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BIOINDUSTRY IN SOUTH KOREA: AN ANALITICAL OVERVIEW AND MAIN PERSPECTIVES OF ITS DEVELOPMENT

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This article provides an analytical overview of South Korea's bioindustry, examining its current status, achievements, and challenges. The article covers various aspects of the economy, including innovation opportunities, government policies, economic impact, and social change. The analysis identifies key achievements, including South Korea's leadership in biopharmaceutical production and innovation, and addresses challenges such as global competition and climate change. It outlines key future development prospects, highlighting the potential of digital healthcare, personalized medicine, and green biotechnology to position South Korea as a leader in the bioeconomy. It also highlights lessons that can be learned from South Korea's experience and their applicability to other countries, including Ukraine and Poland, that are seeking to strengthen their bioeconomy and bioindustry potential. Considering the strategic approach of South Korea, this study aims to identify valuable ideas for promoting innovation, ensuring sustainable development and positioning the bioindustry as a driving force for national economic growth. The analytical analysis of this work concerns the coverage of the current state of industrial production and areas of scientific research in classical biotechnology to improve existing and develop new bioengineering technologies, which are aimed at developing the strategic importance of the bioindustry for achieving sustainable development of the country.

Aim. The article purposed to analyze the current state, key achievements, challenges, and prospects of the South Korean bioindustry, focusing on obtaining valuable knowledge and practices that can be adapted to promote the development of the bioindustry in Ukraine and Poland.

Materials and Methods. Methodological analysis and abstract-logical method of generalizing the criteria for assessing the formation, development, and integration of biotechnological production into the structure of the global output of safe products, as well as bioproducts for improving health and rejuvenation.

Results. The article describes the current state of key industries based on the Korean bioindustry classification code KS J 1009: biopharmaceutical, biochemical, and bioenergy, biofood, bioenvironmental, biomedical equipment, and bioinstrument & bioequipment, bioresource, and bioservice industries. Each sector is characterized by distinct dynamics of growth, levels of innovation implementation, and integration into national and global bioeconomic strategies.

Conclusion. The analysis highlights both the technological achievements and structural priorities shaping South Korea's modern bioindustry.

Key words: South Korea, bioindusry, bioeconomy, sustainable development, innovations, investments, standards.

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Bioindustry has become a cornerstone of modern economic development, combining advanced technologies with sustainable solutions to address global challenges in healthcare, agriculture, and environmental protection. Automation and data-driven processes are increasingly being implemented in biotechnology. They are expected to radically improve the predictability and reproducibility of research and manufacturing outcomes by 2040 through the creation of new bioengineered products, as well as groundbreaking innovations such as mRNA vaccines against cancer and CRISPR-based therapies, improvements in safe delivery systems such as lipid nanoparticles for gene editing for clinical use, etc. Today, the US is the leader in the world of biotechnology products, with a share of almost 50%. However, this depends on the specific data source and year. According to Statista, in 2021, the United States accounted for nearly 59% of the global value of biotechnology. Still, there is a reality of competition between the United States and China in the field of biotechnology. South Korea is also a major player in the global biotechnology market, with a growing presence in the biopharmaceutical sector. However, its share is much smaller than that of the United States. South Korea stands out as one of the world's leading countries in this field, leveraging its material resources, advanced technological base, strong government support, and innovation-driven economy. Over the past two decades, the country has made significant strides in the production of biopharmaceuticals, the use of bioresources and the creation of biomaterials, the investment development of bioenergy, the scaling up of model bioengineering research and pilot developments, establishing itself as a key player in the global bioeconomy, which uses biological resources to produce goods, services, and processes. South Korea has significant potential for bio-based industries, particularly in health, food, and biomaterials.

Global economic growth is expected to remain at 2.8% in 2025, unchanged from 2024. The global biotechnology market will reach approximately USD 2.18 trillion by 2025, up from USD 1.95 trillion in 2024. According to the Biotechnology Industry Outlook 2025 by StartUs Insights (https://www.startus-insights.com), the bioindustry is expected to continue to expand, potentially reaching USD 5.90 trillion by 2034, with a CAGR of 11.6% from 2025 to 2034. In this context, analyzing the structure and priorities of South Korea's bioindustry becomes particularly important, as the country represents one of the most rapidly advancing and innovation-driven markets in Asia. Understanding its strategies, investment trends, and technological focus provides valuable insights into the future trajectory of the global bioeconomy and highlights potential models for sustainable growth, international cooperation, and commercialization of biotech innovations.

Considering South Korea's strategic approach to the development and implementation of biotechnology, this study aims to examine the current state, achievements, and challenges of the bioindustry, identify valuable ideas for promoting innovation, ensuring sustainable development, and positioning the bioindustry as a driving force for national economic growth. Special attention is given to the applicability of South Korea's experience in shaping effective bioeconomic policies and fostering international competitiveness in the biotechnology sector.

Materials and Methods

The work used methodological analysis and abstract-logical method to generalize the criteria for assessing the formation, development and integration of bioengineering biotechnologies and the biotechnological process into the bioindustry with a number of transnational companies, corporations and firms for the production of bioproducts and the provision of services for the use of bioprocesses, taking into account that the main trends in the modern development of the world bioeconomy include globalization, informatization, transnationalization. To process the information, methods of searching for scientific literature, statistical analysis, systematization, comparison, and generalization of information, and processing of the obtained data were used. Analysis of own developments and their generalization regarding the assessment of the sectors of classical biotechnology and cellular and genetic engineering for the formation and development of the bioindustry in South Korea, the use of the biotechnological process in various productions of target bioproducts according to world standards in accordance with the recommendations, requirements and standards with the development of patents of the Eurasian Patent Organization, as well as the creation of a number of promising biotechnologies, the combination of which will constantly vary depending on specific practical

tasks, the development of technical conditions for their production, in particular with regard to the bioindustry of Ukraine.

Results and Discussion

In the 21st century, in the context of changes and transformations in the global economy, the bioindustry is one of the key sectors that determines the technological competitiveness of countries and contributes to their sustainable development. South Korea or the Republic of Korea (hereinafter referred to as Korea) demonstrates the development of the bioindustry, investments in biotechnology research, and active international cooperation [1]. The country's bioorientation is due to strategic state support, developed scientific and research infrastructure, a high level of technological integration, and export orientation to global markets.

The development of the bioindustry in Korea is due to both global challenges and the strategic planning of the country's government. Several stages of the formation of the bioindustry in Korea can be distinguished.

I. The initial stage (1970–1980) is characterized by the development of fermentation and fermentation technologies for the production of traditional products (soy sauce, fermented beverages, etc.) and the emergence of the first research institutes in the field of biotechnology.

II. The stage of the formation of the bioindustry (1990s), which began with the emergence of the first companies specializing in the production of biopreparations and the creation of a basic plan for the promotion of biotechnology (Biotech 2000, Bio-21) in 1994.

III. The stage of expansion and globalization (2000–2010), which is characterized by integration into the global bioindustry, increasing export potential, and the development of bioenergy.

IV. Modern stage (2010s–present). Today, the bioindustry is one of the strategic directions of economic development in Korea and is supported through national programs. It is expected that the bioindustry will solve a number of urgent problems of today, such as the phenomenon of an aging society, depletion of fossil fuel resources, outbreaks of new infectious diseases, water shortages, and global warming [2, 3].

As of 2023, Korea's bioindustry revenue was USD 25.6 billion [4], accounting for 1.7% of global bioindustry revenue. In the same year, the export value of products and services in Korea's bioindustry amounted to KRW 11.6 trillion, equivalent to USD 8.9 billion [5–7]. According to forecasts [4], by 2030, the bioindustry revenue will grow more than 3 times and will reach USD 81.6 billion. The top 10 companies of the Korean bioindustry are given in Table 1.

Samsung Biologics Co Ltd, **Celltrion Inc** are leaders of the Korean bioindustry, as well as prominent players in the global bioindustry [8, 9]. Logos of the top 10 companies of the Korean bioindustry are given on the Fig. 1.

The basis for harmonious cooperation, communication, and coordination of Korean bioindustry producers is the Korea Biotechnology Industry Organization (KoreaBIO) with its logo (Fig. 2). The organization was established on the basis of 3 associations in 2008: Bioindustry Association Korea (BAK), Korea Biotechnology Research

Fig. 1. **Logos of the top 10 Korean biotech companies**

* Author's compilation.

Fig. 2. **Logo of the Korea Biotechnology Industry Organization**

Table 1

The top 10 Korean biotech companies by market capitalization in 2024

No.	Company	Foundation year	Market cap, mln USD	Main products
1.	Samsung Biologics Co Ltd	2011	45,180.00	Development, manufacturing of antibody-drug conjugates (ADCs) and mRNA; CDMO-services.
2.	Celltrion Inc	2002	27,129.00	Biosimilars, novel biopharmaceuticals and monoclonal antibodies (MCAs); CDMO-services.
3.	Alteogen Inc	2008	10,860.00	Development and commercialization of novel biologics (long-acting biobetters) such as ADCs, biosimilars etc.
4.	Yuhan Co Ltd	1926	6,327.00	Dietary supplement, biopharmaceuticals, CDMO-services. Development of active pharmaceutical ingredients (APIs).
5.	SK Biopharmaceuticals Co Ltd	1993	6,184.00	Development of innovative pipeline in CNS, metabolic disorders (epilepsy, myotonia etc).
6.	LigaChem Bioscience Inc	2006	2,740.00	Development of novel biopharmaceuticals, production of medical devices and supplies.
7.	Sam Chun Dang Pharm Co Ltd	1943	2,486.00	Dietary supplement, biopharmaceuticals, over the counter drugs (OTC), APIs; CDMO-services.
8.	Hanmi Pharm Co Ltd	1973	2,446.00	Biopharmaceuticals, dietary supplements and CDMO-services.
9.	SK Bioscience Co Ltd	2018	2,273.00	Biopharmaceuticals, vaccines and infusion solutions.
10.	Daewoong Pharm Co Ltd	1945	1,166.00	Biologics, chemicals, OTC and medical devices; CDMO-services.

