General industrial and innovative approaches in bioeconomics

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Abstract. Biotechnology is defined as any technological application that uses biological systems, living organisms or their derivatives to produce or modify products or processes for a specific use. The large-scale use of biotechnologies in industry, agriculture, as well as in many other types of economic activity is considered in many countries of the West (USA, Germany, France, Great Britain, Italy, etc.) and the East (China, India, Indonesia, Japan, etc.) as the most important condition for innovative and sustainable development. The progress achieved made it possible to consider the created biotechnologies as the basis of a new field of activity - bioeconomy.

1 Introduction

In the second decade of the 21st century, technological advances in industrial biotechnology (as well as in synthetic biology and metabolic engineering) have accelerated the development of new biotechnological processes. These achievements can be grouped into several main areas. First, the emergence of new tools in synthetic biology, which made it possible to accelerate the creation of the required strains of microorganisms. Secondly, the development of conditions for the rapid production of synthetic genes and even entire genomes. Thirdly, the possibility of analyzing "big data" (eg, obtained by "omics") and their integration in order to obtain a detailed phenotypic characterization of the engineered strains. Fourth, improved prediction of various strain design strategies has enabled improved quantitative description of metabolism using advanced metabolic models. Finally, the introduction of robotics, artificial intelligence to ensure multiplexing and high-performance design of the required strains was ensured, and computational biology was developed. One of the important achievements of synthetic biology has been the development of platforms using the "plug-and-play" principle, which are used to form specific regulatory circuits using various biological components[1]. As a result, a number of new methods for constructing cell factories were created, as well as tools that made it possible to automate the experimental stages of the design-create-learn-test cycle. One of the successful examples of the implementation of this principle is the work of Cummings M., which describes a platform that allows combinatorial biosynthesis of aromatic polyketides in the plug-and-play mode. Interest in obtaining polyketides is largely due to

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the fact that some of them are already widely used in the clinic, in particular, such well-known antimicrobial and anticancer compounds as erythromycin and doxorubicin. To increase the efficiency of their production and to search for new bioactive molecules belonging to the class of polyketides, which are synthesized by both eukaryotes and prokaryotes, a promising strategy was proposed, focused on the transfer of polyketide biosynthetic pathways from their native producers to a biotechnologically desirable host, E. coli bacteria. For these bacteria, using a set of synthetic biology tools, it was possible to form a biosynthetic platform that works in the "plug-and-play" mode. According to the developers, such a platform can serve as an engine for the production of new and diverse bioactive polyketides in an automated, fast and versatile way [2]. In addition, thanks to the emergence and development of new biotechnologies, it has become possible to purposefully edit the genomes of various microorganisms, in particular, based on the technology called CRISPR/Cas9 [3]. Although such technologies cannot always be automated and scaled, they are characterized as very promising.

2 Research Methodology

A large number of difficulties in the process of turning the proposed ideas into practical applications are often found at different levels, both in research institutions and in industrial organizations. The reason for this is the fact that there are many problems with the turn of the proposals made into practical applications on different levels of product development (and its life cycle).

Fig. 1. 7 Stages in the New Product Development Process

As Technology Readiness Levels, TRLs 1-3 are typically assigned to the university and TRLs 8 and 9 to industry. At the TRL of 4–7, it is generally considered that the process of discovering is too important for scientific research, but too risky to finance industrial production. Another reason for the "Valley of Death" is that new technologies often fail to overcome the "Valley of Death". It is worth noting that they include excessive bureaucracy, an overabundance of qualified management, insufficient resources for development and unnecessary support. The problem is to create strong targeted links between technology development efforts and industrial applicability. And in particular, among the main constraints for biotechnological development is an understanding of the ratio of marginal and marginal costs in the short term. For biotechnological development products it is possible to identify long development periods, as well as large costs on scientific research and specific staffing requirements, an initial stage in consumer infrastructure for some kinds of biotechnological products that are not included into its list, such as: a long development period with significant costs for special research or specialized staffing requirements, an initial stage in the development of consumer infrastructure for certain categories of biotechnological products, etc., and most importantly, an understanding of the difference between marginal benefits and costs in the short and long term, one can find out how much money will be allocated for this type of work, at the first stage in the development of consumer infrastructure. According to collected materials, it is knowledge that becomes the key condition for the development of bioeconomy. Additionally, special attention is drawn to the training of informed participants in this activity who are capable of creating new knowledge for social need. The shift in the focus of determining the priorities of economic development has occurred: from measuring innovation activity to the dynamics of human capital development. On the basis of these circumstances, there are some general ideas that can be confirmed by many documents and materials on public policy: ensuring an effective process of obtaining new knowledge (at all education levels); to support and actively interact with participants in the process of creating new knowledge; for example, work with "big data" and additive production; - ensuring cybersecurity; I will present in the next chapters of this book materials that illustrate the approaches used to implement such concepts.

