Available Online: 22 April 2026 DOI: 10.54254/3029-0821/2026.32896

Application and development prospects of bioengineering technology in the big health industry

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Abstract. With the in-depth implementation of the *Healthy China* 2030 blueprint, the big health industry has become an important engine driving economic and social development. As a core supporting force, bioengineering technology is profoundly reshaping the development landscape of the health industry. Based on existing research findings, this paper systematically sorts out the application status of bioengineering technology in core sectors of the big health industry, including the pharmaceutical industry, food industry, precision medicine, marine biological resource development, and biomaterial applications. It also analyzes in detail the challenges encountered in technology application, such as insufficient independent innovation, shortage of capital and talents, and ethical and safety risks. Combined with policy guidance and technology development trends, the paper prospects the future development of bioengineering technology in the construction of the whole industrial chain, multimodal integration, and green intelligent manufacturing. Research shows that the deep integration of bioengineering technology and the big health industry demonstrates huge potential in disease prevention and treatment, health management, and product innovation. However, it is necessary to break through development bottlenecks through multi-dimensional measures such as technological breakthroughs, policy improvement, and talent training, so as to promote the high-quality and sustainable development of the big health industry.

Keywords: bioengineering technology, big health industry, precision medicine, application status, development prospects

1. Introduction

The big health industry is a comprehensive industrial system that takes maintaining, improving and promoting health as the core goal, covering medical services, health management, nutrition and health care, biomedicine, medical devices and other fields. In recent years, the continuous upgrading of global health demand, the high incidence of chronic non-communicable diseases, and the intensification of population aging have pushed the big health industry into a period of rapid development. As a populous country, China has an especially urgent demand for health. The number of patients with hypertension, diabetes and cardiovascular and cerebrovascular diseases all exceeds 100 million, and the demand for high-quality health products and services is growing day by day. Against this background, the *Healthy China 2030* Outline clearly proposes to foster the health industry into a pillar industry of the national economy, with the total scale of health services reaching 16 trillion yuan by 2030 [1].

As a core component of modern biotechnology, bioengineering technology covers multiple branches such as genetic engineering, cell engineering, enzyme engineering, fermentation engineering and synthetic biology. It provides a brand-new technical path and product form for the big health industry through the design, transformation and utilization of biological systems. From the upgrading of traditional fermented foods to modern gene therapy and precision medicine, every breakthrough in bioengineering technology has driven the leapfrog development of the big health industry. At present, bioengineering technology has been widely used in key links such as drug research and development, food nutrition fortification, accurate diagnosis and treatment of diseases, and health management, becoming an important means to alleviate the shortage of medical resources, improve the efficiency of health services and reduce health costs.

2. Connotation definition of bioengineering technology and big health industry

2.1. Core connotation and technical system of bioengineering technology

Bioengineering technology is a technical system that comprehensively applies theories and methods of biology, chemistry, engineering and other disciplines to design, transform, cultivate or utilize organisms or bioactive substances to produce healthy products with economic value or provide health services [2]. Its core technical system includes:

1. Genetic engineering: Realizing the directional transformation of genetic traits of organisms through in vitro recombination, editing or transfer of genes, providing technical support for drug research and development, gene therapy and precision medicine.
2. Cell engineering: Producing biological products, constructing disease models or conducting cell therapy through cell culture, fusion, differentiation and other technologies, serving as an important foundation for biopharmaceuticals and regenerative medicine.
3. Enzyme engineering and fermentation engineering: Efficiently producing food additives, biopharmaceuticals, nutritional chemicals and other products through enzyme immobilization, directed evolution or microbial fermentation technology.
4. Synthetic biology: Realizing green biomanufacturing of target products by designing and reconstructing biological metabolic pathways, providing new production modes for food, medicine and other fields.
5. Bioinformatics and big data technology: Integrating and analyzing multi-source data such as biological omics, clinical diagnosis and treatment, and health monitoring, providing data support for precise diagnosis, personalized treatment and health management.

