pests, and preventing mildew and spoilage in grains. Microbial fertilizers have become the pillar of modern green agriculture because of their excellent characteristics for improving soil fertility, crop growth, crop quality, and stress resistance. It also reduces environmental pollution caused by crop planting, ensuring that crops conform to food quality and safety [9]. Microbial fermented feed and pet probiotics play an obvious role in promoting animal growth and development, improving immunity to prevent diseases, and improving feed palatability and conversion rates.

3 Development status and trend of international microbial industry

3.1 Industrial layout and technological progress

The biological industry is a hot spot in the global scientific and technical competence and the strategic commanding heights where countries compete for layout. Over 50 countries and regions have issued national bioeconomy-related policies. In biotechnology, the importance of microorganisms in modern biotechnology is self-evident, and microbial manufacturing is a key direction.

The microbial manufacturing industry has become an important measure for achieving sustainable economic development in developed countries and regions. The *Roadmap for Biomass Technologies* was drawn up by the United States in 2002. According to the roadmap, 25% of organic chemicals will be replaced by bio-based products, 20% of petroleum fuels for transportation will be replaced by bioenergy by 2030 [10], and most related products will be produced by microbial manufacturing. The *Industrialization of Biology: A Roadmap for Accelerating the Manufacturing of Advanced Chemical Products* formulated in 2015 proposes the specific targets for microbial manufacturing to accelerate chemical product productions. The European Union launched the *European Joint Bio-based Industry Development Plan* in 2014. According to the *Industrial Biotechnology Vision Plan*, 6%–12% of chemical raw materials will be replaced by bio-based raw materials by 2030, of which 30%–60% of fine chemicals will be manufactured by bio-based methods, and microbial manufacturing will play a key role in this process [10]. In 2019, the total market scale of bio-based chemicals in Europe was EUR 9.17 billion, accounting for only 2.6% of the European chemical market, having massive potential for growth and development. The German government has successively issued *Bioeconomy 2030: National Research Strategy* (2010), *Biorefinery Roadmap* (2012), and *National Bioeconomy Policy Strategy* (2013), strongly supporting the use of biomass raw materials and microorganisms to realize sustainable development and utilization of resources. In 2002, Japan proposed the development vision of “building a country with biotechnology industry” and incorporated the biological industry into the national core industry category. Japan has also introduced a policy system, represented by the “creation of a circular industrial system based on the use of biological functions”, aiming to accelerate the utilization of biotechnology and promote the development of the bio-industry.

The development rate of the world’s biotechnology industry has remained at twice the average economic growth rate. Additionally, the enthusiasm for related social investment is relatively high; for example, venture capital investment in 2017 exceeded 10 billion US dollars (second only to the information technology industry), becoming an important driving force for economic growth. The upstream region is dominated by technical service companies from the global microbial industry chain, providing product R&D support, including metagenomic sequencing, microbial detection, identification and analysis, and clinical diagnosis. The middle and downstream companies are mainly based on human health applications, such as microbial scientific research, microbial therapy and drug R&D, and health management. The US companies have a dominant position in microbes, with advanced technology and dense distribution [11].

With the rapid development of big data technology, the R&D of microbial technology is turning to a scientific development mode of data, providing new technical support for the microbial industry. The cross-integration of physics, materials, computer science, and other disciplines with life sciences has promoted biological imaging, gene editing, single cells, life omics, and other technologies. In addition, the rapid development of sequencing technology, gene editing, regenerative medicine, additive manufacturing, synthetic biology, and other technologies has promoted the development of the biotechnology industry. According to statistics from the IncoPat patent database, during 2010–2020, there were 485 714 patent applications and 72 500 authorizations in the field of microbiology

technology worldwide. Patent applications have increased annually, particularly in China (Fig. 1).