* Developed by the authors based on [8].

Association (KBRA), and Korea Bio-venture Association (KoBioVen). KoreaBIO is intended to promote technological development, industrialization, and development of the national economy according to Article 38 of the Industrial Development Act of the Ministry of Trade, Industry, and Energy [10].

The enormous potential of Korean biotech companies is determined by government support and developed infrastructure. And the sector's growth to become a competitive and innovative global force — underpinned by a dynamic economy, a highly skilled workforce, and significant government and commercial infrastructure investment — is bringing major opportunities for international companies [11].

The biotechnology classification code — KS J 1009: Classification of the bioindustry (set by the Korean agency for technology and standards (KATS) in 2008) — was developed to classify bioindustry into sectors, facilitate the collection of statistical data, and shape public policy. According to the standard, the bioindustry is divided into eight sectors:

1. biopharmaceutical industry;
2. biochemical and bioenergy industry;
3. biofood industry;
4. bioenvironmental industry;
5. biomedical equipment industry;
6. bioinstrument and bioequipment industry;
7. bioresource industry;
8. bioservice industry [2, 3, 12].

In the context of the development of the bioindustry, this standard is aimed at ensuring quality, safety, and efficiency in the production of bioproducts in various bioindustrial sectors. Among these sectors, the biopharmaceutical industry stands out for its exceptional support, as evidenced by the highest level of investment in research and development (R&D) in the bioindustry. In 2023, it amounted to about KRW 3.7 trillion (equivalent to USD 2.7 billion) [13].

Fig. 3. **Biopharmaceutical market size of South Korea in 2012–2023**
* Developed by the authors based on [19].

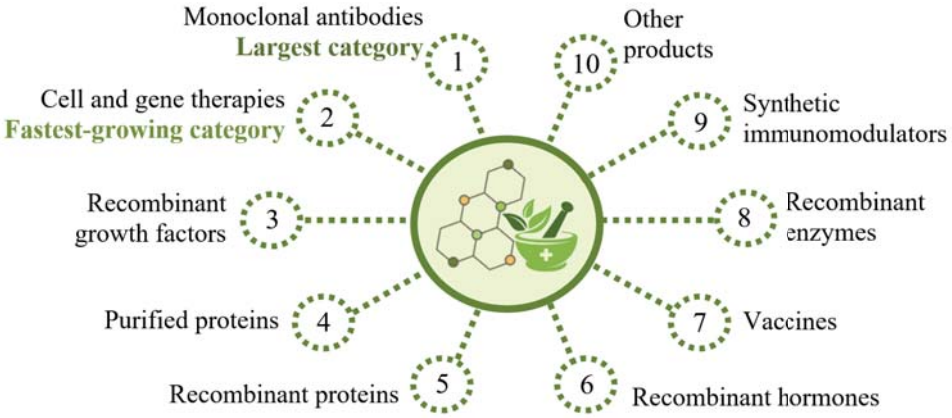

Fig. 4. **Product types of Korea's biopharmaceutical industry**
* Developed by the authors based on [20].

In 2023 Korean bioindustry had 1293 enterprises, including 328 biopharmaceutical, 261 biochemical and bioenergetic, 264 biofood, 89 bioenvironmental, 138 biomedical equipment, 60 bioinstrumental and bioequipment, 27 bioresource, 126 bioservice (including bioservices in other production sectors that integrate bioobjects and/or bioprocesses into their operations) [14]. Each of the areas is characterized by achievements and challenges that need to be overcome for the sustainable development of Korea's bioindustry [12, 14, 15].

Biopharmaceutical industry

It's focused on production and R&D of biopharmaceuticals: bioantibiotics, biologically manufactured low-molecule medicines, hormones, vaccines, therapeutic antibodies and cytokines, blood products, cell-based and gene therapeutics, biomaterial-based medicine, veterinary biopharmaceuticals, etc. The industry also includes biological diagnostic products, generics, and biosimilars.

In 2022, the Korean biopharmaceutical industry ranked 12th in the world by market capacity [16–18]. The graph (Fig. 3) shows a gradual growth since 2015. The decrease in market volumes in 2022 is associated with a reduction in demand for "COVID-19-products", increased regulation of clinical trials and genetic research, a fall in share prices of industry leaders such as Celltrion Inc. and Samsung Biologics Co. Ltd, and the global economic downturn.

There are nine dominant types of bioproducts on the Korean biopharmaceutical industry market (Fig. 4): MCAs (1), cell-based and gene therapeutics (2), recombinant growth factors (3), purified (4) and recombinant (5) proteines, recombinant hormones (6), vaccines

Fig. 5. **Korean biopharmaceutical companies**

* Author's compilation.

Fig. 6. **Logo of the Korea pharmaceutical and biopharma manufacturers association**

(7), recombinant enzymes (8), synthetic immunomodulators (9) [20].

Leading Korean biopharmaceutical companies are (Fig. 5): Samsung Biologics Co Ltd, Celltrion Inc, Alteogen Inc, Hanmi Pharmaceutical Co Ltd, SK Bioscience Co Ltd, GC Pharma Co Ltd, Chong Kun Dang Pharmaceutical Co Ltd, KoreaVaccine Co Ltd, Daewoong Pharmaceutical Co Ltd, D&D Pharmatech Inc, Boryung Biopharma Co Ltd, and Eubiologics Co Ltd [13].

The companies have their specialization and areas of leadership. Samsung Biologics Co., Ltd is a global leader in providing CDMO services due to its large-scale production capacity and technology. Celltrion Inc. is distinguished by the production of biosimilars, in particular Remsima™ — the first biosimilar of MCAs in the world, approved by the FDA. Hanmi Pharmaceutical Co., Ltd focuses on providing biopharmaceuticals for the treatment of metabolic and autoimmune disorders, infectious diseases, oncology, and rare diseases. It also produces OTCs and dietary supplements. SK Bioscience Co Ltd, KoreaVaccine Co Ltd, Boryung Biopharma Co Ltd, and Eubiologics Co Ltd specialize in making vaccines. D&D Pharmatech develops drugs for the treatment of neurological disorders, such as Alzheimer's and Parkinson's disease. GC Pharma Co., Ltd produces plasma protein therapeutics and biopharmaceuticals. Daewoong Pharmaceutical Co Ltd develops drugs for regenerative medicine and chronic diseases [10, 13].

Investments in the development of Korea's bioindustry are made by the state, private entrepreneurs, and foreign companies. The Korean government provides subsidies to support clinical trials, works on the legislative and regulatory aspects of the bioindustry, and creates a regulatory framework in accordance with current needs. In particular, in August 2019, it adopted the Act on advanced regenerative medicine and advanced biological products (ARMAB), which significantly simplifies the introduction of innovations in the bioindustry [21]. At the same time, the implementation of laws to regulate the activities of manufacturers ensures the quality of bioproducts and the introduction of innovative technologies into the industry. In 1945, the Ministry of Health and Welfare (MoHW) facilitated the creation of the Korea Pharmaceutical and biopharma manufacturers association (KPBMA) with its logo (Fig. 6). The Association represents the interests of Korean pharmaceutical companies, ensures partnerships of manufacturers with related and international organizations, and government agencies. In 2025, KPBMA includes 174 domestic pharmaceutical firms and 21 multinational companies, among which 24 are biopharmaceutical [22].

The revival of investment activity by foreign companies indicates the level of and confidence in the Korean biopharmaceutical industry. Investment agreements provide a stable income stream while reducing the risks and costs of full-scale drug development.

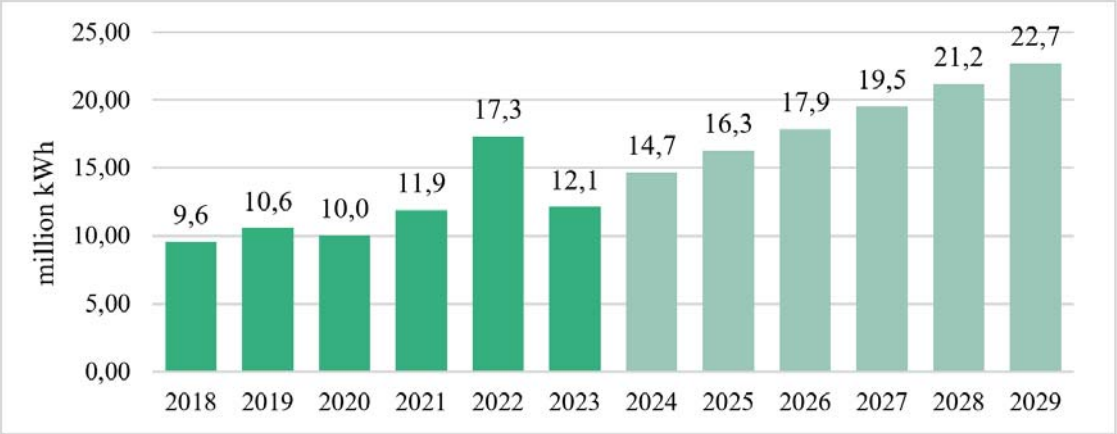

Fig. 7. **Bioenergy market size of South Korea in 2018–2023 and forecast to 2029**
* Developed by the authors based on [23].