2.2. Category and development characteristics of the big health industry

The big health industry covers three core sectors: health product manufacturing, health services and health management, including biomedicine, functional foods, medical devices, medical services, health monitoring, elderly care and other subdivisions. At present, the big health industry presents three major development characteristics:

First, full life cycle coverage, building a comprehensive health service system from prevention, diagnosis and treatment to rehabilitation and elderly care. Second, technology-driven innovation, with the deep integration of high-tech such as bioengineering, artificial intelligence and big data with the health industry, giving birth to new products, new services and new business models [3]. Third, diversified demand orientation, with consumers' health needs expanding from traditional disease treatment to multi-dimensional fields such as preventive health care, personalized health management and mental health.

2.3. Integration logic of bioengineering technology and big health industry

The integration of bioengineering technology and the big health industry is essentially a precise matching process between technological innovation and health demand. On the demand side, the demand of the big health industry for efficient disease treatment, personalized health services and safe health products provides a clear application scenario for bioengineering technology. On the supply side, bioengineering technology can solve the problems of resource constraints, low efficiency and insufficient precision faced by the traditional health industry through the in-depth development and efficient utilization of biological resources [4]. The integration of the two not only promotes the transformation and upgrading of the big health industry, but also provides a broad market space for the industrial application of bioengineering technology, forming a virtuous cycle of "demand pulling technological innovation and technology supporting industrial development".

3. Core application fields of bioengineering technology in the big health industry

3.1. Application in the pharmaceutical industry

Bioengineering technology has become the core driving force for the innovative development of the pharmaceutical industry, comprehensively innovating the technical path and product form of the pharmaceutical industry from drug research and development, production to clinical application [5].

Research and development of genetic engineering drugs is the core field of biopharmaceuticals. Recombinant human insulin, interferon, growth hormone and other protein drugs can be efficiently produced through gene cloning and recombination technologies, solving the problems of insufficient raw materials and low purity in traditional extraction methods. For example, the production of recombinant human insulin using the Escherichia coli expression system has become the core drug for diabetes treatment. Monoclonal antibody drugs developed based on genetic engineering technology have shown significant efficacy in the treatment of tumors and autoimmune diseases [6]. As an emerging treatment technology, gene therapy achieves the radical cure of intractable diseases such as genetic diseases and tumors by introducing exogenous therapeutic genes into patients. By the end of 2018, 2,930 gene therapy clinical trials had been carried out globally, covering cancer, rare diseases, cardiovascular diseases and other fields. Among them, CAR-T cell immunotherapies such as Novartis' Kymriah and Kite Pharma's Yescarta have been approved for marketing, providing a new treatment option for patients with hematological tumors. Luxturna developed by Spark Therapeutics delivers the RPE65 gene through an AAV vector, successfully treating Leber congenital amaurosis, becoming the first approved in vivo gene therapy.

The application of cell engineering in the pharmaceutical industry is mainly reflected in vaccine production, monoclonal antibody preparation and other aspects. Hybridoma cells constructed through cell fusion technology can produce monoclonal antibodies on a large scale for disease diagnosis and treatment. Inactivated vaccines and recombinant vaccines produced using animal cell culture technology play a key role in infectious disease prevention and control. Enzyme engineering and fermentation engineering provide an efficient and green technical path for drug production. Antibiotics, vitamins and other drugs produced through microbial fermentation reduce production costs and environmental pressure. For example, the production of penicillin using microbial strains modified by genetic engineering has greatly improved production efficiency and reduced drug prices.

3.2. Application in the food industry

Bioengineering technology has promoted the transformation of the food industry from "meeting food and clothing" to "nutrition and health", showing unique advantages in nutrition fortification, food preservation, functional food development and other aspects.

Synthesis of nutritional chemicals is an important application direction of bioengineering technology in the food field. Through the reconstruction of microbial metabolic pathways by synthetic biology technology, amino acids, vitamins, functional lipids and other nutritional components can be efficiently produced. For example, essential amino acids such as lysine and tryptophan produced by engineered Escherichia coli or yeast strains are widely used as food nutrition fortifiers in infant formula foods and health foods. Functional lipids such as DHA and EPA produced by microalgae fermentation provide raw material support for the development of functional foods. These biosynthesis technologies not only solve the problems of limited raw materials and high costs in traditional animal and plant extraction methods, but also realize precise regulation and green production of products.

