Economic potential of biotechnologies

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Abstract. Biotechnology is one of the most promising areas of development of modern science and technology. Within the framework of biotechnology, the potential of using living systems and their metabolic products to solve various technological problems is being studied, and methods are being developed to create new organisms using recombinant DNA in accordance with the concepts of genetic engineering. The interdisciplinary nature of biotechnologies makes it possible to use their results in various economic sectors: in agriculture and the food industry, in pharmaceuticals, medicine, in the production of biofuels, in waste processing and in the fight against pollution of natural ecosystems. This article provides a comprehensive study of the economic potential of biotechnologies and the possibility of their application in the modern world.

1 Introduction

The term "biotechnology" was introduced to the scientific community by Hungarian engineer Karl Ereky in 1917. Ereki defined biotechnology as “all types of work in which certain products are produced from raw materials with the help of living organisms” [1]. In the 1960s, the term "Biotechnology" began to be used in the context of research into the production of a product or service that involves living organisms and biological processes. Currently, most researchers define biotechnology as a scientific discipline and tools for the use of biological systems (mainly microorganisms, cells and their components) to solve various technological problems [2].

It should be noted that throughout its history, humanity has used microorganisms in the production of alcoholic beverages, fermentation of dough, and production of fermented milk products. But only in the middle of the 19th century, the French scientist Louis Pasteur scientifically proved the relationship between the activity of microorganisms and fermentation processes, therefore he is considered the father of biotechnology. The main stages of further development of this science are presented in Fig. 1.

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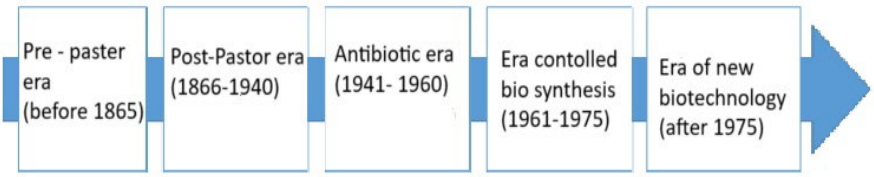

Fig. 1. Stages of biotechnology development

Scientific approaches to biotechnology began to take shape in the mid-twentieth century on the basis of the microbiological industry that already existed by that time. Initially, the main focus of biotechnological production was the production of viral vaccines and the production of antibiotics by submerged fermentation, and after 1961, the era of controlled biosynthesis began, characterized by the industrial use of immobilized enzymes and cells and the production of amino acids and pure enzymes. The period of modern use of biotechnology begins after 1972, when genetic and cellular engineering appears, and it becomes possible to obtain monoclonal antibodies, hybrids from protoplasts and clonal propagation methods.

2 Materials and Methods

In the 21st century, there is a rapid development of bioenergy, environmental biotechnologies, and the creation of biopolymer materials. Biotechnology also makes it possible to increase the yield of cereal crops and obtain new medicines, vaccines and food products. Biofuels based on soybeans, rapeseed and sugar cane are successfully replacing traditional fuels produced from petroleum products. A current direction is the design of genes, which makes it possible to control the life activity of animals and plants, creating organisms with new properties. The polyvariance of the use of biotechnologies necessitates their differentiation, while the "color" classification is currently most often used (Fig. 2).

Red biotechnologies (ensuting human health, production pharmaceuticals)
Green biotechnologies (agricultural plants)
White biotechnologies (industrial biotechnology)
Yellow biotechnologies (food biotechnology)
Grey biotechnologies (environmental biotechnology)
Blue biotechnoloies (use of marine organisms and raw materials resources)
Brown biotechnologies (desert and arid land management regions)
Golden biotechnologies (bioinformatics, nanobiotechnology)
Purple biotechnoloies (legal, ethical, philosophical aspects of the use of biotechnologies)
Black biotechnologies (biological weapons, bioterrorism)

Fig. 2. Color classification of biotechnologies

The leading place in the "red" sector of biotechnology is occupied by the biopharmaceutical industry, which specializes in the production of various medical products, such as antibodies, proteins, RNA, DNA, and antisense oligonucleotides. This area also includes the development of vaccines, gene therapy, and molecular diagnostics. A promising direction for the further development of "red" biotechnologies is the cultivation of organs and tissues for further implantation.

