MODERN BIOLOGICAL HAZARDS IN FOOD SAFETY SYSTEMS: A LITERATURE REVIEW

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Abstract. *This article presents a review of scientific literature on modern biological hazards in the food safety system, their sources, and their impact on human health. Bacteria, viruses, parasites, mycotoxins, and antibiotic-resistant microorganisms are considered the main biological threats to food safety. Based on scientific sources, it is substantiated that globalization, intensive agriculture, increasing complexity of logistics systems, and climate change significantly contribute to the spread of biological hazards. The importance of modern monitoring technologies, biosensors, and molecular diagnostic methods is highlighted.*

Keywords: *food safety, biological hazard, pathogenic microorganisms, mycotoxins, zoonoses, antibiotic resistance, monitoring.*

INTRODUCTION

At present, food safety is recognized as one of the most important priority areas of the global healthcare system. Due to population growth, the acceleration of urbanization processes, the expansion of international trade relations, and the intensification of food production technologies, ensuring the quality and safety of food products has become an urgent issue not only at the national but also at the international level. In modern conditions, the concept of food safety is defined not only by the sufficiency or availability of food products, but also by their biological, chemical, and physical safety, as well as their compliance with sanitary requirements and hygienic standards.

Among the factors threatening food safety, biological hazards occupy a special place. Biological hazards refer to pathogenic microorganisms, viruses, parasites, fungi, and their metabolites that may be present in food products. When these agents enter the human body, they may cause infectious diseases of varying severity, toxic poisoning, and chronic pathological conditions. According to statistical data, foodborne diseases occupy one of the leading positions in the global structure of morbidity and cause harm to the health of millions of people every year. This situation indicates the necessity of conducting in-depth scientific studies of biological hazards and improving mechanisms for their control.

Modern scientific studies indicate that the occurrence of biological hazards in the food system is a multifactorial process that may arise at any stage of food production, processing, storage, and transportation. Table 1 presents the main biological hazards found in food products and their characteristics. The widespread use of antibiotics and pesticides in agriculture, the application of intensive technologies in livestock production, contamination of water resources, and non-compliance with sanitary regulations increase the risk of pathogenic microorganisms entering the food chain. At the same time, the development of the global logistics system enables food products to travel long geographical distances in a short period of time, thereby creating conditions for the transboundary spread of biological hazards.

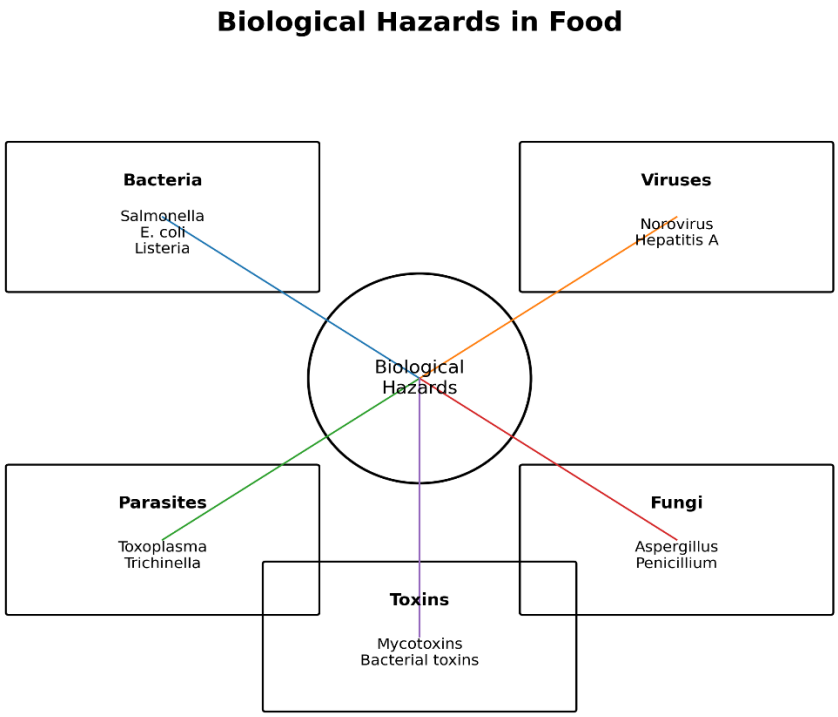


Figure 1. Classification of biological hazards in food products.