Upgrading of traditional fermented foods is an important application scenario of bioengineering technology. The output value of traditional fermented foods in China (liquor, soy sauce, vinegar, etc.) accounts for nearly 30% of the total output value of the food industry, but the traditional production mode has problems such as long fermentation cycle and unstable product quality. The analysis of microbial community structure and function in the fermentation process using biotechnology such as genomics and transcriptomics can realize precise regulation of the fermentation process. For example, high-throughput sequencing technology is used to analyze the dynamic changes of microorganisms in the liquor fermentation process, identify key functional microorganisms, optimize the fermentation process, and improve liquor quality and production efficiency. A Harvard research team analyzed the relationship between cheese microbial community and flavor substances, and constructed a reproducible fermentation system to realize the modern production of traditional fermented foods.

Green biomanufacturing of food additives is another important application field of bioengineering technology. Natural pigments, spices, preservatives and other food additives can be produced through microbial fermentation or enzymatic conversion, replacing chemically synthesized products and improving food safety. For example, natural red pigment produced by Monascus fermentation is used for food coloring instead of synthetic pigments. The application of biological preservatives such as nisin and natamycin prolongs the shelf life of food and reduces the use of chemical preservatives. In addition, enzyme engineering technology is increasingly widely used in food processing, such as using cellulase to improve dough quality, protease to produce hydrolyzed protein, and lipase to improve oil utilization rate, which not only improves food processing efficiency but also enhances product quality.

3.3. Application in precision medicine

Precision medicine is a new medical model that realizes precise disease diagnosis, personalized treatment and health management based on individual genetic characteristics, clinical data, living environment and other factors [7]. The integration of bioengineering technology and big data technology provides core support for the implementation of precision medicine.

In precise diagnosis, bioengineering technology has promoted the transformation of diagnosis from "empirical diagnosis" to "molecular diagnosis". The analysis of patients' genome information through gene sequencing technology can accurately identify disease susceptibility genes and pathogenic genes, providing a basis for early disease screening and diagnosis. For example, the detection of EGFR, ALK and other genes in lung cancer patients can guide the selection of targeted drugs and improve the therapeutic effect. The construction of disease models using gene editing technology helps to deeply analyze the pathogenesis of diseases and develop new diagnostic markers. Bioinformatics technology integrates and analyzes multi-source data such as clinical diagnosis and treatment, biological omics and imaging to construct disease prediction models and realize early warning of diseases. For example, machine learning algorithms based on electronic medical record data can predict the risk of chronic diseases such as diabetes and cardiovascular diseases in patients, providing guidance for preventive intervention [8].

In precise treatment, bioengineering technologies such as gene therapy and cell therapy have realized the treatment concept of "prescribing the right medicine". For monogenic genetic diseases, defective genes can be repaired through gene supplementation, gene editing and other technologies to achieve radical cure of diseases. For example, for severe combined immunodeficiency (ADA-SCID) caused by adenosine deaminase deficiency, the ADA gene is introduced into patients' hematopoietic stem cells through γ-retrovirus to successfully repair the immune deficiency of patients. For β-thalassemia, the β-globin gene is delivered through a lentiviral vector to free patients from transfusion dependence. In tumor treatment, CAR-T, TCR-T and other cellular immunotherapies modify patients' T cells through genetic engineering to specifically recognize and kill tumor cells, realizing personalized treatment. In addition, by analyzing the relationship between patients' genetic characteristics and drug sensitivity, precise medication can be achieved to avoid adverse drug reactions and improve therapeutic effects.

