



BIOTECHNOLOGICAL METHODS FOR THE PRODUCTION OF VACCINES AND ANTIVIRAL PREPARATIONS

To'rayeva Munisa Furqat qizi

3rd-Year Student, Biotechnology Program

Namangan State Technical University

<https://doi.org/10.5281/zenodo.20731179>

ARTICLE INFO

Received: 02nd June 2026

Accepted: 08th June 2026

Online: 09th June 2026

KEYWORDS

Biotechnology, vaccines, antiviral preparations, recombinant DNA technology, mRNA vaccines, cell culture, monoclonal antibodies, interferons, genetic engineering, viral diseases.

ABSTRACT

This article discusses the role of biotechnology in the development and production of vaccines and antiviral preparations. The scientific principles and practical applications of modern biotechnological methods used in preventing and controlling viral diseases are analyzed. Particular attention is given to recombinant DNA technology, cell culture techniques, genetic engineering, and mRNA-based platforms employed in vaccine development. In addition, the production of antiviral agents through biotechnological approaches, including monoclonal antibodies, interferons, and antiviral proteins, is examined. The advantages, limitations, and future prospects of these technologies in strengthening global health security and improving responses to emerging infectious diseases are also highlighted.

Introduction

Viral infections continue to represent one of the greatest challenges to global public health. The rapid spread of emerging and re-emerging viral diseases, such as influenza, HIV/AIDS, hepatitis, Ebola, and the recent COVID-19 pandemic, has emphasized the urgent need for effective preventive and therapeutic strategies. Vaccines and antiviral drugs remain the primary tools for reducing morbidity and mortality associated with viral infections.

Traditional methods of vaccine production have played a significant role in disease prevention; however, advances in biotechnology have revolutionized this field by enabling the development of safer, more efficient, and

highly specific products. Modern biotechnological approaches have accelerated the discovery, design, and large-scale manufacturing of vaccines and antiviral agents, providing rapid responses to newly emerging pathogens. This article explores the major biotechnological methods employed in vaccine and antiviral drug production, their mechanisms of action, practical applications, and future prospects.

Main part

Biotechnological basis of vaccine production: Biotechnology has become one of the fundamental pillars of modern vaccine development and production. It involves the application of living organisms, biological systems, cellular components, and molecular techniques



to create products that contribute to the prevention and treatment of diseases. In the field of vaccinology, biotechnology provides innovative tools for identifying protective antigens, understanding host immune responses, and designing safer and more effective vaccines. The development of vaccines through biotechnological approaches begins with the identification of specific antigenic targets capable of stimulating protective immunity. Advances in molecular biology and genomics have enabled researchers to analyze the genetic composition of pathogens and determine which proteins or genetic sequences are most suitable for vaccine design. This targeted strategy has significantly improved the precision and effectiveness of vaccine development.

Furthermore, biotechnology allows vaccine production to be carried out under highly controlled laboratory and industrial conditions. Through the use of recombinant microorganisms, cultured cells, and sophisticated purification systems, vaccine manufacturers can ensure product consistency, quality, and safety on a large scale. These technologies also facilitate rapid adaptation of vaccine formulations in response to newly emerging infectious agents. Unlike conventional vaccines, which are commonly produced by attenuating or inactivating whole pathogens, modern biotechnological vaccines utilize advanced molecular techniques such as recombinant DNA technology, genetic engineering, viral vectors, and nucleic acid platforms. These approaches reduce the risk associated with handling pathogenic organisms and minimize undesirable

side effects while maintaining strong immunogenicity.

Recombinant DNA technology in vaccine development: Recombinant DNA technology represents one of the most significant breakthroughs in modern vaccine development. This technology enables scientists to manipulate genetic material in order to produce specific antigens capable of inducing protective immune responses without exposing individuals to the complete pathogenic organism. As a result, recombinant vaccines have become safer, more efficient, and easier to manufacture than many traditional vaccines.