- bacteria — 60%
- viruses — 25%
- parasites — 10%
- toxins — 5%

Table 1. Main biological hazards found in food products

No	Type of Biological Hazard	Source	Diseases	Food Type	Risk Level
1	*Salmonella* spp.	Poultry meat	Salmonellosis	Meat, eggs	High
2	*E. coli* O157:H7	Beef	Enterocolitis	Meat	High
3	*Listeria monocytogenes*	Dairy products	Listeriosis	Milk, cheese	High
4	Norovirus	Contaminated water	Gastroenteritis	Vegetables	Moderate
5	Mycotoxins	Mold contamination	Food poisoning	Grain	High
6	Parasites	Meat	Helminthiasis	Meat	Moderate
7	Antibiotic-resistant bacteria	Livestock production	Infections	Meat	High

Climate change is also one of the factors that significantly affects the biological component of food safety. Increases in temperature, changes in humidity levels, and extreme weather events directly influence the ecology of microorganisms, which may accelerate their growth rate or contribute to their spread into new regions. As a result, pathogens that were previously absent in certain areas are increasingly being detected in new geographical zones. This situation creates new challenges for epidemiological surveillance systems.

Another important aspect of biological hazards is their evolutionary adaptability. Microorganisms acquire new characteristics through genetic mutations and horizontal gene transfer, which contributes to the emergence of antibiotic-resistant strains. The increase in

antibiotic resistance is directly associated with food safety, and the use of prophylactic antibiotics in livestock production is considered one of the key factors accelerating this process. As a result, resistant bacteria entering the human body through food complicate treatment processes and exacerbate the outcomes of infectious diseases.

In recent years, the implementation of modern scientific technologies has gained significant importance in ensuring food safety. Molecular biology, genomics, biosensor technologies, rapid diagnostic systems, and monitoring platforms based on artificial intelligence enable the early detection of biological hazards, prediction of their spread, and prevention of potential risks. These technologies provide higher accuracy, speed, and sensitivity compared with traditional laboratory methods, thereby advancing the food control system to a qualitatively new level.

In this regard, conducting a systematic analysis of the current state of biological hazards in the food safety system based on scientific literature, identifying the mechanisms of their occurrence, and evaluating control strategies represent important scientific tasks. The significance of this study lies in the fact that it summarizes scientific approaches aimed at ensuring food safety and provides a theoretical basis for developing effective mechanisms for the management of biological hazards.

Materials and Methods. The article analyzes international scientific publications published between 2005 and 2024, including reports of the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the European Food Safety Authority (EFSA), as well as monographs related to food microbiology and hygiene. The literature was selected according to the following criteria: epidemiology of foodborne diseases; biology of pathogenic microorganisms; toxicology of mycotoxins; the problem of antibiotic resistance; and food monitoring technologies. The analysis was conducted using methods of systematic comparison, conceptual generalization, and scientific synthesis.

Literature Review.

Concept of Biological Hazards. In the food safety system, biological hazards refer to microorganisms, parasites, or their toxins that may be present in food products and have the potential to harm human health (WHO, 2022). These hazards may occur at all stages of the food chain, from production to consumption (FAO, 2021). In scientific literature, biological hazards are generally classified into several groups, including bacteria, viruses, parasites, and mycotoxins (Adams & Moss, 2018).

Bacterial Pathogens. The majority of foodborne diseases are associated with bacterial contamination, and the most significant pathogens include Salmonella, Escherichia coli, Listeria monocytogenes, and Campylobacter (CDC, 2022). These microorganisms can rapidly multiply in food products, and some of them are capable of growing even under refrigerated conditions (Jay, 2012). In particular, Listeria monocytogenes is considered especially dangerous for refrigerated food products due to its ability to grow at low temperatures (EFSA, 2023).

Viral Biological Hazards. Among foodborne viruses, noroviruses and the hepatitis A virus are considered the most epidemiologically significant (WHO, 2022). Although viruses do not multiply in food, they can persist for long periods and are capable of causing disease even at very low infectious doses (FAO, 2021). Viral contamination is mainly associated with poor compliance with hygiene and sanitation regulations (Adams & Moss, 2018).

Parasitic Hazards. Parasites cause less frequent but often more severe forms of foodborne diseases. For example, infections caused by Toxoplasma gondii and Trichinella spiralis are

transmitted through insufficiently heat-treated meat (WHO, 2022). The development of global trade systems has contributed to the spread of parasitic diseases into new geographical regions (FAO, 2021).