In precise health management, bioengineering technology combined with wearable devices and big data technology constructs a comprehensive health monitoring and management system. Biological sensors are used to monitor human physiological indicators in real time, and big data analysis technology is combined to evaluate health status and provide personalized health suggestions. For example, personalized diet and exercise plans are formulated for users based on genetic test results and daily health data to prevent chronic diseases. Microbiomics technology is used to analyze intestinal flora structure and guide users to improve intestinal health and enhance immunity through diet regulation.

3.4. Application in marine biological resource development

Marine biological resources have become an important resource treasure house for the big health industry due to their unique bioactive substances, and bioengineering technology provides key support for the efficient development of marine biological resources.

In marine drug research and development, bioengineering technology promotes the efficient extraction and industrialization of marine bioactive substances. Alkaloids, polypeptides, polysaccharides and other active substances produced by marine organisms have significant effects such as anti-tumor, antiviral and antibacterial. New drugs can be developed by extracting these active substances through biological separation technology, combined with structural modification and synthetic biology technology. For example, cytarabine extracted from Caribbean sponges has become an important drug for the treatment of acute leukemia. Ziconotide isolated from cone snails is used to treat severe pain. The new anti-colon cancer drug K-80003 developed by Xiamen University has entered Phase I clinical trials in the United States. In addition, the production of marine-derived active substances using microbial fermentation technology can solve the problem of scarcity of natural marine biological resources and realize large-scale production.

In the field of functional foods and health products, the development and application of marine biological resources are increasingly widespread. High-quality proteins, polysaccharides, unsaturated fatty acids and other nutritional components in marine organisms are extracted through bioengineering technology to develop functional foods. For example, products such as coenzyme Q10 produced by Xiamen Kingdomway Group and vitamin AD drops produced by Shandong Dyne Marine Biopharmaceutical Co., Ltd. are favored by the market. The seaweed soda water developed by Tsingtao Brewery Group uses the nutritional characteristics of seaweed extracts to achieve a healthy drink positioning of zero sugar and zero calories. Marine biological polysaccharides have the effects of lowering blood lipid, anticoagulant and regulating intestinal flora, and have been widely used in health products, food additives and other fields through biological extraction and purification technology.

In medical and health materials, marine biomaterials show broad application prospects due to their good biocompatibility and degradability. Marine biological polysaccharides such as alginic acid and chitosan can be used to prepare medical products such as wound dressings, hemostatic materials and drug delivery carriers. For example, Shandong Weigao Orthopedic Device Co., Ltd. uses modified marine polysaccharides as raw materials to develop injectable bone repair materials and realize independent brand industrialization. The fourth-generation limulus reagent detection kit developed by Fuzhou Xinbei Biochemical Industry Co., Ltd. can quickly detect bacterial endotoxin infection and is widely used in clinical diagnosis.

3.5. Application in biomaterials and beauty care

Bioengineering technology has promoted the development of biomaterials towards high performance and multi-function, and its application in tissue repair, beauty care and other fields is increasingly widespread [9].

As a natural biomaterial, wool keratin has good biocompatibility and absorbability due to its high consistency (91%) with human keratin. Keratin can be extracted from wool through mechanical, acid-base, redox, biological enzyme and other extraction technologies, and further prepared into biomaterials in various forms such as gels, films and scaffolds. In the biomedical field, wool keratin hydrogel can be used for burn repair, nerve regeneration, wound healing, etc. For example, 9% keratin hydrogel can prevent burn aggravation and promote skin regeneration, and 15% keratin hydrogel has a positive effect on nerve regeneration. Keratin films and scaffold materials can be used in tissue engineering to promote cell adhesion and proliferation, showing good effects in bone tissue regeneration, pulp-dentin regeneration and other aspects.

In the field of beauty care, wool keratin hydrolysates can be used in cosmetics production, with effects such as water replenishment, moisturizing and hair quality improvement. Keratin peptides can supplement hair moisture and improve hair gloss and softness. For the skin, keratin hydrolysates can be used as humectants to supplement intercellular lipids of the stratum corneum and enhance the skin barrier function. In addition, wool keratin can also be used in nail care products to improve the condition of nail plates. In addition to wool keratin, marine-derived biomaterials such as collagen and polysaccharides are also widely used in the field of beauty care. For example, facial masks and essences prepared using marine collagen have moisturizing, anti-wrinkle and other effects.