The fundamental principle of recombinant DNA technology involves isolating genes that encode immunologically important antigens from pathogens and introducing them into suitable host organisms. These host systems subsequently produce the desired antigen in large quantities, allowing it to be purified and formulated into vaccines. Through this approach, the risks associated with cultivating large amounts of infectious agents are substantially reduced.

The production process generally includes several important stages:

- identification and isolation of antigen-coding genes from the pathogen;
- insertion of the target genes into appropriate expression vectors;
- transfer of recombinant vectors into host cells such as bacteria, yeast, or mammalian cells;
- expression of recombinant proteins under controlled conditions;
- purification and quality assessment of the produced antigens;



– formulation of the purified proteins into vaccines suitable for human administration.

One of the most notable examples of this technology is the recombinant hepatitis B vaccine. In its production, the gene encoding the hepatitis B surface antigen (HBsAg) is inserted into genetically engineered yeast cells. These modified yeast cells synthesize large quantities of the antigen, which is subsequently purified and used to formulate the vaccine. Since the vaccine contains only a specific viral protein rather than the whole virus, it cannot cause infection while still effectively stimulating the immune system to produce protective antibodies.

Recombinant DNA technology has also contributed to the development of vaccines against other infectious diseases, including human papillomavirus (HPV). The success of these vaccines has demonstrated the reliability and versatility of recombinant approaches in preventive medicine. Compared with conventional vaccines produced through attenuation or inactivation of pathogens, recombinant vaccines offer numerous advantages. They exhibit high levels of purity and batch-to-batch consistency, reduce the likelihood of contamination with infectious materials, and provide an improved safety profile. In addition, recombinant systems can be rapidly adapted to address emerging pathogens, making them valuable tools in responding to global health threats.

Cell culture technology: Cell culture technology is one of the most important biotechnological approaches used in the production of vaccines and antiviral

preparations. It involves the cultivation of animal or human cells under controlled and sterile laboratory conditions to support viral replication, antigen production, and the synthesis of various biological products. This technology has largely replaced the use of embryonated eggs and other traditional methods in many areas of vaccine manufacturing due to its efficiency, flexibility, and ability to meet industrial demands.

In vaccine development, cell cultures provide an appropriate environment for the growth of viruses required for antigen production. The cells are maintained under optimal conditions of temperature, pH, nutrient supply, and sterility, allowing researchers to obtain high yields of viral particles or recombinant proteins. The use of well-characterized cell lines also contributes to the consistency and reproducibility of vaccine production.

Several cell lines are commonly employed in biopharmaceutical manufacturing, including:

- Vero cells – derived from the kidney epithelial cells of the African green monkey and widely used in the production of viral vaccines, including those against poliovirus and rabies;
- CHO (Chinese hamster ovary) cells – extensively utilized for the production of recombinant proteins, monoclonal antibodies, and therapeutic biological agents because of their ability to perform complex post-translational modifications;
- MDCK (Madin–Darby Canine Kidney) cells – frequently used for influenza virus propagation and influenza vaccine production;



– HEK293 (Human Embryonic Kidney 293) cells – human-derived cell lines commonly employed in gene expression studies, viral vector production, and the development of advanced vaccines.

Cell culture systems provide numerous advantages over conventional production methods. They significantly reduce the risk of contamination associated with animal-derived materials and enable strict control of manufacturing conditions. Furthermore, these systems allow for standardized production processes, ensuring consistent product quality and safety.

Another important advantage of cell culture technology is its scalability. Production can be expanded from small laboratory experiments to large industrial bioreactors capable of manufacturing millions of vaccine doses. This characteristic became particularly important during global health emergencies, where rapid and large-scale vaccine production was essential to meet worldwide demand.