Among the information on foreign cooperation and investment in 2025 are the following:

• Alteogen In announced a licensing agreement with UK-based MedImmune (AstraZeneca) to develop subcutaneous (SC) formulations for three of AstraZeneca's IV-administered cancer drugs.

• OliX Pharmaceuticals Inc announced a global licensing agreement with USA-based Eli Lilly to complete the 1st phase of clinical trials of a candidate drug OLX702A.

• Genome & Company signed a licensing deal last month with UK-based Ellipses Pharma for its immuno-oncology drug candidate GENA-104.

Among the results of cooperation in 2025 are the completion of the third phase of trials of the subcutaneous form of the drug Keytruda in collaboration with Alteogen Inc and Merck & Co the completion of the third phase of trials of combination therapy with the drugs Leclaza from Yuhan Co Ltd and Rybrevant from Johnson & Johnson [7].

Unfortunately, as of 2025, no examples of direct Ukrainian-Korean and Polish-Korean commercial projects or investments in the biopharmaceutical industry have been found.

Biochemical and bioenergy industry

It's focused on production and R&D of chemicals: biopolymers, enzymes, and reagents for research and industry, biocosmetics, biological agrochemicals, etc. The essential sub-sector is biofuel and bioenergy products, which form the basis of the country's energy security.

The bioenergy industry is developing rapidly. In 2024, the Korean bioenergy industry produced 14.67 billion kilowatt-hours of electricity. The market is expected to grow by 9.13% by 2029 (Fig. 7). Despite this, the volume of Korean bioenergy on the global market remains relatively modest [23]. Therefore, Korea is increasingly investing in bioenergy, which reflects its commitment to sustainable development and reducing greenhouse gas emissions in its energy sector.

The industry's main products include biopolymers, biocosmetics, and biofuels. Leading Korean biochemical and bioenergy companies are (Fig. 8): SK Chemicals Co Ltd, Orient Bio Inc, Anygen Co Ltd, Elecseed Pty Ltd, CheilJedang Bio Co Ltd, Beauty of Joseon Ltd, GS Caltex Co Korea South-East Power Co., Ltd.

Orient Bio Inc and CJ Bio Co Ltd are producers of a wide range of biochemicals and reagents. Anygen Co Ltd is a bio-venture company and specializes in the development of peptides and their biomaterials. Beauty of Joseon Ltd develops and produces different types of biocosmetics.

There is particular interest in bioenergy. It is expressed both in government support and in the desire of manufacturers to follow trends and introduce new approaches to energy production on an industrial scale. The country's government is actively promoting the development of biohydrogen production. On February 5, 2021, the Hydrogen Economy and Hydrogen Safety Management Act ("Hydrogen Act"), the world's first hydrogen law, came into force in Korea. After that, Hanwha Group, Hyosung Group, Hyundai Group, SK Group and Posco International, and other companies invested USD 38 billion to stimulate the country's hydrogen economy by 2030. The participating companies plan to increase hydrogen production and consumption many times over by 2030. In

addition to biohydrogen, entrepreneurs are introducing the production of other types of biofuels from various types of raw materials or industrial waste to support Korea's energy security. In Fig.9, bioenergy facilities in Korea in 2024 are marked.

Jungrang Water Recycling Centre is a leader in biogas production with a daily capacity of 5,112 m^3 of biogas. The leaders in the generation of electricity from municipal waste are: waste gasification demo-plant by plasma, owned by GS Platech (capacity of 50 kW, Cheongsong city); waste-to-energy plant, owned by NowOn Technologies Pvt Ltd (capacity of 281 thousand tons per year, Seoul city); landfill gas-to-energy plant, operated

Fig. 8. **Korean biochemical and bioenergy companies [10]**
* Author's compilation.

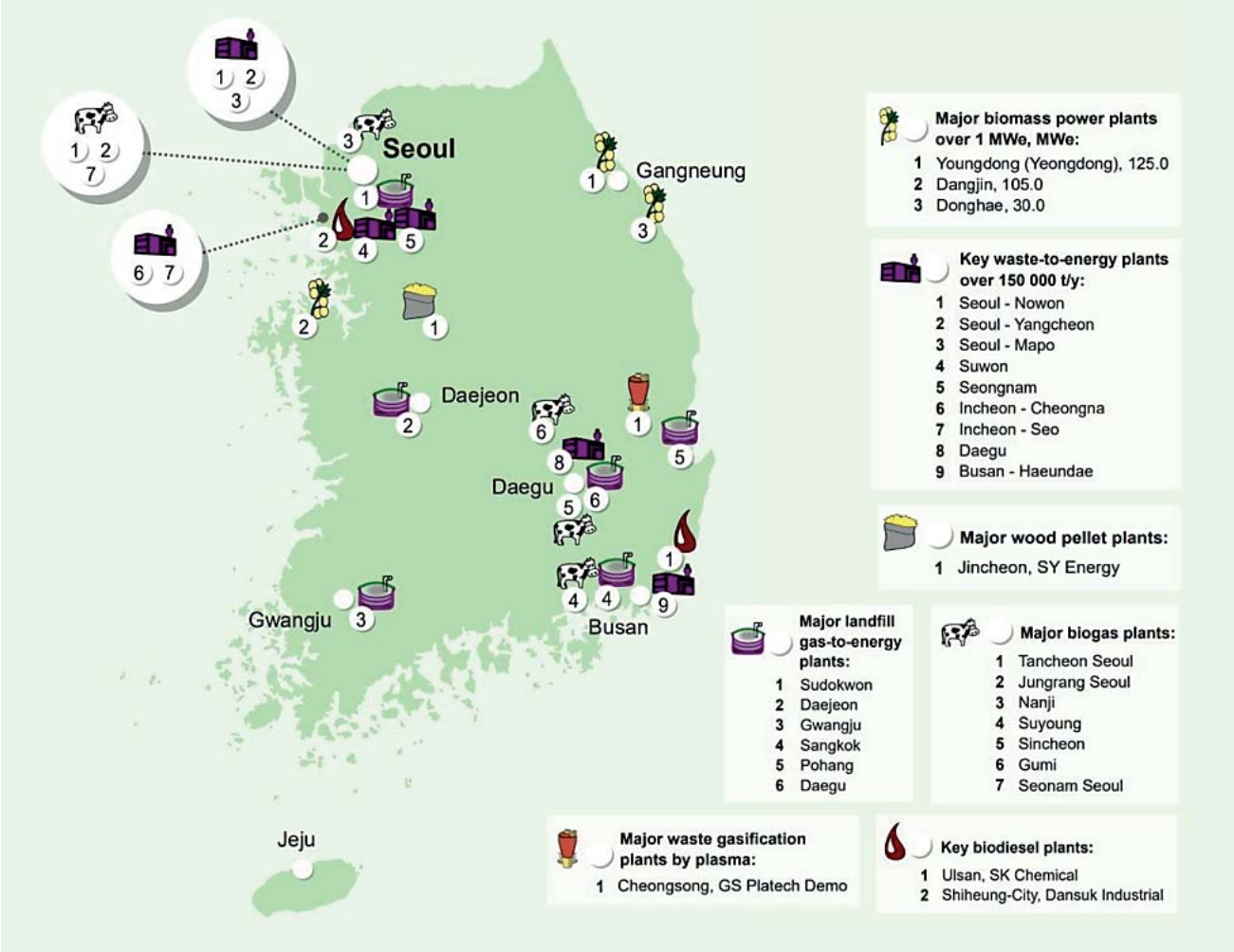

Fig. 9. **Korea's bioenergy infrastructure facilities in 2024**
* The development from website of the research project Advanced Energy Technologies [24].

Table 2

Comparison of bioenergy production and forecast of its annual growth rate in 2025

No.	Country	Bioenergy production, billion kWh	CAGR,%
1.	South Korea	16.28	8.68
2.	Poland	11.09	2.02
3.	Ukraine	0.70	1.40

* Developed by the authors based on [8].

by Sudokwon Landfill Site Management Corporation (processes about 18 thousand tons, Incheon city) and wood pellet enterprise, owned by SY Energy Co Ltd (300 thousand tons of pellets per year, Jincheon city) [24].

The leading manufacturers of biodiesel are SK Energy Co Ltd, S-Oil Co, GS Caltex Co and Hyundai Oilbank Co Ltd [24–26]. The enterprises are working on increasing production capacities and expanding export opportunities in the field of sustainable aviation fuel (SAF). This activity is correlated with a SAF expansion strategy of Korea's Ministry of Trade, industry and energy and the Ministry of land, infrastructure and transport. The aim is to capture 30% of the global blended SAF export market [26]. Among these enterprises, HD Hyundai Oilbank Co Ltd stands out for its use of the supercritical process, which involves the use of high temperatures and pressures without a catalyst. This technology expands the raw material base for biodiesel production, as it allows the use of inedible, difficult-to-process raw materials, such as palm oil from residues [25].

The above-listed production facilities are part of Korea's strategy to decarbonize the energy sector and increase the use of renewable energy sources, aimed at achieving carbon neutrality, strengthening energy security. and stimulating innovation in the field of the green economy. In the comparative context of bioenergy in Korea, Poland, and Ukraine, the former is the undisputed leader (Table 2).