Green biotechnology is a field of biotechnology that focuses on the use of biological systems, microorganisms, plants and animals to solve agricultural production. This segment includes genetic modification of plants in order to increase productivity, improve product quality, and increase resistance to changing climatic conditions, various diseases and pests.

The term “white” biotechnology characterizes the use of biological systems in industrial production. One of the most promising areas of “white” biotechnology is the production of biopolymers based on plant materials (corn, potatoes, sugar cane), microorganisms (bacteria or algae) or products of animal origin (for example, the chitinous cover of arthropods). These materials undergo fermentation, purification and modification to provide such significant characteristics as strength, elasticity and heat resistance. Biopolymers can then be molded into various products using extrusion, casting, compression molding and other molding processes. Biopolymers are gradually becoming an alternative to plastic; they are not inferior to it in terms of basic indicators,

Another area of “white” biotechnology is the production of biofuel, which is considered a more environmentally friendly source of energy compared to coal and petroleum products. The most common type of biofuel is biodiesel, which is produced from soybean, rapeseed or sunflower oil, as well as various wastes of plant or animal origin. Biodiesel is mixed with regular diesel in various proportions to create diesel grades such as B5 (contains 5% biodiesel) or B20 (contains 20% biodiesel). An environmentally friendly alternative to gasoline is bioethanol, obtained by processing sugar cane, corn or sorghum. Bioethanol can be added to gasoline to increase octane number and reduce emissions of harmful substances. Methane decomposition of food waste, manure and plant biomass makes it possible to produce biogas, which can replace natural gas and be used in the production of electricity. Fischer-Tropsch installations make it possible to obtain synthetic biofuel with a minimum amount of impurities.

“Yellow” biotechnology includes both classical microbiological production (winemaking, brewing, cheesemaking) and the latest technologies for the production of carotenoids, steroids, nucleotides, amino acids, as well as other food additives and preservatives. Various bacteria and enzymes are also used to improve the efficiency of disposal of food residues.

“Gray” biotechnology is focused on solving environmental problems associated with environmental pollution and the generation of various categories of waste. Thus, to purify water, soil and atmosphere, the metabolic processes of plants, fungi, insects, worms and other biological organisms are used - this process is called bioremediation. Bioremediation has proven its effectiveness in cleaning up oil spills in water and soil, neutralizing heavy metal pollution, treating wastewater, combating the consequences of industrial accidents and large-scale pollution.

Blue biotechnology (aquabiotechnology) is an area of biotechnology that involves the use of marine organisms and resources to produce food, supplements, vitamins and biologically active substances, as well as the use of algae as renewable energy sources. “Brown” biotechnologies are designed to counter a serious environmental problem – desertification. As part of this area, specialists are creating genetically modified plants that can survive in conditions of heat and low humidity, prevent soil erosion, and promote the reclamation of degraded lands.

“Golden” biotechnology is a term used to denote a set of high-tech methods and innovative approaches to the study of living organisms; this area includes nanobiotechnology and bioinformatics. Nanobiotechnology combines nanotechnology and biotechnology to create new materials, devices, and techniques at the molecular level. Key areas of development in this area are nanomaterials, nanoparticles and nanorobots, which can be used in various tasks, for example, to monitor biological processes in the body or to transport drugs directly to cancer cells. Bioinformatics plays an important role in genomic sequence analysis and protein structure prediction. Within the framework of this direction, the study of genetic abnormalities is carried out,

The use of biotechnology raises a wide range of legal, ethical and philosophical questions about the admissibility of the transformation of biological organisms for utilitarian purposes

- these issues are directly addressed by “purple” biotechnology. Within the framework of this area, the problem of the admissibility of testing drugs on the human body is being resolved, while taking into account the individual’s right to an informed choice and the confidentiality of data on biotechnological interventions. The possibility of using artificial intelligence in medical diagnoses, prognoses and recommendations also raises the question of the responsibility of doctors to patients.

Biotechnologies such as CRISPR-Cas9 make it possible to edit genetic material, raising questions about the ethical permissibility of such transformations and their consequences for future generations. A serious ethical dilemma arises from the issue of cloning organisms (including humans) for medical, scientific and other purposes. Thus, within the framework of “purple” biotechnology, issues of balancing the potential benefits and possible negative consequences of interference in biological processes are resolved. Also acute is the problem of “black” biotechnology, in which the latest scientific achievements and innovations are used to conduct biological warfare and terrorism. Also acute is the problem of “black” biotechnology, in which the latest scientific achievements and innovations are used to conduct biological warfare and terrorism.