4. Challenges in the application of bioengineering technology in the big health industry

4.1. Technical level: insufficient independent innovation and lagging industrial transformation

Although China's bioengineering technology has made certain progress in the application of the big health field, the independent innovation capacity of core technologies is still insufficient. In key fields such as gene editing, synthetic biology and biopharmaceuticals, core technologies and high-end equipment are mostly dependent on imports. For example, gene sequencers and bioreactors are mainly monopolized by foreign enterprises. In the research and development of marine biomedicine, the technical system for efficient discovery, precise preparation and druggability evaluation of compounds is not perfect, and most studies stay in the laboratory stage with low industrial transformation rate. In the field of food bioengineering, basic research and science popularization are relatively lagging, and the R & D capacity of products such as special medical foods and functional factors is insufficient.

Lagging industrial transformation is another prominent problem. The R & D cycle of bioengineering technology products is long, with large investment and high risk. It often takes more than 10 years from laboratory R & D to industrial application, and faces many technical bottlenecks such as pilot scale-up and process optimization. For example, the R & D of gene therapy products involves multiple links such as vector optimization, delivery efficiency and safety evaluation, with high technical complexity and great industrialization difficulty. In addition, the docking mechanism of "R & D-pilot test-industrialization" is not perfect, and there is a lack of effective cooperation between scientific research institutions and enterprises, resulting in a large number of scientific research achievements difficult to transform into actual productive forces.

4.2. Industrial level: shortage of capital and talents

Shortage of capital is an important factor restricting the application of bioengineering technology in the big health industry. The R & D of bioengineering technology requires a lot of capital investment for laboratory construction, equipment purchase, clinical trials, etc. However, China's biopharmaceutical enterprises are generally small in scale with single financing channels, making it difficult to bear high R & D costs. For example, insufficient R & D investment in the marine biomedicine industry leads to difficulties in breaking through core technologies and a small proportion of high value-added products. In emerging fields such as gene therapy and cell therapy, the low enthusiasm of social capital investment due to high investment risk and long return cycle further aggravates the problem of capital shortage.

Shortage of talents is another key constraint. The integration of bioengineering technology and the big health industry requires interdisciplinary talents with professional knowledge of bioengineering, medicine, food science and other fields, as well as economic awareness and management ability. At present, China's relevant professional talent training system is not perfect, university talent training is out of line with industrial demand, and there is a lack of professional teachers with rich practical experience. At the same time, due to the high intensity and high risk of R & D work in the bioengineering field, the loss of high-end talents is serious, further exacerbating the talent shortage dilemma.

4.3. Ethical and safety level: ethical controversies and risk control challenges

The rapid development of bioengineering technology has triggered a series of ethical controversies. In the application of gene editing technology, germ cell gene editing may lead to genetic changes, triggering ethical and legal disputes. Issues such as "designer babies" and "gene enhancement" in gene therapy challenge the bottom line of social ethics. In the application of medical large models, algorithm bias may lead to differences in diagnostic accuracy and deviations in treatment suggestions, exacerbating health inequality. The doctor-patient relationship has changed from the traditional "doctor-patient" dual model to the "doctor-patient-artificial intelligence" tripartite model, posing challenges to traditional ethical relations.

Safety risk control faces many difficulties. Data security and privacy protection are prominent problems. Health and medical big data involves personal sensitive information, which is prone to leakage risks in the process of collection, storage and analysis. For example, the training of medical large models involves a large amount of clinical data, and incomplete data desensitization may lead to the leakage of patient privacy. In gene therapy, random integration of vectors may cause insertional mutation, leading to safety risks such as cancer. In cell therapy, engineered T cells may trigger cytokine storm, threatening the life of patients. In addition, the safety evaluation system of bioengineering products is not perfect. For example, there is a lack of mature methods for long-term safety evaluation of gene therapy products, making it difficult to predict potential risks.