The issue of energy security and further economic recovery is particularly acute and relevant for Ukraine in the context of the Russian-Ukrainian war. Due to damage to the infrastructure, the country needs reliable energy sources. Bioenergy reduces dependence on traditional fuels (coal, oil, and gas) and contributes to the decentralization of the energy system, which is critically important in the context of military operations. In the long term, bioenergy also contributes to the ecological modernization of the country, the reduction of greenhouse gas emissions, and harmonization with European environmental standards, which is an essential component of Ukraine's European integration course. Thus, the development of bioenergy is becoming not only a tool for survival in crisis conditions, but also a strategic direction for the recovery and sustainable growth of the state. Based on these factors, cooperation in the bioenergy industry between Ukraine and Korea is being intensified. In particular, in 2023, representatives of the Ministry of Energy of Ukraine and the Ministry of Land, Infrastructure and Transport of the Republic of Korea confirmed mutual interest in further cooperation in hydropower, nuclear industry, and renewable energy [27].

In 2024, a framework intergovernmental agreement was signed with Korea, according to which the Ukrainian economy will receive USD 2.1 billion in soft loans from the Korean Economic Development Cooperation Fund (EDCF). The priority area for the development of future cooperation between Ukrainian and Korean businesses is green metallurgy and the development of modern energy infrastructure. Posco International will actively participate in Ukraine's recovery projects. One of its upcoming projects is the construction of a cogeneration power plant in Odessa using RDF (refuse-derived fuel). This initiative, worth USD 106 million, will be implemented in cooperation with EDCF [28]. The payback period of the project is estimated at 6.5 years.

By the agreement, there is an opportunity to involve The Fund's finances in state initiatives and recovery projects from The Unified Project Portfolio. Under favorable conditions, the scope of this agreement will expand to the private sector, the number of projects will increase, and the size of investments will increase.

Korea is the largest Asian investor in Poland. According to the National Bank of Poland, in 2018, the value of South Korean investments amounted to EUR 978.8 billion. However, as of 2025, no examples of direct Polish-Korean commercial projects or

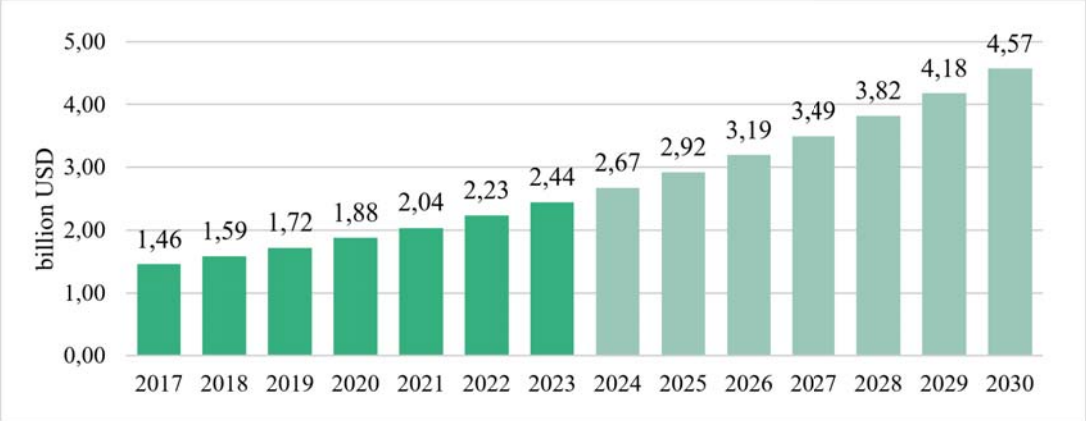

Fig. 10. **Functional health foods market size of South Korea in 2017–2023 and forecast to 2030**
* Developed by the authors based on [31].

Fig. 11. **Korean biofood companies**
* Author's compilation.

investments in the biochemical and bioenergy industry have been found. Given Korea's interest in building a hydrogen economy and the potential of Poland and Ukraine in bioenergy, future cooperation between the states and the exchange of technologies will contribute to their sustainable development and decarbonization of economies for environmental safety. Thus, Poland and Ukraine have the potential for leadership in European bioenergy, provided that regulatory barriers are overcome and investment is actively attracted [29].

Biofood industry

It's focused on production and R&D of functional health foods (e.g., eubiotics, nutraceuticals), fermented foods, food additives (dietary supplements), feed additives, and other biofoods. The industry receives active support from the government, stimulating exports and global popularization of Korean cuisine [30].

Priority is given to creating functional health foods, alternative protein sources (vegetable), as well as environmental technologies in production and packaging. In 2023 Korean functional health foods market reached a revenue of KRW 3.19 trillion or USD 2.44 billion (Fig. 10). The expected CAGR to 2030 for this branch is 9.4%, which is one of the most significant indicators in the world.

Leading Korean biofood companies are (Fig. 11): CJ CheilJedang Co Ltd, Daesang Co Ltd, SeaWith Inc, Haerim Fucoidan Ltd, Greengene Inc, Simple planet Inc, Bereum Co Ltd, Advanced Protein Technologies Co [10].

CJ CheilJedang Co Ltd produces amino acids for humans and animals and functional foods with probiotics, enzymes, fiber, and other bioactive components (including probiotics and postbiotics under its brands BiomeNrich™ and WellNrich™). It works in the direction of molecular cuisine, experimenting with cooking processes at the molecular level, enzymes, stabilizers, and emulsifiers of biological origin. The company's brand Bibigo™ popularizes Korean dishes such as mandu, kimchi, etc.

Functional foods are also produced by Simple Pplanet Inc and probiotics and postbiotics by Bereum Co Ltd.

Daesang Co Ltd specializes in the production of fermented foods, food additives, and amino acids. It is widely known for its fermented products such as miso and soy sauce.

Haerim Fucoidan Ltd focuses on products containing seaweed fucoidan, which is used in pharmaceuticals, dietary supplements, and cosmetics.

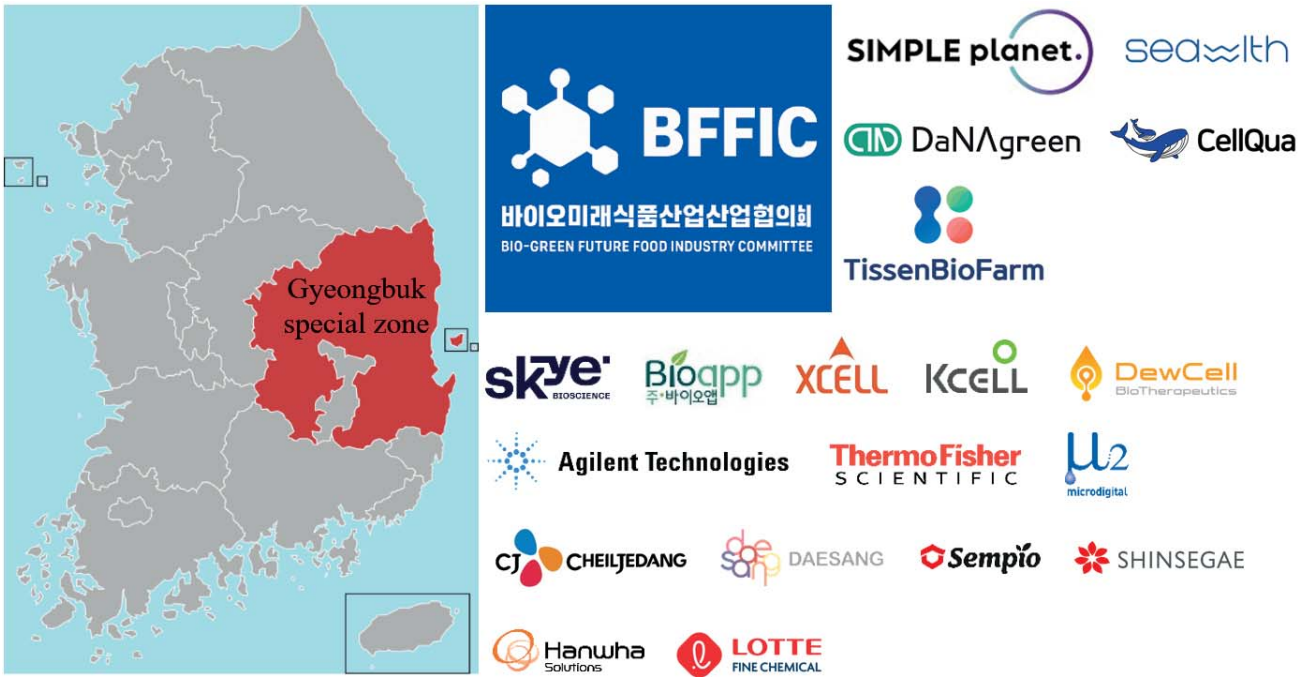

Fig. 12. **Gyeongbuk special zone on the map. Logo of Bio Future Food Industry Association and logos of its members**

* Developed and compilated by the authors based on [36].

SeaWith Inc specializes in the production of cultured meat under the brand name Welldone™. The company aims to create a sustainable alternative to traditional livestock farming, reducing its environmental impact and ensuring ethical protein production.

Greengene Inc. is working on a chloroplast gene editing technology that improves the absorption of carbon dioxide during photosynthesis. The method helps to increase the nutritional value of products (GREENedit™) by increasing the synthesized plant protein.

The innovativeness and multi-vector nature of the developments of the enterprises mentioned above indicate their desire for sustainable development of the state, overcoming the global food crisis, energy challenges, and environmental problems [30]. Support for innovative solutions in industry is provided by scientific institutions, organizations, associations (scientific and technological base), and the government (regulatory support). Thus, in 2018, the Bio-Green 21 Project was founded in cooperation with academies, research centers, industry, and the Rural Development Administration. The goal of the project is to ensure the global competitiveness of Korean agrobiotechnologies by creating an infrastructure for research and its use for the development of new technologies [32, 33].