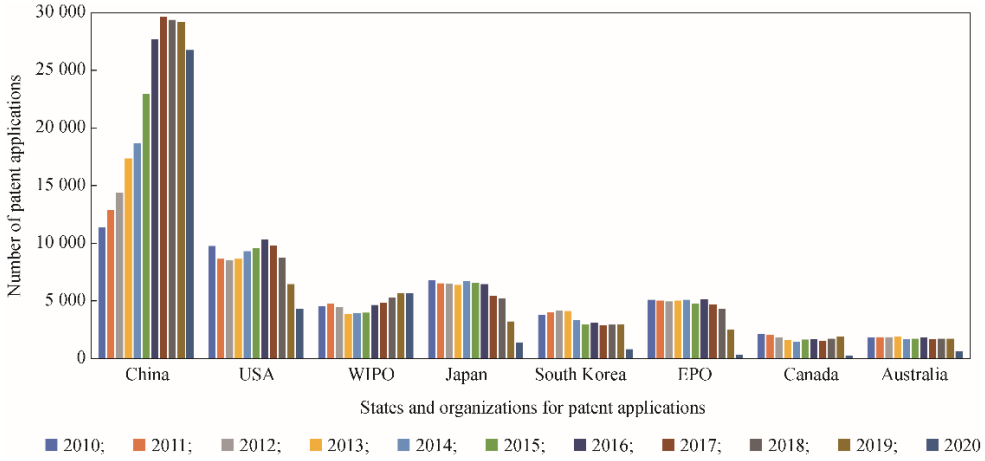

Fig. 1. Patent applications in the field of microbial technology in the world

Note: WIPO refers to World Intellectual Property Organization; EPO refers to European Patents Organization.

3.2 Development trends

The threat of major infectious diseases, foodborne diseases, and pathogenic drug-resistant super bacteria globally is becoming serious, threatening human health. As the most important technical means, microbial detection and prevention are leading the microbial safety industry to a period of rapid development. Detection products that combine the Internet, big data, cloud computing, and artificial intelligence (AI) are considered long-term hotspots for microbial detection.

The microbial health economy is developing rapidly, and microbial health products with modern biotechnology as the core are quickly seizing the market. With the advancement of technology, the intestinal microbiota, known as the second genome of human beings, has become an emerging hot research direction. The research results of the intestinal microbiome can provide a continuous impetus for the innovative development of the microbial health industry.

Integrating omics, information, cutting-edge biology, and other technologies with basic disciplines, such as mathematics and physics, promotes significant progress in microbial manufacturing systems. Using the cyber-physical system formed by big data, AI, and other technologies, we will develop an intelligent manufacturing industry chain with self-perception, self-learning, self-decision-making, self-execution, and adaptive functions. We will jointly promote standardization, refinement and intelligence in microbial manufacturing.

The world's biomedical industry is growing rapidly. Therefore, the microbial medicine industry quickly develops from a high-tech industry with the highest development potential to a high-tech pillar industry. Furthermore, with the development of modern biotechnology, such as genetic engineering and cell engineering, precision medicine based on biological data integration and precision drug design combined with AI and big data will become an important development direction for innovative microbial drug R&D and precision medicine.

4 Analysis of the development of microbial industry in China

4.1 Macro-development trends

4.1.1 The policy environment continues to improve

Bio-manufacturing is a key development field for building a powerful country in science and technology. For more than a decade, relevant departments have issued several industrial policies to support the development of bio-manufacturing. The *Decision of the State Council on Accelerating the Cultivation and Development of Strategic Emerging Industries* (2010) listed biomanufacturing as an important part of the bioindustry, highlighting the strategic emerging industry attributes of biomanufacturing. The National Strategic Emerging Industry Development Plan during the 13th Five-Year Period further clarifies that biomanufacturing, as a national key development industry, is the main direction of China's strategic emerging industries. The National Bureau of Statistics announced the *Classification of Strategic Emerging Industries (2018)*, including bio-based materials, microbial manufacturing products, biological enzyme products, marine biological products, biological engineering-related equipment

DOI 10.15302/J-SSCAE-2021.05.007

manufacturing, biological services, and other industries. The *Letter of the Ministry of Science and Technology on Supporting the Construction of the National Synthetic Biotechnology Innovation Center* (2019) highlighted that the focus should be on breaking through the technical bottlenecks of independent construction and engineering application of industrial enzymes and core strains. This leads to the construction of new technological paths for future bio-manufacturing.

4.1.2 The scale of the industry continues to grow

The demand and supply of microbial safety and health products in China have maintained a rapid growth trend, with great market space and potential. The output value of the microbiological testing industry continued to rise from 19 million CNY in 2010 to 467 million CNY in 2019, with a compound annual growth rate of more than 40% [12]. The supply and demand for microbial health products have continued to grow rapidly. The market scale was 46 billion CNY in 2017, considering probiotics as an example, and is expected to increase to 89.6 billion CNY in 2022, with an average annual growth rate of approximately 14% [13]. Fermentation engineering is an important component in the microbial manufacturing industry. In recent years, the development of related industries in China has been stable, changing toward quality and efficiency. Various new fermentation products and derived new products have continued to increase. In 2018, the output of main fermentation products was 29.62 million tons, with a total output value of 247.2 billion CNY [14]. According to the predictions of the China Commercial Industry Research Institute, the scale of China's biopharmaceutical market will reach 831 billion CNY by 2025 and more than 8 trillion CNY by 2035 [15].