4.4. Policy and market level: lack of standards and insufficient market awareness

Lack of standards restricts the marketization process of bioengineering technology products. In the field of biopharmaceuticals, the quality control standards and clinical evaluation methods of emerging products such as gene therapy and cell therapy are not unified, resulting in long product approval cycles and difficult marketing. In the field of food bioengineering, the strain safety identification of fermented foods and the labeling standards of genetically engineered foods are not yet perfect, affecting the large-scale production and market promotion of products. In the field of health and medical big data, the standards for data collection, sharing and use are not unified, leading to serious data silos and difficulty in realizing cross-institutional and cross-regional data integration.

Insufficient market awareness also affects the promotion and application of bioengineering technology products. Some consumers have misunderstandings and concerns about bioengineering products, such as doubts about the safety of gene-edited foods and biopharmaceutical products, affecting product market acceptance. In emerging fields such as gene therapy and cell therapy, due to the high technical complexity, limited public awareness and high product prices, it is difficult to release market demand quickly. In addition, some bioengineering products have serious homogeneous competition and lack core competitiveness, further exacerbating the difficulty of market promotion.

5. Development prospects of bioengineering technology in the big health industry

5.1. Technology development trend: multidisciplinary integration and innovative breakthroughs

Multimodal integration will become an important development direction of bioengineering technology. In the medical field, multimodal large models will integrate multi-source data such as text, images and genomes to realize the precision and intelligence of disease diagnosis and treatment plan formulation [10]. For example, a multimodal model integrating clinical text data, medical image data and gene sequencing data can comprehensively analyze patients' conditions and provide personalized treatment suggestions. In the food field, the combination of synthetic biology with artificial intelligence and big data technology will realize the precise design and efficient synthesis of nutritional components, such as optimizing microbial metabolic pathways through artificial intelligence algorithms to improve the production efficiency of nutritional chemicals.

Core technologies will continue to make breakthroughs. Gene editing technology will develop towards high fidelity and high efficiency. For example, the development of high-fidelity CRISPR/Cas9 nuclease variants will significantly reduce off-target effects and improve the safety of gene therapy. Vector technology will be continuously optimized, and the research and development of new viral vectors and non-viral vectors will improve gene delivery efficiency and reduce immunogenicity. In the field of biomaterials, multifunctional composite biomaterials will become a research hotspot. For example, biomaterials with both tissue repair and drug release functions will show broad application prospects in wound healing, tumor treatment and other fields.

5.2. Industrial development direction: whole industrial chain construction and cluster development

The construction of the whole industrial chain will promote the high-quality development of the big health industry. In the field of marine biological resource development, a full life cycle industrial chain from resource acquisition, technological innovation, achievement transformation to industrialization will be established to explore the value of marine organisms in multiple dimensions such as treatment, prevention and health care. In the field of biopharmaceuticals, a complete industrial chain from target discovery, drug research and development, clinical trials to production and sales will be formed to improve industrial competitiveness. In addition, cross-field industrial chain integration will become a trend. For example, the combination of bioengineering technology with medical devices, health services and Internet technology will build an integrated health industry ecosystem of "product + service + data".

Cluster development will enhance the overall competitiveness of the industry. The government will increase support for bio-industrial parks, build industrial clusters integrating scientific research, pilot test, production and sales, and attract the agglomeration of talents, capital, technology and other resources. For example, industrial clusters such as Xiamen Haicang Biomedical Port and Yantai Shandong International Bio-Technology Park will further exert the agglomeration effect and cultivate product clusters with independent intellectual property rights. At the same time, industry-university-research collaborative innovation will be deepened, and scientific research institutions and enterprises will establish long-term and stable cooperative relations to accelerate the transformation of scientific research achievements.