3 Results and Discussions

Cultivated plants are traditionally regarded as the main source of starch, a product consisting of two types of polysaccharides: linear amylose and branched amylopectin. It is well known that glucose is the monomer for both of these polymers, but in amylose the monomers are linked by α1-4 glycosidic bonds, while in amylopectin, along with α1-4 glycosidic bonds, α1-6 glycosidic bonds are present at the branching sites. These bonds are hydrolyzed by human digestive enzymes, which leads to the formation of glucose and allows this sugar to be used in metabolic processes. Relevant materials are presented in detail in many biochemistry textbooks [5]. As a result, the biochemical properties of starch allow it to be widely used both in the food and non-food industries, including for the production of bioethanol. The production of bioethanol (see fig.2), obtained from sugar cane and starch-containing vegetable raw materials (in particular, from corn grain, corn straw and grains of other plants, is largely based on biotechnologies using enzymes, primarily capable of hydrolyzing α-glycosidic bonds, and then metabolizing glucose to ethanol The country that became a pioneer in this activity should be recognized as Brazil, in which the state program for the production of bioethanol (“Proalcool”) was created back in 1970, which continues in new forms to the present day. that raw materials from sugar cane cannot provide stable production of bioethanol throughout the year, since during the rainy season the plantation fields are inaccessible to harvesting equipment.Moreover, sugar cane cannot be stored during the off-season, because it must be processed within several hours after harvest. As a result, due to seasonality, there is a downtime of bioethanol-producing plants up to five months [6].

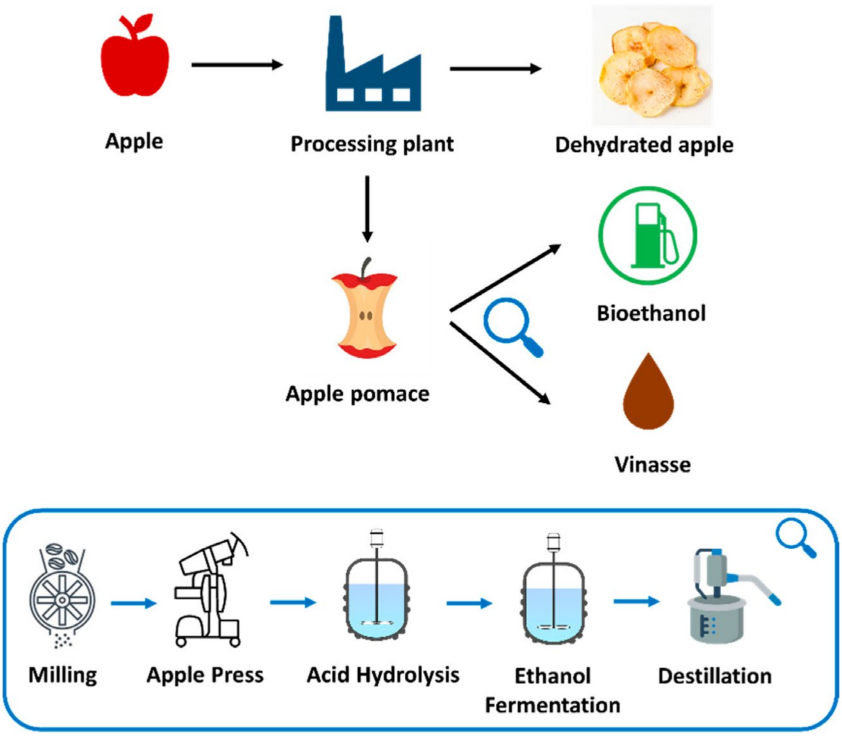

Fig. 2. Apple pomace ethanol and vinasse production overview.