Despite these benefits, cell culture technology also presents certain challenges, including the high costs of infrastructure and maintenance, the requirement for specialized expertise, and strict regulatory standards to ensure product safety and efficacy. Nevertheless, continuous improvements in cell engineering, bioreactor design, and culture media optimization are helping to overcome these limitations.

Future perspectives of biotechnological approaches: The future of vaccine and antiviral development is closely linked to the continuous advancement of biotechnology. Recent progress in genomics, proteomics,

bioinformatics, synthetic biology, and artificial intelligence has opened new opportunities for designing more effective, safer, and rapidly deployable medical interventions. These technological innovations are expected to transform the way infectious diseases are prevented and treated, enabling faster responses to emerging health threats.

One of the most promising directions is the development of personalized vaccines based on individual genetic and immunological profiles. By analyzing a person's immune system and genetic characteristics, scientists can design vaccines that provide more targeted and efficient protection. This approach has the potential to maximize vaccine effectiveness while minimizing adverse reactions.

Another important area of research is the creation of universal vaccines capable of protecting against multiple strains or variants of a virus. Traditional vaccines often require periodic updates due to the rapid mutation of pathogens. Universal vaccines aim to target highly conserved regions of viral genomes, providing broader and longer-lasting immunity. Such vaccines could significantly reduce the global burden of diseases such as influenza and coronavirus infections.

The application of CRISPR-based technologies also represents a groundbreaking advancement in antiviral therapy. CRISPR systems can be engineered to identify and destroy viral genetic material within infected cells, offering a highly specific method for combating viral infections. Researchers are actively investigating the potential of



this technology for the treatment of diseases caused by HIV, hepatitis viruses, and other pathogens.

In addition, nanoparticle delivery systems are gaining increasing attention in modern biotechnology. Nanoparticles can protect vaccine components from degradation, enhance their stability, and improve targeted delivery to specific cells or tissues. This technology may increase vaccine efficacy while reducing the required dosage and frequency of administration.

Artificial intelligence (AI) is also playing a growing role in vaccine and antiviral development. AI-powered algorithms can analyze vast amounts of biological data, predict antigen structures, identify potential drug targets, and optimize vaccine formulations. By accelerating research and development processes, AI can significantly reduce the time required to create new vaccines and therapeutic agents.

Furthermore, advances in synthetic biology and genetic engineering are expected to facilitate the development of next-generation vaccine platforms capable of rapid adaptation to newly emerging pathogens. These innovations will improve global preparedness and strengthen public health systems against future outbreaks and pandemics.

Conclusion: Biotechnology has fundamentally transformed the production of vaccines and antiviral preparations. Modern approaches such as recombinant DNA technology, cell culture systems, mRNA platforms, and monoclonal antibody production have improved the safety, efficacy, and accessibility of preventive and therapeutic agents. Continued investment in biotechnological research and innovation will play a critical role in strengthening global health systems and combating future viral threats.

References:

1. Plotkin S. A., Orenstein W. A., Offit P. A., Edwards K. M. *Plotkin's Vaccines*. 8th ed. Philadelphia: Elsevier, 2024. – 1824 p.
2. Rappuoli R., Aderem A. A 2020 vision for vaccines against HIV, tuberculosis and malaria // *Nature*. 2011. Vol. 473. – P. 463–469.
3. Krammer F. SARS-CoV-2 vaccines in development // *Nature*. 2020. Vol. 586. – P. 516–527.
4. Abbas A. K., Lichtman A. H., Pillai S. *Cellular and Molecular Immunology*. 10th ed. Philadelphia: Elsevier, 2021. – 560 p.
5. Murphy K., Weaver C. *Janeway's Immunobiology*. 10th ed. New York: Garland Science, 2022. – 928 p.
6. Walsh G. *Biopharmaceuticals: Biochemistry and Biotechnology*. 3rd ed. Chichester: Wiley, 2018. – 536 p.
7. World Health Organization. *Global Vaccine Action Plan and Immunization Agenda 2030*. Geneva: WHO, 2021.