Mycotoxins. Mycotoxins produced by fungi are among the most dangerous biological factors affecting food safety (Pitt & Hocking, 2009). Aflatoxins are particularly known for their hepatotoxic and carcinogenic effects and are commonly found in grain products (WHO, 2022). One of the main characteristics of mycotoxins is their resistance to thermal processing, meaning that they are not completely destroyed during cooking (Jay, 2012).

Antibiotic-Resistant Microorganisms. Antibiotic resistance has become one of the major global challenges of modern food safety systems. The extensive use of antibiotics in livestock production contributes to the emergence of resistant bacterial strains that may enter the human body through food consumption (WHO, 2023). This situation complicates the treatment of infectious diseases and increases epidemiological risks (FAO, 2021).

Modern Diagnostic and Monitoring Methods. In recent decades, methods for detecting biological hazards in food safety systems have significantly improved. Traditional microbiological culture methods remain the primary diagnostic tools; however, due to the time required for their implementation, they are increasingly complemented by rapid molecular techniques in modern laboratory practice (Jay, 2012).

Table 2. Modern diagnostic methods used for detecting biological hazards in food products.

Method	*Target Detected*	*Advantage*
PCR	Bacterial DNA	Rapid detection
ELISA	Toxins	High accuracy
Cultivation	Bacteria	Standard method
Biosensor	Toxins	Modern technology

One of the most effective innovative technologies is the polymerase chain reaction (PCR), which enables the rapid detection of the genetic material of pathogenic microorganisms within a short period of time. The real-time PCR modification not only allows the detection of the presence of pathogens but also enables the quantification of pathogen load, which is an important indicator for epidemiological assessment (EFSA, 2023).

The development of genome sequencing technologies has significantly expanded the possibilities for identifying foodborne pathogens and determining their sources. Through the use of whole-genome sequencing (WGS), it has become possible to determine the degree of genetic similarity between bacterial strains, thereby enabling the identification of infection sources and the tracking of outbreaks (CDC, 2022). This method is particularly important for monitoring the transboundary spread of pathogens under conditions of global trade.

Immunological diagnostic methods, including enzyme-linked immunosorbent assay (ELISA), are widely used for the detection of toxins and antigens. The main advantage of this method is its rapidity and high sensitivity, making it particularly effective for identifying mycotoxins and viral contamination (Adams & Moss, 2018). Biosensor technologies represent one of the most promising directions in food safety monitoring. Biosensors consist of a combination of a biological element (enzyme, antibody, or DNA fragment) and a physical detector, which enables the real-time detection of pathogens. These devices allow monitoring to be carried out directly on production lines, thereby facilitating the early detection of contamination (FAO, 2021).

The implementation of artificial intelligence and digital monitoring systems is further improving food safety control. Through the use of databases and algorithm-based predictive models, it has become possible to identify potential pathways of pathogen spread and to develop preventive measures in advance (WHO, 2022). This approach shifts the food safety system from a reactive model toward a proactive monitoring strategy. Analysis of the literature indicates that biological hazards represent one of the most complex components of food safety. Unlike chemical or physical hazards, biological threats involve living systems that are capable of rapid reproduction, adaptation, and mutation. In particular, the global logistics system accelerates the geographical spread of pathogens. In addition, climate change expands the ecological niches of microorganisms, leading to the emergence of new epidemiological risks. This situation demonstrates that classical control methods alone are no longer sufficient for ensuring food safety.

CONCLUSION.

The results of the literature analysis indicate that biological hazards represent one of the most complex and dynamic components of the food safety system. Bacteria, viruses, parasites, and fungal toxins constitute the major biological threats to human health and account for a significant proportion of disease incidence worldwide (WHO, 2022). The widespread occurrence of these hazards is directly associated with the intensification of food production technologies, the expansion of international trade, ongoing urbanization processes, and climate change (FAO, 2021). An important characteristic of biological hazards is their evolutionary adaptability and genetic variability. Microorganisms can rapidly adapt to new environmental conditions and form antibiotic-resistant strains. The issue of antibiotic resistance is also highly relevant in the food system and is considered a serious threat to global public health (WHO, 2023).

The introduction of modern molecular diagnostic methods, biosensor technologies, and genome analysis techniques has significantly improved the accuracy of detecting biological hazards and has advanced monitoring systems to a new level (EFSA, 2023). These technologies enable the early detection of pathogens and help prevent epidemiological risks. Thus, ensuring food safety requires an integrated approach that combines production control, laboratory monitoring, epidemiological surveillance, and digital technologies within a systematic strategy. The development of scientifically based monitoring mechanisms and the strengthening of international cooperation remain essential conditions for the effective management of biological hazards.

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