This difficulty was overcome by the parallel use of raw corn as a substitute for sugar cane in special "flexible" plants capable of processing both types of raw materials. It has been shown that due to high yields (in some Brazilian states, corn accounts for up to 90.4% of total grain production) and the ability to save raw corn during the off-season, this crop product has become a significant contributor to Brazil's PBT. Since both sugarcane and corn can be used in the food industry, these raw materials and related technologies (in particular with amylases for the hydrolysis of corn starch) are characterized as the first generation of bioethanol production. At present, with the advent of industrial biotechnologies capable of hydrolyzing lignocellulosic materials, the production of second-generation bioethanol is actively developing. At the end of the second decade of the 21st century, Brazil was characterized as the second largest producer of bioethanol in the world (after the USA). According to the data provided, in 2020, 32.6 million m3 of ethanol was produced in Brazil, of which 69.3% is in the hydrated form, and the rest is in the anhydrous form [7]. The bioethanol produced was mainly used in the transport sector either as a pure fuel (hydrated ethanol) or blended with gasoline at 27% by volume (in anhydrous form). In Brazil, there is also the production of biodiesel, in which lipases have received industrial use, capable of converting triacylglycerols into free fatty acids from certain vegetable oils or animal fats. The produced biodiesel is used to partially replace conventional diesel fuel, although the volume of this production is significantly less than the production of bioethanol. Thus, it is clear that the development of the bioeconomy in Brazil has been going on for several decades, and it is largely associated with the production of biofuels [8]. It is known that in the second and early third decades of the 21st century, various approaches were taken to optimize the production of bioethanol from starch-containing vegetable raw materials. It was believed that the main obstacles in obtaining a competitive bioethanol fuel are the high cost of raw materials and enzymes, in particular, used for pretreatment before fermentation. At the same time, it was proposed to expand the range of enzymes that cleave α1-4 and α1-6 glycosidic bonds in starch and use enzymes with other activities. Significant efforts have been made (and continue to be made) to create efficient technologies for the production of bioethanol using industrial strains of Saccharomyces cerevisiae and to breed new more productive strains by metabolic engineering. In addition, research is being carried out on plant breeding aimed at improving the quality of corn starch, and the creation of bioengineering technologies for the regulation of starch biosynthesis in order to increase its content in plant raw materials used in industry. A qualitative change in the industrial production of bioethanol occurred after the development and implementation in practice the development of second-generation biotechnologies, which made it possible to use materials from cellulose- and lignin-containing plants as raw materials. In such biomasses (commonly referred to as lignocellulosic) cellulose, hemicellulose and lignin are present as the main structural components [9]. At the same time, the ratios of cellulose, hemicellulose, and lignin vary significantly. For the bioconversion of these compounds containing β-glycosidic and other bonds that are not hydrolyzed by enzymes commonly used in the processing of starch-containing vegetable raw materials, completely different enzymes with appropriate substrate specificity were required. In addition, lignocellulosic biomasses are characterized as being difficult to biodegrade raw materials, which are considered to be subjected to thermochemical treatment (including alkaline and acidic solutions) before and/or during enzymatic depolymerization. The approaches and technologies used for the conversion of lignocellulosic biomasses also include the use of pyrolysis, a process during which thermochemical decomposition of these materials occurs rapidly at elevated temperatures and in the absence of oxygen. Well-studied cellulose is a large linear biopolymer of 500–14,000 glucose units linked by β14 glycosidic bonds. To convert it into biofuel, the polymer must first be converted into monomers (glucose), which can then be converted into bioethanol [10]. As part of plant biomass, cellulose retains a complex multilevel architecture consisting of bundles of microfibrils, each of which can contain from 36 to 1200 cellulose molecules, and form highly ordered crystalline structures. It is believed that the main repeating unit of cellulose is the disaccharide cellobiose, due to which well-organized crystalline structures are formed, interspersed with disordered or disorganized domains (amorphous cellulose). According to some authors, it is in the amorphous regions that cellulose molecules are accessible to water molecules and enzymatic attack.

4 Conclusions

The contribution of the bioeconomy to the innovative development of a country depends on the level of research, development and production in the biotechnology sector. The results of research in the field of biotechnology aimed at creating biologically active compounds are successfully used to develop enzymes, vaccines, vitamins, hormones and antibiotics. In addition, research is actively developing on the creation and production of preparations for protecting plants from pests and increasing their phytoimmunity, as well as on breeding new varieties of plants and animal breeds, developing new types of food and animal feed, creating new strains of beneficial microorganisms and using biotechnologies to environmental protection. The introduction of biotechnologies makes it possible to reduce production costs in industry and agriculture, increase the availability of medicines and the quality of medical diagnostics and treatment, and improve the state of the environment. Numerous international and domestic scientific conferences, publications, reports and reviews prepared by leading consulting firms, stock analysts and structures of various government authorities and non-profit organizations are devoted to the study of trends in the field of biotechnology, their role in the global world and the issues of assessing the impact on national economies. Biotechnology is expected to become the fastest growing industry in the 21st century. According to leading experts, by 2030 biotechnology will provide 2.7% of GDP in developed countries. For developing countries, the contribution of biotechnology will be even greater. Based on the application of biotechnological developments, by 2030, 80% of medical products, 35% of chemical industry products and 50% of agricultural production will be produced. By 2050, the global bioenergy market will provide $150 billion, with 30% of the total global energy demand coming from renewable sources. Among the countries, the greatest progress in the development of biotechnologies was achieved by the USA, Germany, Great Britain, China, and Japan. Russia's presence in the global biotechnology market is currently estimated at only one tenth of a percent.

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