In 2024, the Bio Future Food Industry Association (BFFIC) was established to support and develop the cultivated meat market. The association consists of 33 companies, including biofood industry innovators (Simple Planet Inc, SeaWith Inc, TissenBioFarm Co Ltd, CellQua Inc), well-known food conglomerates (CJ CheilJedang Group, Daesang Group), nutrient media developers, production process developers, etc. To facilitate the BFFIA initiative, the Korean government has designated the Gyeongbuk cell-cultured foods regulatory-free special zone (RFSZ) (Fig. 12), free from legal obstacles and intended for the creation of industrial facilities for the production of cultured meat.

In the first phase of the project, companies will create banks of highly purified animal cells and establish quality and safety standards for these products. The second phase includes a demonstration of mass production and commercialization using 3D scaffolding and molecular cuisine technologies to improve the taste and texture of the final product.

The Gyeongbuk special zone is designed to accelerate the commercialization of cultured meat and will expire in 2028. During the project, the government will work on a regulatory framework to remove legal obstacles to developers and establish standards for such products [34–35].

Korea is witnessing the dynamic development of new areas of the biofood industry, in particular in the field of functional nutrition, molecular gastronomy, catering, fusion cuisine, and smart farming. Some of the products produced within these segments are already presented on the markets of Ukraine and Poland, which indicates a growing interest in this area. Both countries show a high interest in the development of biotechnology in the agro-industrial complex, in particular bioingredients, dietary supplements, and innovative food solutions. Ukrainian and Polish manufacturers express their readiness to cooperate with Korean companies, in particular by supplying specialized products for the needs of the innovative gastronomy segment, which meets modern global trends in sustainable nutrition.

In particular, on 2023 July 15, as part of the visit of the Korean President to Ukraine, issues of security and economic cooperation between the countries were discussed [37]. Among the promising areas of cooperation in the bioindustry, the parties are considering the introduction of nnovative farming and organic farming into the agro-industry and the development of environmentally friendly technologies for building a modern city and its infrastructure, which concerns the next sector of the bioindustry [38–40].

Regarding the raw material base for the bioindustry, an important initiative is the use of new methods of classical biotechnology and bioengineering in the agro-industry.

Bioenvironmental industry

It's focused on production and R&D of bioenvironmental products and services: biological treatment agents and systems for treatment and recycle, materials and equipment for bioimmobilization, measuring apparatus and services for environmental pollution and assessment. Key areas include: biological wastewater treatment, soil bioremediation, organic waste processing, air biofiltration, green biotechnologies in the urban environment (e.g., phytoremediation, vertical farms, ecological facades with moss and microalgae), etc.

According to the analyzed sources of information, the most significant growth, development, and investments are biological wastewater treatment (CAGR = 7.2%), bioremediation (CAGR = 12.1%), and vertical farming (CAGR = 21.0%) (Fig. 13) [41–44].

Modern biotechnological solutions, in particular biological wastewater treatment, bioremediation, and vertical farming, play a key role in ensuring environmental safety, increasing economic efficiency, and contributing to the sustainable development of the state through the rational use of resources and minimizing environmental impact.

Biological wastewater treatment is an essential phase for reducing anthropogenic pressure on the environment, as it ensures safe disposal and reuse of water resources. Among the methods of biological wastewater treatment, aerobic methods dominate, providing 53% of the industry's revenue in 2024. Interest in these methods is confirmed by scientific works, research, and development of Korean scientists [42, 45, 46]. Anaerobic and anoxic methods are less common [42].

In turn, bioremediation is aimed at deeper removal of contaminants in soils and water, which complements the ecological restoration system. In 2021, in situ, soil bioremediation provided 56.36% of the industry's revenue [43]. Toxic compounds in soil and groundwater pose a threat to human health and nature. In particular, an accidental oil spill is a significant environmental disaster, which disrupts the complex networks of biotic and abiotic interactions of ecosystems. Bioremediation, as a set of bioprocesses and interactions between microorganisms, is a soft and cost-effective approach to removing organic pollutants [47].

The final link in the ecological coexistence of nature and industry is the use of green biotechnology in the urban environment, in particular, vertical farming. It allows for the effective use of purified resources, ensuring food security for society, and creating a closed, environmentally friendly cycle for sustainable agricultural production in urbanized conditions.

Leading Korean bioenvironmental companies are (Fig. 14): EcoBio Holdings Co Ltd, KERT Korea Environmental Restoration Technology Co Ltd, NeoEcogene Co Ltd, N.Thing Inc, Farm8 Co Ltd [48].

EcoBio Holdings Co Ltd is engaged in the business of waste recycling. At the same time, KERT Co Ltd specializes in soil purification, which can treat oil pollution, heavy metals, and complex contaminated soil.

N.Thing Inc and Farm8 Co Ltd specializes in vertical farming.

In the post-war period, the development of the bioenvironmental industry in

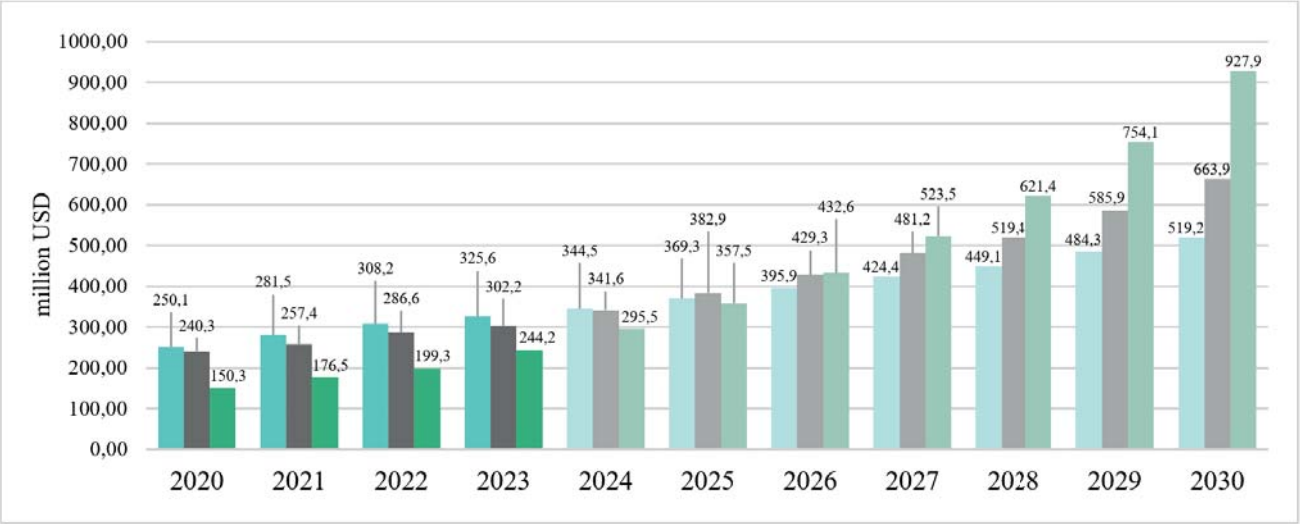

Fig. 13. **Aspects of bioenvironmental industry: biological wastewater treatment ( ), bioremediation ( ) and vertical farming ( ) market size of South Korea in 2020–2023 and forecast to 2030**
* Analised, developed, and compilated by the authors based on [41–44].

Fig. 14. **Korean bioenvironmental companies**
*** Author's compilation.**

Ukraine will be of utmost importance for ecological restoration, food security, energy independence, and sustainable economic growth. Large-scale destruction of the natural environment, soil degradation, pollution of water resources, and the atmosphere as a result of hostilities will require the use of biotechnological solutions for environmental remediation (cleaning) and restoration of ecosystems. One of the key areas will be biological wastewater treatment and bioremediation — technologies that allow using safe biological methods to eliminate soil, water, and air pollution. Vertical farming will ensure local, environmentally friendly food production with minimal use of land resources, which is especially relevant in conditions of destroyed infrastructure and potentially dangerous zones.

Other promising areas include:

- Composting and reuse of organic waste to create fertilizers and biogas;
- Phytoremediation — the use of plants to clean the environment;
- Production of biopolymers and biodegradable materials from renewable raw materials;
- Creation of energy-efficient ecological buildings using bioinsulation materials;
- Agroecology and organic farming — to restore degraded soils and reduce chemical loads.

The development of these areas will allow Ukraine not only to restore its ecological potential but also to become a regional leader in the field of green bioeconomy.

South Korean companies are interested in participating in projects for the development of a smart city and infrastructure in Ukraine. One of such potential projects is the transformation of Truhaniv Island in Kyiv into an environmentally friendly innovation park with research laboratories and residential real estate. But so far this is just an idea [38].