China has made remarkable progress in supporting the microbial industry. Domestic raw materials are widely used, and they play an important role in preventing and controlling COVID-19. Domestic enterprises mainly rely on mergers, acquisitions, original equipment manufacturers, and industrial cooperation with foreign technology-leading enterprises regarding microbial instrument research. China has established a relatively complete technical R&D capability. For example, 13 domestic gene sequencers have been approved by the Nation Medical Products Administration (as of October 2019) and can be used in clinical practice. In addition, domestic enterprises have broken the monopoly pattern of foreign markets, exported equipment to many countries, and provided customers with higher quality and more cost-effective sequencing equipment and services [16] in the sequencing industry.

4.2 Current situation of subdivided industries

4.2.1 Microbial safety industry

The microbial safety industry includes microbial detection, diagnosis, prevention and control. From the perspective of industrial chain distribution, the detection and control technology of pathogenic microorganisms is mainly mastered by large multinational companies in developed countries. In contrast, Chinese enterprises lack detection and control technology with independent intellectual property rights. For example, new technologies and products for molecular detection are restricted due to the lack of independent intellectual property rights of detection targets. In addition, regarding microbial detection and diagnosis, it has not been possible to form a reasonable aggregation of profitable industries because of the weak domestic foundation, late start, insufficient attention, and lack of leading enterprises in the industry with international competitiveness.

4.2.2 Microbial health industry

In recent years, the structure of microbial health products in China has been diversified; new probiotics, edible fungi, spirulina, and other products have emerged, and the market scale has gradually expanded. However, most probiotic products use foreign strains. For example, the nine strains approved for use in infant food in China are all imported. The aging trend in China's population is evident. With improved economic conditions and health awareness, consumers' demand for health products and services will inevitably grow. The consumption expenditure on microbial health products and the proportion of total consumer expenditure have shown an upward trend, reflecting the great market demand potential of the microbial health industry [17].

4.2.3 Microbial manufacturing industry

China's microbial manufacturing industry has entered a stage of industrialization and has become a new growth point in the national economy [18]. China ranks first globally in the output of bulk microbial manufacturing products. A distinctive biological industry cluster has been formed in the Beijing–Tianjin–Hebei, Yangtze River Delta, Pearl River Delta, and other regions. Antibiotics, vitamins, amino acids, alkaloids, antipyretic analgesics, and hormones are the main raw materials for export in China [19]. The layout of microbial manufacturing enterprises has changed

from small- and medium-sized enterprises to large enterprises and larger groups, forming several enterprises with strong market competitiveness. Notably, despite the support of national policies and preferential resource input, the industrial structure of microbial manufacturing still needs to be transformed and upgraded to enter the high-end value of the industrial chain.

4.2.4 Microbial pharmaceutical industry

China is prominent in microbial pharmaceuticals (mainly antibiotics) production, and the biomedical industry has achieved leapfrog development under strong state support. With the advancement of biomedical technology, upgrading of information and digital technology, and promotion of policies such as the *Healthy China 2030 Planning Outline*, the scale of China's biomedical market has ranked second globally. Innovative drugs have been defined as the main theme of the industry's future development [20]. From the industrial layout and regional distribution perspective, China has formed three leading regions in the Bohai Rim, Yangtze River Delta, and Pearl River Delta based on industrial relations and geographical proximity. The related enterprises are still in the development period. They will maintain a good development space with the steady expansion of market demand.

4.3 Challenges to industrial development

4.3.1 Insufficient original innovation capabilities of the industrial chains

Although China's microbial strains are rich in resources, and the development technology is constantly improving, it is still relatively backward in core strains and key technologies. It is difficult to cultivate strains and key enzymes with independent intellectual property rights and high production potential in a short time, and the sustainable development ability of the industry is imperfect. International oligopolies and domestic enterprises monopolize upstream raw materials concentrated downstream of the sector considering probiotics. The import proportion of core strains exceeds 90%, and there are hidden dangers in the safe development of the industrial chain.

4.3.2 Less advanced core equipment and technologies

In microbial testing, manufacturing, and medicine, domestic enterprises are mature in the technology and production of conventional materials (such as chemical raw materials and auxiliary materials), but some high-purity reagents rely on imports. Microorganism-related instruments and equipment involve machinery, electronics, software, and intelligent integration, and the technical content is generally high. The core components used in bioreactors, precision testing equipment, and microbial diagnostic devices are still being supplied by foreign companies.