5.3. Application scenario expansion: personalized and intelligent upgrading

Personalized health services will become the core growth point of the big health industry. Based on data such as genetic testing, microbiome analysis and health monitoring, bioengineering technology will provide users with personalized disease prevention, diagnosis, treatment and health management plans. For example, personalized vaccines and targeted drugs will be developed according to individual genetic characteristics. Personalized diet and probiotic supplementation plans will be formulated based on intestinal flora structure. In the field of elderly care, bioengineering technology will be combined with rehabilitation medicine to develop rehabilitation equipment, nutritional foods, tissue repair materials and other products suitable for the elderly to meet the health needs of an aging society.

Intelligent upgrading will promote the efficiency of big health services. The combination of bioengineering technology with artificial intelligence, big data, Internet of Things and other technologies will build an intelligent health management system. For example, smart wearable devices monitor human physiological indicators in real time, and big data analysis technology is combined to predict health risks and push early warning information and health suggestions in a timely manner. Artificial intelligence-assisted diagnosis systems quickly and accurately diagnose diseases based on biomedical data, alleviating the pressure of shortage of medical resources. In the food industry, intelligent production equipment will realize precise regulation of fermentation process and production technology, improving product quality stability and production efficiency.

5.4. Policy and market environment optimization: policy support and market expansion

Policy support will provide a strong guarantee for the integrated development of bioengineering technology and the big health industry. The government will further improve relevant policies and regulations, formulate quality standards, clinical evaluation methods, ethical norms and other bioengineering products, and provide institutional guarantee for technological innovation and industrialization. At the same time, capital investment will be increased to support core technology research and development, industrial park construction, talent training and other aspects. For example, the National Key R & D Program, Natural Science Foundation and other projects will continue to support research in gene therapy, synthetic biology, precision medicine and other fields. In addition, policies will encourage social capital participation, broaden financing channels, and form a diversified investment and financing system guided by the government and led by the market.

Market demand will continue to expand. With the improvement of residents' health awareness and the upgrading of consumption structure, the demand for bioengineering technology products will continue to grow. The market scale of nutritional chemicals, functional foods, biopharmaceuticals and other products will continue to expand. It is estimated that by 2023, the global nutritional food ingredients market will reach 336 billion US dollars with a compound annual growth rate of 7.8%. In emerging fields such as gene therapy and cell therapy, market demand will be released rapidly with technological maturity and cost reduction. At the same time, the in-depth advancement of the Belt and Road Initiative will provide opportunities for China's bioengineering technology products to go global and further expand market space.

6. Conclusion

As a core supporting force of the big health industry, bioengineering technology has been widely used in many fields such as the pharmaceutical industry, food industry, precision medicine, marine biological resource development and biomaterials, promoting the development of the big health industry towards precision, personalization and intelligence through technological innovation. In the pharmaceutical industry, technologies such as gene therapy and cell therapy have achieved breakthroughs in the treatment of intractable diseases. In the food industry, technologies such as biosynthesis and microbial fermentation have promoted the innovation and upgrading of healthy foods. In precision medicine, the combination of bioengineering technology and big data has built a full-process precision service system from diagnosis to treatment. In the fields of marine biological resource development and biomaterials, bioengineering technology has realized the efficient utilization and high value-added transformation of resources.

However, the application of bioengineering technology in the big health industry still faces many challenges such as insufficient independent innovation, shortage of capital and talents, ethical and safety risks, and lack of policy standards. In the future, it is necessary to break through core bottlenecks through technological innovation, strengthen industry-university-research collaborative innovation, and accelerate the industrial transformation of scientific research achievements. It is necessary to improve institutional guarantee through policy support, increase capital investment and talent training, and optimize the industrial development environment. It is necessary to prevent potential risks through ethical norms and safety control to ensure the healthy development of technology. It is necessary to improve consumer awareness and expand market space through market cultivation and science popularization.

With the continuous innovation and multidisciplinary integration of bioengineering technology, its application in the big health industry will be further deepened, and the construction of the whole industrial chain, personalized services and intelligent upgrading will become the mainstream of development. Bioengineering technology will inject stronger development momentum into the big health industry, help achieve the goal of *Healthy China 2030*, and provide the people with higher-quality, more efficient and more convenient health products and services.

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