Biomedical equipment industry

It's focused on production and R&D of biomedical equipment, biosensors, biomarkers, and *in vitro* diagnostics. Biomedical devices are designed for therapeutic and diagnostic purposes and cover a wide range of technologies: from advanced imaging systems and surgical instruments, implantable devices (pacemakers and insulin pumps), to biometric

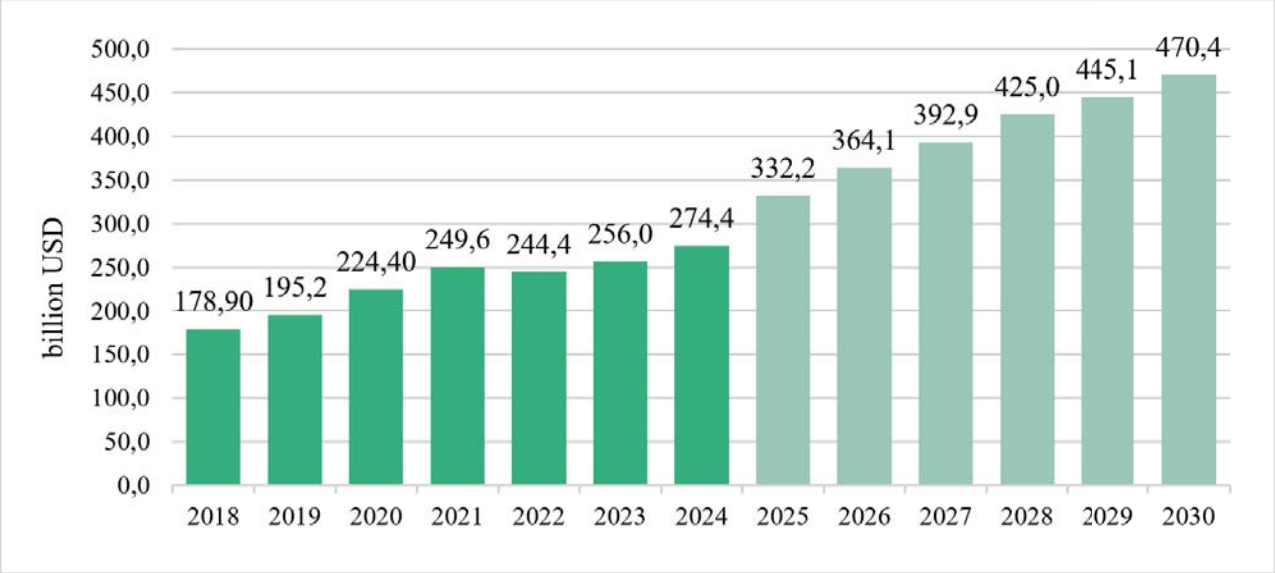

Fig. 15. **Biosensors market size of South Korea in 2018–2022 and forecast to 2030**
* Developed by the authors based on [49].

Fig. 16. **Korean companies that provide biomedical equipment**
* Author's compilation.

sensors and biosensors for continuous health monitoring.

Since rapid diagnostics play a vital rolerole in preventing the spread of infectious diseases (such as the coronavirus disease caused by SARS-CoV-2), the biosensor medical device industry has excellent investment potential. The growth of the sector is also due to rapid urbanization, technological progress, and increasing disposable incomes, especially in developing economies. In 2024, the Korean biosensors market generated a revenue of USD 274.4 million. It is expected that by 2030 its CAGR will be 9.6% (Fig. 15) [49].

Korea's biosensor market, as a leader in the electronics industry, shows significant growth potential due to technological advancements, growing consumer demand, and changing regulatory frameworks. As the market matures, product innovation and digital transformation are expected to drive its expansion. Growing interest in sustainable and environmentally friendly solutions will drive product demand. Sales are expected to shift towards high-quality, premium products, contributing to rising disposable incomes and the dominance of quality over quantity. Government initiatives that promote industrial modernization and international trade partnerships will further expand growth opportunities.

Among the leading Korean biomedical equipment manufacturers (Fig. 16): MiCo BioMed Co Ltd, GeneMatrix Inc, KogeneBiotech Co Ltd, Genomictree Inc, Huinno Inc, Dx&Vx Co Ltd, Calth Inc, Inogenix Inc.

MiCo BioMed Co Ltd, GeneMatrix Inc, KogeneBiotech Co Ltd, Calth Inc, and Inogenix Inc. specialize in the development and production of molecular diagnostics.

Genomictree Inc focuses on the development of innovative *in vitro* molecular diagnostics technologies. The company is working on the discovery of DNA methylation biomarkers for early diagnosis of diseases such as colorectal cancer.

Huinno Inc develops biodevices for monitoring cardiac activity, such as smart watches and patches, equipped with artificial intelligence technology for analyzing biometric signals

Dx&Vx Co Ltd offers multiomics solutions for personalized medicine, including the development of vaccines and strains for treatment.

The Ukrainian biosensor market is in a stage of active development, focused primarily on scientific research and prototyping. The country has already developed dozens of effective biosensors suitable for use in various fields, including medical diagnostics, agro-industry, and environmental monitoring. At the same time, the widespread implementation of such technologies is hampered by limited funding, lack of production capacity, and complex licensing procedures.

Among the leading companies working in this area, BIOsens stands out — the developer of a mobile analyzer for the rapid detection of mycotoxins in grain crops. This solution has significant practical significance for farms and contributes to increasing food security. The BIONANOSENS project, dedicated to analytical biotechnology and innovative management, was also an important initiative. Despite the difficult conditions caused by the pandemic and war, its implementation confirmed the high potential of Ukrainian science in the field of biosensors.

Thus, although the development of the market requires overcoming a number of challenges, Ukraine has significant prerequisites for becoming an essential player in the field of biosensor technologies. With state support and investment, scientific developments can turn into effective commercial solutions with great applied value for healthcare, the agricultural sector, and the environment.

Bioinstrument and bioequipment industry

It's focused on production and R&D of equipment for analysis, synthesis, and manufacturing of genes, proteins, peptides, cell cultures, and other bioproducts and bioprocesses.

Bioservice industry

It's focused on providing R&D and/or manufacturing services, processing treatment & warehousing services, biodiagnostic services, and consulting cooperation. Bioservices in Korea is a key component that supports research, development, and innovation in the biotechnology sector. This industry focuses on providing specialized services and technologies necessary for the successful development of biotechnology, pharmaceuticals, medicine, agro-industry, and other related fields. Due to the wide range of bioservices that bioindustry enterprises can provide, we propose to conditionally divide the types of bioservices into two categories: production-related bioservices and intellectual bioservices or practical and intellectual support.

Production-related bioservices, as the name suggests, include services related to the development, research, analysis, quality control, and production of bioproducts.

Practical support includes:

– Contract research organization services (CROs), which provide processes for the development and research of bioproducts, improving their quality, optimizing their production technology, etc. CROs can also consist of the study of laboratory and toxicological properties of the product and the use of genetic and cellular engineering to modify bioproducers and bioprocesses:

– Contract manufacturing organization services (CMOs), which provide processes for the mass production of bioproducts to order: from the preparation of raw materials to the filling and packaging of the finished product, as well as its quality control (molecular diagnostics, biosensor analysis, physicochemical and microbiological expertise, certification according to GMP/GLP/ISO);

– A separate category can be distinguished, contract development and manufacturing organization services (CDMOs), which provide the entire cycle of commercialization of bioproducts from development and research to mass production;

– Contractual provision of auxiliary production processes (CP — biopurification of water, industrial effluents, air zones, and territories, bioremediation, etc.), supply of consumables, reagents, and equipment for scientific institutions and companies.

Intellectual support includes:

– biodata processing, genetic analysis services (study of hereditary diseases, personalized treatment, disease screening, use of CRISPR-Cas9, for modification of genetic material, as well as use of next-generation sequencing (NGS) technologies for genome analysis), development of algorithms for bioanalytics and diagnostics, IT solutions for the bioindustry (electronic laboratory journals, management systems, etc.);

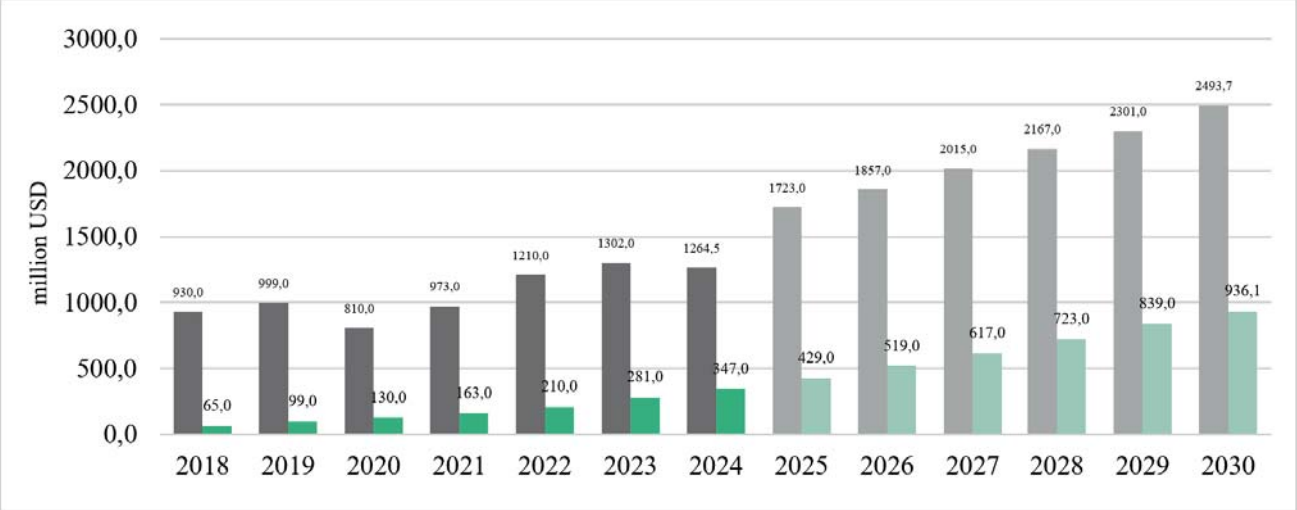

Fig. 17. **Biopharmaceuticals contract manufacturing market size ( ) and biosimilars contract manufacturing market size ( ) of South Korea in 2018–2023 and forecast to 2030**

* Analised, developed, and compiled by the authors based on https://surli.cc/kthelk.