4.3.3 Fierce competition against external resources and the market

China's microbial industry is at a transitional stage of upgrading and development. Limited by market inertia, domestic brands and independent products do not have competitive advantages, and many products rely on imports, not conducive to the high-quality development of China's microbial industry. With the increasing intensity of international competition, the core raw materials, technologies, and products of China's microbial industry may face a more uncontrollable situation, bringing uncertainty to industrial development. In addition, the constant emergence of new viruses poses a direct threat to human health, and the risk of reshaping the microbial industry chain under the impact of the COVID-19 epidemic has increased, a challenge that requires attention in developing the microbial industry.

5 Key measures for the development of microbial industry in China

5.1 Systematic construction of big scientific facilities for microorganisms

5.1.1 Comprehensive investigation of microbial resources

Given the forward-looking, targeted, and inaccurate problems of phenotypic identification and in-depth mining of microbial resources, we will strengthen the exploitation of microbial resources and conduct a comprehensive and continuous investigation and collection of important resources in the microbial safety and health industry. According to the regional characteristics of extreme natural environments in China, salt lakes, alkali lakes, hot springs, and the deep sea with certain chemical factors are selected to comprehensively carry out species and gene analyses of microbial genetic resources. We excavated the strains and gene resources of extreme microorganisms and microorganisms that are difficult to cultivate based on the existing microbial genetic resource acquisition technology. We revealed the distribution law and species diversity, created high-value strain genes and big data, and provided

DOI 10.15302/J-SSCAE-2021.05.007

raw materials for microbial scientific research and application development.

5.1.2 Establishment of microbial resource platform

Molecular markers and other technical means are used to efficiently screen and accurately evaluate microbial strains, genes, and metabolites and obtain core strains, complex microbial systems, genes, enzymes, and other metabolites with potential applications in the microbial industry. Establishing a microbial germplasm resource platform provides conditions for organic integration of the reserve, evaluation, development, and utilization of microbial resources in China. Microbial germplasm and microbial gene databases were established to collect biological resource information using modern information technology. This included microbial species and cell resource collection information, biological and biochemical information, enzymatic and metabolite activity information, and nucleic acid sequence information. By establishing a professional software environment, such as bioinformatics data processing, functional analysis, and structural design, we will give full play to the characteristic functions of network technology and big data analysis to promote data sharing of microbial resources nationwide.

5.1.3 Construction of standardization system and cloud laboratory

By issuing a system of microbial resource preservation and sharing, a standards system including microbial health product testing, function evaluation, and quality control, is formulated. Cloud control, robot operation experiments, and AI computing are used to develop a basic support system for standardized processes and cloud-based services in the microbial industry. By constructing a collaborative development technology system, including microbial manufacturing equipment development, fermentation process development, and pilot scale-up production, we solve for the test-retest reliability of experiments, standardization of experimental data, open sharing of testing facilities, and crowdsourcing of scientific research to promote the national radiation of cloud laboratory platforms.

5.2 In-depth research and development of microbial development technology system

The molecular mechanisms of environmental tolerance, environmental adaptation, and prebiotic function of strains are analyzed through genomics, transcriptomics, proteomics, and other technical means. A series of technical facilities required by microorganisms for isolation, screening, and evaluation of the corresponding end products are established, covering basic research, functional research, experimental verification (including clinical research), industrial applications, and other links.

By developing industrial application technologies, such as high-density fermentation, cryoprotection, microencapsulation, and activity maintenance of strains, the production efficiency of functional microbial products has been significantly improved. Additionally, the strict proportion of medium raw materials and ingredients, temperature parameters, and time parameters can be realized. The optimization parameters can be set according to the differences in functional microbial strains to substantially improve industrialization. The development of microbial instruments and equipment with a high degree of automation can meet the needs of quality evaluation, efficacy evaluation, bacterial production, reliable preservation, processing product regulation, and special facilities for microbial strains.

5.3 Promoting the industrial application of microbial resources

5.3.1 Regulations- and standards-driven safety evaluation of functional microbial applications

In the fields of invention patents, biosecurity, agricultural safety, environmental safety, and other areas and directions, researching and formulating rules and systems for the preservation and sharing of microbial resources with certain mandatory requirements can prevent the loss and abuse of microbial resources to support industrial safety and healthy development. Furthermore, given the unclear effects of microorganisms and their metabolites and the lack of unified evaluation standards for microbial health products such as probiotics, we conducted research on the efficacy mechanism, efficacy evaluation, and the efficacy and stability of microbial health products. This was done to solve problems such as the poor stability of microorganisms and their metabolites in product applications.