Currently, biotechnology has become an important industry with macroeconomic significance. Developed countries are creating international and national programs aimed at developing biotechnologies in various sectors of the economy. The global biotechnology market is growing by 7% annually; the priority areas for sales of biotechnological drugs are agriculture, food industry, pharmaceuticals, enzymes for the production of detergents, seed material of genetically modified plants and medicinal cosmetics.

According to forecasts, the annual growth of the biotechnology market in the coming years will be over 9%, the main growth factors will be an increase in the production of biopharmaceuticals. Market growth is driven by increased investment in the development and production of new products created using biotechnology. The annual turnover of the global bioindustry is currently more than 160 billion US dollars. The largest biotechnology market is the United States, where almost half of the world's biotechnology products are created. There are 1,500 companies involved in the biotechnology sector in the country, with a total capitalization of about $360 billion. For example, Elon Musk’s American neurotechnology company Neuralink is working on creating brain implants to directly connect the human mind with computers. Impossible Foods develops vegetarian and vegan meat alternatives using biotechnology. Zymergen uses biological engineering to create new materials and products, including bioplastics and electronics. Up to 26 billion US dollars are allocated for scientific development every year. Funding is provided by both government and private investors; the largest investor in this area is the National Institutes of Health (NIH), whose annual budget is about $30 billion [3].

3 Results and Discussion

In European countries today there are more than 1,700 enterprises that use biotechnology in their activities. The total income of these companies is already more than 40 billion US dollars [3]. The main centers for biotechnology development are located in the UK, France, Germany, Belgium, Switzerland and the Netherlands. Thus, the Swiss corporation CRISPR Therapeutics is developing drugs for the treatment of genetic diseases. Oxford Nanopore Technologies specializes in nanopore sequencing technology, which allows direct analysis of long DNA or RNA fragments in real time. The Swedish company Flow Neuroscience is developing a headset for transcranial brain stimulation to help treat severe depression.

Most European companies are focused on developments in the field of cell and gene therapy, the creation of new drugs and treatment methods, including the creation of therapy for cancer and diseases of the central nervous system. European universities and research

institutes provide a strong basis for sourcing and developing scientific and clinical innovations. In terms of the number of publications in the field of biotechnology, European research centers are on par with the United States and three times ahead of China.

In China, the biotechnology industry consists of 900 enterprises and more than 40 technology parks located in Beijing, Shanghai and other cities [3]. Sales of products made using biotechnology amount to more than 10 billion USD. The intensive development of biotechnology is due to the support of the state, which finances investments under the National Basic Research Program and the National High Technology Research and Development Program, as well as providing preferences to all scientific and technological start-ups in China. Particular attention in China is paid to "red" biotechnologies: the production of pharmaceuticals and the development of therapeutic methods using bacteria and microorganisms. There are about 600 companies operating in the country, manufactured products occupy more than 7% of the global market for biological drugs. There is also active support for the segment of "gray" biotechnologies related to ensuring environmental safety.

Brazil is a leader in the application of biotechnology throughout Latin America. There are more than 300 companies operating in the country; the total biotechnology market is worth 15 billion USD [3]. Most Brazilian companies operate in the fields of agriculture and pharmaceuticals. To promote biotechnology, two business clusters have been created, in Sao Paulo and Minas Gerais, in which scientific research and the launch of new projects are carried out. The most successful research has been in the development of new vaccines, skin stem cells and genetic modification. Investments in the production of renewable energy sources have allowed Brazil to become the second largest producer of bioethanol in the world.

India is one of the top three countries for biotechnology development in the Pacific region, behind only Australia and China. There are currently more than 850 companies involved in the biotechnology industry in the country, with the Indian government investing $5 billion in human capital development, infrastructure and research initiatives. The biotechnology sector in India is expected to have a turnover of over USD 100 billion by 2025 [3].

India is dominated by biotechnology in pharmaceuticals and research outsourcing services. Research centers in India are conducting large-scale research on new medications created by leading international pharmaceutical corporations, including AstraZeneca, Pfizer and Merck. Investment in the biotechnology sector is carried out by the Department of Biotechnology, created under the Ministry of Science and Technology back in 1986. The Department is implementing the National Biotechnology Development Strategy, which provides for a high level of investment in research and production and support for the development of the industry at the legislative level.