Fig. 18. **Korean bioservice companies**

* Author's compilation.

– bioproject consulting, business planning, and support of startups, and training, training of qualified personnel.

The development of the bioservice industry is evidenced by the dynamics of the growth of the contract manufacturing of bioproducts. In particular, in 2024, contract manufacturing of biosimilars more than doubled in the period 2018–2021, and is projected to grow 9 times by 2030 (Fig. 17). Rapid growth will also be observed in the larger market of contract manufacturing of biopharmaceuticals by 2030.

Among the leading Korean companies in the bioservices industry are (Fig. 18): Samsung Biologics Co Ltd, Celltrion Inc, Clinomics Inc, Woojung Bio Inc, SpMed Co Ltd, Binex Co Ltd, and Invites Biocore Co Ltd.

Strict adherence to international standards such as GMP, ISO, and GLP (Good Laboratory Practice) ensures high-quality services. Korea is one of the world's leading bioservices centers, providing services to companies in the US, EU, and other regions. Bioservices ensure the effective implementation of innovations in the bioindustry and medicine, and contribute to the rapid development of scientific research, the commercialization of innovations, and increasing the country's global competitiveness. Thanks to infrastructure, government support, and highly qualified specialists, Korea is consolidating its position as a worldwide leader in bioservices [50]. In particular, the development of the bioservice industry is supported by the research base of scientific institutions. Over the past decade, Korea has become a global clinical center. For example, in 2017, 213 clinical trials of biopharmaceutical products (Fig. 19) were approved [8, 16].

Innovation. Korea has a very high level of academic achievement. The country ranked 6th out of 133 countries surveyed in the 2024 Global Innovation Index. The country ranks 4th in the world in terms of the number of patents granted to Korean citizens both domestically and abroad, behind Japan and China in the region. The country also has a higher number of active patents than the world average, indicating a favorable environment for innovation in the country [24].

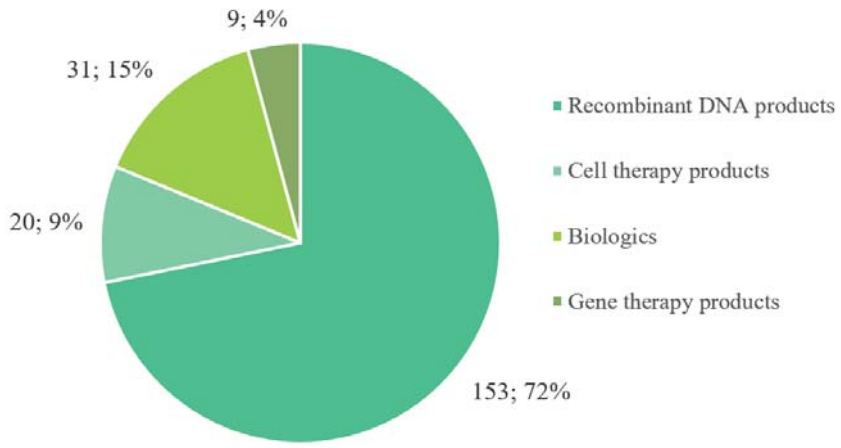

Fig. 19. **Number of approvals for clinical trials of biopharmaceuticals in 2017**
* Developed by the authors based on [16].

Among the research institutions, organizations, and associations, the following should be mentioned:

1. The Korea Drug Research Association (KDRA) was founded in 1986 as a non-profit organization. KDRA represents innovative Korean companies focused on research and development. The association supports the development of new, improved drugs by promoting information exchange and outsourcing [51].

2. The Korea Pharmaceutical and Bio-Pharma Manufacturers Association (KPBMA) has played a key role in the development of the pharmaceutical industry in Korea since its establishment in 1945. KPMA's objectives are to develop new drugs through R&D and supply of pharmaceutical products [18].

3. The Korea Research Institute of Bioscience & Biotechnology (KRIBB) is a leading research center in Korea that conducts basic and applied research in bioscience and biotechnology. It was founded in 1985 in Daejeon. The institute operates under the auspices of the Korea Institute of Science and Technology (KIST), is funded by the Korean government, and specializes in research on new biomaterials, development of environmentally friendly biotechnology, new energy sources, and biofood innovations [52].

4. Korea Research Institute of Chemical Technology (KRICT) is a leading state-owned research institute in South Korea, which is engaged in the development of advanced chemical technologies for industry, ecology and medicine. Founded in 1976, Daejeon. Key research areas: green chemistry, new generation chemical materials, pharmaceutical, and medicinal chemistry [53].

5. Korea Institute of Oriental Medicine (KIOM) is a leading research institution that researches and develops traditional oriental medicine, in particular Korean (Hanbang). The institute was founded in 1994, Daejeon. Key projects concern acupuncture, cerebrovascular diseases, and complicated diabetic diseases [54].

6. The National Cancer Center of Korea (NCC) is Korea's leading medical institution specializing in cancer prevention, treatment, research, and education. The center plays a key role in the national cancer control strategy and in implementing advanced technologies to improve cancer treatment [55].

7. The Mogam Biotechnology Research Institute (MBRI) is the first government-approved non-profit research organization established in 1984. It specializes in the development of innovative biologics. The institute plays a key role in the development of Korea's pharmaceutical industry by contributing to the creation of new drugs and therapies [56].

The logos of the leading research infrastructure organizations are shown in Fig. 20.

Technoparks and infrastructure

The Korean government is developing the bioindustry by promoting and supporting **bioclusters**, taking into account their regional characteristics. To encourage the development of a regional innovation system and ensure balanced national growth, a biocluster system was introduced in 1998, establishing bioindustry complexes in each region. There are 18 bioclusters (Fig. 21) according to the "Third master plan for

Fig. 20. **Logos of the leading research infrastructure organizations in South Korea**
* Author's compilation.

fostering and supporting pharmaceutical and bio industries", jointly announced by Korean government ministries on March 24, 2023 [57–59]. The main of them are:

– Biomedical R&D Cluster (Seoul City);
– Bio Cluster (Incheon City);
– High-tech Medical Complex (Chungcheongbuk Province);
– Bio Venture Town (Daejeon City);
– Biomedical Cluster (Hwasun County);
– Natural Product and Medical Instrument Cluster (Gangwon Province);
– Gyeonggi Bio-center (Gyeonggi Province);
– Pangyo Techno Valley (Gyeonggi Province);
– High-tech Medical Complex (Daegu City) [59].

The bioindustry in Korea is regulated by several key government agencies that ensure control, safety, and development of the industry. At the same time, the government is trying to support the development of the bioindustry as much as possible. Ministry of Food and Drug Safety Ministry of Food and Drug Safety (MFDS) is the main regulatory body for the bioindustry and its products. The ministry sets standards for production and testing; it monitors the long-term results of the use of innovative therapies. Under its jurisdiction is the control of vaccines, drugs, genes, and cell therapy products. Each regional center has its own Food and Drug Safety (FDS) units or offices that are engaged in the regulation and approval of products, including medicines, herbs, and other similar products in South Korea. To control the quality and safety of bioindustry production, the experience of the FDA and the units that continue the FDA's control function at the national level for entering the international market are taken into account [57].

Ministry of Science and ICT (MSICT) promotes research and development in the fields of genetic engineering, bioinformatics, artificial intelligence in medicine, and the development of bioenergy. The ministry funds research projects and promotes international cooperation in this area.

The Ministry of Health and Welfare (MoHW) focuses on the implementation of biotechnology in the healthcare system. It develops the legal framework for the integration of regenerative medicine into medical practice and monitors its impact on public health.

There are also specialized regional development agencies in various regions of Korea that promote clustering of companies and research centers, creating conditions for the growth of the bioindustry at the local level. The coordinated work of all these institutions ensures effective regulation and active development of the bioindustry [57].

All production scientific state institutions affect the harmonious, sustainable development of the state.

Based on the experience of the Korean bioindustry, we can identify the "three pillars" for the sustainable development of the bioindustry:

– research institutions, organizations, associations;
– industrial associations of entrepreneurs;
– government support for innovative solutions and response to trends and developments.

To strengthen cooperation between representatives of the Ukrainian bioindustry and foreign colleagues, it is necessary to develop a clear strategy for its development. The key provisions of the Strategy should include:

1. Initiating government dialogue. Launch an intergovernmental platform for dialogue in the field of biotechnology (at the level of the ministries of economy, health, and science). Include bioindustry issues in bilateral economic forums.

2. Supporting scientific exchange. Promote academic partnership between the Ukrainian NAS, Ukrainian universities (e.g., KNU, NUFood Technologies, Lviv Polytechnic NU), and Korean universities (e.g., KAIST, POSTECH). Create scholarships/grants for internships and joint research in biotechnology, pharmaceuticals, and agrobio.