5.3.2 Development of diversified microbial products

Through the steady development of new chemical application expansion strategies, new biocatalytic reactions can be used to modify and optimize existing natural biological systems to create a series of microbial products with controllable synthesis and specific functions from the source. For specific groups of pregnant women, the older people, people in sub-health status, and other specific needs in chemistry, biology, materials, agriculture, and so on, we need to develop microbial products with diversified dosage forms and different functions. This can provide

important support for biosecurity and life and health, provide technical support for natural chemicals and organic chemical raw materials to eliminate dependence on natural resources, and comprehensively improve the energy level of the microbial industry.

5.3.3 Improvement of the innovation ecology of the microbial industry

By improving the application and promotion of innovative microbial products, supporting the application of new microbial products to benefit the people, and reasonably giving play to the role of industrial investment funds and venture capital, we will enhance the ability of finance to support the construction of microbial industry clusters. Furthermore, through active participation in high-level international cooperation of the microbial industry chain, we will support enterprises in the global division of labor and strengthen their interaction with developed countries and countries along the Belt and Road to carry out microbial industry interactions. We will also establish a microbial R&D service chain, including microbial research, clinical research, technology transfer services, and consulting services, and cultivate microbial industry R&D and production outsourcing service institutions. Additionally, we will support outsourcing service firms engaged in microbial medicine and technology R&D or testing to declare technologically advanced service enterprises.

6 Suggestions

6.1 Establishment of an industrial policy system for collaborative innovation and development

We should pay attention to the top-level design of the microbial industry policy planning; cultivate the microbial industry into a pillar industry in the field of high technology and a national strategic emerging industry. We should promote the accumulation of technology, talents, funds, and other elements to the microbial industry and promote the innovation and industrialization of microbial technology. By establishing an industrial policy system, such as integrated circuits, we will focus on supporting high-tech R&D in the microbial industry with basic, strategic, forward-looking, and major key commonalities. We will encourage enterprises, scientific research institutes, colleges, and universities to jointly construct innovation platforms with foreign enterprises or institutions. Through the deep integration of the innovation and the industrial chains, we will promote the construction of an industrial technology innovation system with enterprises as the main body, the market as the guide, and the combination of production, education, research, and application; and comprehensively enhance the ability of independent innovation.

6.2 Comprehensive layout strengthening of scientific and technological research and development in the microbial industry

Based on the characteristic functional microbial germplasm resources, we will accelerate the development of key technologies in the microbial industry such as microbiome big data, bioinformatics analysis, new microbial fermentation, tumor immunotherapy, and synthetic biology. Guided by technological breakthroughs, we will reasonably gather element resources, build a new model of high-quality development of the microbial industry, and actively respond to major challenges such as microbial safety, health, manufacturing, and medicine facing humanity in the future. By constructing microbial strain genes and biosafety big scientific facilities, we will focus on five major platforms for: microbial strain resource preservation; microbiome; bioinformatic analysis supercomputing centers; mining of new microbial genes, new compounds, and new technologies; incubation of high-tech biological achievements. It is necessary to strength research on basic theory, engineering technology, and systematic innovation in microbiology and related fields. This would form a solid scientific and technological foundation for the sustainable development of the microbial industry. Furthermore, by improving the cultivation and evaluation of high-level talent in microbial technology and industry, we actively introduce professionals and incubate innovative teams to ensure the basic needs of industrial technology breakthroughs.

6.3 Centralization, demonstration, and extension of microbial industry clusters

Relying on the National Microbial Seed Industry Technology Innovation Strategic Alliance, we maintain cooperation with domestic and foreign advantageous innovation resources. Additionally, we give full play to the first-mover advantage of microbial technology research and industrial transformation and accelerate the construction of the Guangdong–Hong Kong–Macao Greater Bay Area Microbial Safety and Health International Science and Technology Innovation Center. We should seize the opportunity of the construction of “Microbial Strain Gene and Biosafety Big Scientific Device” and “Microbiome National Technology Innovation Center”. Meanwhile, we are

DOI 10.15302/J-SSCAE-2021.05.007

committed to incubating the frontier technologies of microorganisms mastered and transforming the major scientific research results on microorganisms that have been achieved. Furthermore, we give full play to the key role of enterprises in the industrialization process. This improves the innovation system of deep integration of production, education, and research, accelerating the transformation of scientific research results into actual productivity and building a microbial industry development ecology in which technological innovation and industrialization interact efficiently. We appropriately introduce advanced technology, pay attention to digestion, absorption and re-innovation, and strive to develop microbial industrial clusters with distinctive characteristics and significant benefits. Meanwhile, we summarize the experience of regional industrial development, actively radiate domestic enterprises, strive to promote the application and form national industrial advantages, and give full play to the demonstration role of emerging industries.

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