In the Russian Federation, the biotechnology market is estimated at 270 billion rubles, and over the past eight years it has grown by 30%. Factors driving the growth of the industry were measures such as stimulating innovation using public-private partnership tools, creating business clusters with preferential conditions for launching business projects, financing research activities and supporting innovative companies. More than 60% of the Russian biotechnology market is occupied by the pharmaceutical sector, about 20% in agriculture and 15% in industry and food production.

Biotechnologies, along with nanotechnologies, are a priority direction for the development of the domestic economy. Federal programs are aimed at the development of biotechnologies, providing for the allocation of subsidies for the implementation of innovative business projects, financing of scientific developments and start-ups, reimbursement of part of the costs of investment loans, and information support.

4 Conclusion

The Comprehensive Program for the Development of Biotechnology in the Russian Federation, adopted in 2012, provided for the creation of a global competitive bioeconomy sector based on the development of advanced technologies in medicine, industry, agriculture, and bioenergy. The program provided for an 8-fold increase in the consumption of products using biotechnology, a 25-fold increase in the export of bioproducts, a reduction in imports of biotechnological products by 50%, ensuring the share of bioproducts at the level of 1% of GDP by 2020 and at least 3% of GDP by 2030.

A number of large projects in the field of biotechnology are currently being implemented in Russia. The production company “Bionovatic” became the first in Russia to launch the production of effective biological plant protection and nutrition products based on biotechnology. The project received an investment of 1 billion rubles, which was intended for scientific development, testing of samples, state registration of new products, creation of a research laboratory and production workshops. As a result of the project, the production of biological pesticides and plant nutrition products has been established, and productivity has been achieved, assessed by experts as one of the largest in the world in this field.

The Phytovita project is the development of a universal feed additive with a preset composition based on cell cultures. The additive is produced by growing cells; it can be used not only in agriculture when raising birds and animals, but also in the food industry, in the production of dietary supplements and natural cosmetics.

A unique technology for three-dimensional bioprinting from stem cells was created by the Russian company 3D Bioprinting Solutions. The company's scientific department created the first domestic FABION bioprinter, which uses bioink from stem cells and creates a magnetic trap in which the spheroids themselves assemble into muscle tissue. The company signed a contract with the United Rocket and Space Corporation and conducted a successful experiment on bioprinting muscle tissue on board the ISS. In conditions of weightlessness, the process of muscle tissue growth occurs much faster, which opens up new opportunities for the creation of artificial human organs. This project laid the foundation for the search for renewable sources of protein for long-term space missions and became a revolutionary technology for creating artificial organs using 3D printing using bioprinters.

Despite the lag behind leading countries in the application of biotechnology, the Russian Federation has a number of prerequisites for the development of this industry. First of all, we are talking about the creation of new medicines, the production of biofuels, the processing of renewable biomass and the production of food products. The development of biotechnology in Russia is facilitated by the presence of scientific and technical potential, large reserves of water and energy resources, and accessible sugar-containing raw materials in the form of sugar beets, corn and wheat.

Currently, there is a high demand for biotechnology in such sectors of the Russian economy as the chemical industry, agriculture, mining, pharmaceuticals, and food industry. Biotechnology can also help solve global issues such as food safety and environmental protection (cleaning up contaminated soils, producing biofuels). A necessary condition for the development of biotechnologies in Russia is support from the state in the form of financing, adoption of long-term programs, provision of tax benefits to business and improvement of the legal framework. One of the priority tasks for the coming years is the creation of a modern bioindustry that will meet the country’s needs for products created using biotechnology.

References

1. D. A. Kudlay, Biotechnology: the future has already arrived. In the world of science, **5-6**, 80-87 (2022)
2. D. A. Novik, A. S. Saratovsky, Historical development of the concept of biotechnology, legal regulation of biotechnology. Science Week 2022, 279 (2022)
3. N. V. Zagoskina, L. V. Nazarenko, *Biotechnology: textbook and workshop for universities*, 384 (2023)
4. V. A. Kolodyaznaya, M. A. Samotrueva, *Biotechnology: textbook*, 382 (2020)
5. Scientific and technical non-profit partnership “Technological platform BioTech2030”, (2023), http://biotech2030.ru/
6. I. S. Belik, A. S. Dutsinin, N. L. Nikulina, The Manager, **13(6)**, 44-55 (2022)