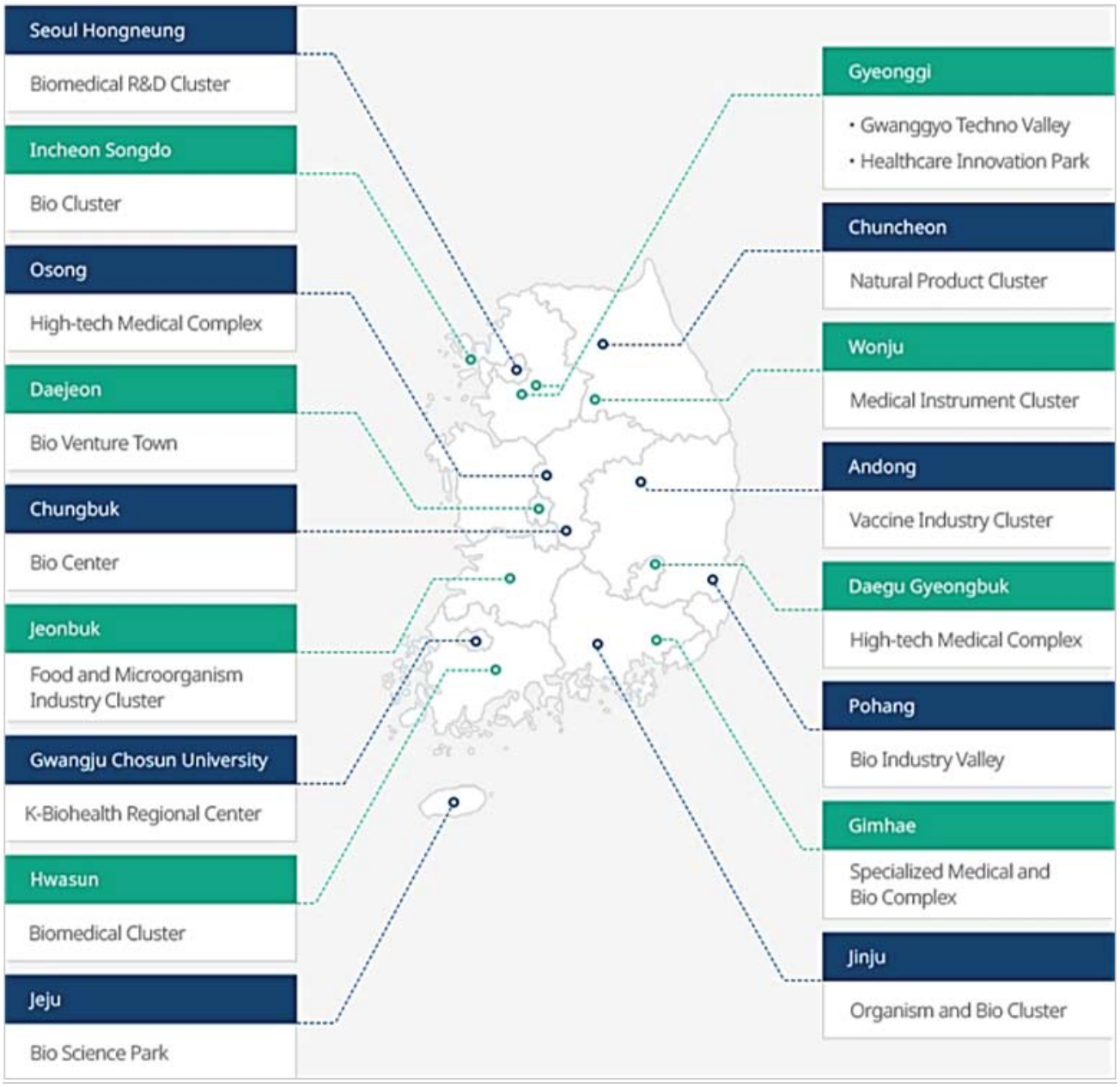

Fig. 21. **Bioclusters in South Korea**
* The development from Invest KOREA platform website [59].

3. Attracting investors. Organize roadshows for Korean investors in Kyiv/Seoul with presentations of Ukrainian R&D startups and the potential of pharmaceutical production. Offer preferential conditions for the creation of production clusters in medical or agrobiotechnologies.

4. Develop pilot projects (e.g., DS or vaccines) to reduce risks and demonstrate yourself as a reliable partner.

Conclusions

Korea's bio-industry is rapidly developing, becoming one of the key sectors of the country's economy. Thanks to government support, innovative technologies, and a favorable business climate, Korea has established itself as a global leader in biotechnology, biopharmaceuticals, and functional foods. Government initiatives such as the Bio-21 strategy and Bio-vision have become the basis for the growth of the industry. Through funding, the creation of bioclusters, and legislative reforms, the Korean government

is stimulating the development of both large corporations and small startups.

Key achievements of the Korean bioindustry include:

1) Development of biopharmaceuticals. Korea is a leading player in the production of biologics such as monoclonal antibodies (MABs), vaccines, and other drugs. Leading Korean companies such as Samsung Biologics Co., Ltd, and Celltrion Inc. occupy an essential place in the global market.

2) Functional foods. Thanks to advanced technologies, Korean companies are creating products that not only meet nutritional needs but also contribute to improving health.

3) Innovation in manufacturing. The development of cultured meat, bioplastics, and animal protein substitutes demonstrates an environmentally friendly approach to product manufacturing.

The role of the bioindustry for the sustainable development of Korea is decisive, as it contributes to the achievement of environmental, economic, and social goals of sustainable development:

– environmental sustainability, which involves the development of bioenergy and the production of biomaterials. By 2050, the country plans to transition to carbon neutrality and reduce dependence on fossil fuels through the use of biofuels (bioethanol, biodiesel) and biogas;

– economic development, which is a result of supporting biotechnology startups and scientific research through government grants and investments;

– social initiatives, such as supporting food security and environmental policies.

The bioindustry is the foundation of the country's transition to a green economy. The government has identified biotechnology as one of its national development priorities, seeing it as a tool for diversifying the economy, creating jobs, and ensuring technological leadership in the global market. Overall, the bio-industry has become a driver of Korea's economic growth, contributing to the transition from traditional industry to a high-tech knowledge economy. It is also an essential factor in strengthening the country's international image as a center of innovation and a leader in the field of sustainable development.

The dynamic growth of the food bioindustry in South Korea, driven by innovations in functional foods and sustainable production technologies, has created favorable conditions for the expansion of adjacent sectors. One of the most rapidly developing areas within this framework is the dietary supplement industry, which leverages biotechnological advancements to meet growing consumer demand for health-promoting products. Building upon the foundations of food biotechnology, the production of nutritional supplements in South Korea integrates scientific research, natural ingredients, and stringent quality control to offer targeted solutions for various physiological needs and lifestyle challenges.

Given the increasing relevance of this sector, a more detailed analysis of South Korea's dietary supplement industry is considered a promising direction for further research. It will be addressed in a subsequent publication.

Author contributions

A.D.: conceptualization, study design, data collection, drafting the manuscript, and original draft preparation. O.S.: critical revision, manuscript editing, translation editing, and language polishing. T.K.: language polishing, supervision, reviewing, and final approval of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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БІОПРОМИСЛОВІСТЬ У ПІВДЕННІЙ КОРЕЇ: АНАЛІТИЧНИЙ ОГЛЯД ТА ОСНОВНІ ПЕРСПЕКТИВИ ЇЇ РОЗВИТКУ

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Подано аналітичний огляд біоіндустрії Південної Кореї, її поточний стан, досягнення та виклики. Висвітлено різні аспекти економіки, зокрема й інноваційні можливості, державну політику, економічний вплив та соціальні зміни. Визначено ключові досягнення, лідерство Південної Кореї у виробництві та інноваціях біофармацевтики, а також розглянуто такі проблеми, як глобальна конкуренція та зміна клімату. Окреслено ключові перспективи майбутнього розвитку, підкреслюючи потенціал цифрової охорони здоров'я, персоналізованої медицини та зеленої біотехнології для позиціонування Південної Кореї як лідера в біоекономіці. Висвітлено уроки, які можна винести з досвіду Південної Кореї, та їхню застосовність до інших країн, зокрема України та Польщі, які прагнуть зміцнити свій потенціал біоекономіки та біоіндустрії. Враховуючи стратегічний підхід Південної Кореї, це дослідження має на меті визначити цінні ідеї для сприяння інноваціям, забезпечення сталого розвитку та позиціонування біоіндустрії як рушійної сили національного економічного зростання. Висвітлено сучасний стан промислового виробництва та напрямів наукових досліджень у класичній біотехнології для вдосконалення існуючих і розроблення нових біоінженерних технологій, що спрямовані на розвиток стратегічного значення біоіндустрії для досягнення сталого розвитку країни.

Мета. Аналіз поточного стану, ключових досягнень, викликів та перспектив південнокорейської біоіндустрії, зосереджуючись на отриманні цінних знань та практик, які можна адаптувати для сприяння розвитку біоіндустрії в Україні та Польщі.

Матеріали й методи. Методологічний аналіз та абстрактно-логічний метод узагальнення критеріїв оцінки формування, розвитку та інтеграції біотехнологічного виробництва у структуру світового випуску безпечної продукції, а також біопродуктів для покращення здоров'я та омолодження.

Результати. Описано сучасний стан ключових галузей промисловості на основі корейського класифікаційного коду біопромисловості KS J 1009: біофармацевтична, біохімічна та біоенергетична, біохарчова, біоекологічна, біомедичне обладнання, а також біоінструменти та біообладнання, біоресурсна та біосервісна галузі. Кожен сектор охарактеризовано різною динамікою зростання, рівнями впровадження інновацій та інтеграції в національні та глобальні біоекономічні стратегії.

Висновок. Аналіз висвітлює як технологічні досягнення, так і структурні пріоритети, що формують сучасну біоіндустрію Південної Кореї.

Ключові слова: Південна Корея, біоіндустрія, біоекономіка, сталий розвиток, інновації, інвестиції, стандарти.