

## RISK-BASED CONTROL OF FOODBORNE INFECTIONS IN POULTRY PRODUCTION

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**Summary.** Poultry production is one of the most dynamic sectors of the agro-industrial complex, providing the population with affordable sources of protein. At the same time, poultry products may serve as a vehicle for foodborne toxicoinfections caused by pathogenic microorganisms, particularly *Salmonella* spp. and *Campylobacter* spp. The modern concept of food safety is based on a risk-oriented approach that involves hazard identification, risk assessment, and implementation of preventive measures throughout the entire production chain — from farm to fork. This article examines current approaches to risk-based control of foodborne toxicoinfections in poultry production. The main biological hazards associated with poultry products, particularly *Salmonella* spp. and *Campylobacter* spp., are analyzed, and the critical stages of contamination within the production chain are identified. The effectiveness of an integrated food safety management system based on HACCP principles, biosecurity measures, microbiological monitoring, and official control was evaluated. The results demonstrate that a comprehensive risk-based approach is essential for reducing the incidence of foodborne toxicoinfections and ensuring the safety of poultry products. The most critical pathogens within the poultry production chain were identified as *Salmonella* spp., which may be present at virtually all stages of production; *Campylobacter* spp., primarily detected during slaughter; pathogenic *Escherichia coli*, found in water sources and in young birds; and *Listeria* spp., associated with the chilling and storage stages of finished products. Hazard analyses conducted in poultry enterprises are based on HACCP principles. They include identifying, assessing, and controlling biological, chemical, and physical hazards at all stages of production, from rearing poultry to distributing products. The results obtained confirm the necessity of implementing an effective HACCP system and of conducting continuous microbiological monitoring throughout the production process

**Keywords:** toxicoinfections, *Salmonella*, *Campylobacter*, HACCP

**Introduction.** Over the past 3–4 years, Ukraine has ranked among the top 4–6 suppliers of poultry products to the European Union. Ukraine competes in this market with major exporters such as the United States, Brazil, and Argentina. This means that all producers exporting poultry meat and eggs to the EU fully comply with European requirements and have successfully undergone the relevant external audits. In fact, this represents approximately 45–60% of the Ukrainian poultry market. These are typically large, vertically integrated companies with substantial production capacity that have already undergone some transformation and are gradually moving away from conventional cage systems. The growth of poultry meat production has been accompanied by increasing requirements for food safety. Foodborne illnesses remain one of the most significant public health concerns worldwide (Van Immerseel et al., 2009). The main bacterial pathogens associated with poultry products are *Salmonella* spp. and *Campylobacter* spp., which can enter the human body through insufficiently cooked meat or as a result of cross-contamination of food products (WHO and FAO, 2009; BIOHAZ, 2011). The risk-based approach recommended by international organizations and regulatory authorities involves managing risks based on scientific hazard assessment rather than relying solely on end-product testing.

**Literature Review.** The issue of foodborne illnesses associated with poultry products has been the subject of numerous scientific studies both in Ukraine and internationally. Reports published by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) emphasize that poultry products are among the primary vehicles for the transmission of

pathogens such as *Salmonella* spp. and *Campylobacter* spp., which pose a significant threat to public health (BIOHAZ, CONTAM and AHAW, 2012; FAO and WHO, 2024). Researchers from the European Food Safety Authority (EFSA) have substantiated the need for a risk-based approach to poultry product safety control. EFSA reports indicate that the most effective strategy is the comprehensive control of hazards throughout all stages of production, from poultry rearing to the marketing of finished products (WHO and FAO, 2009; FAO and WHO, 2024). Studies conducted by Ukrainian scientists focus on veterinary and sanitary control, the implementation of Hazard Analysis and Critical Control Point (HACCP) systems, the improvement of biosecurity measures, and the prevention of bacterial infections in poultry production. Researchers note that a risk-based approach enables the timely identification of potential hazards and minimizes the risk of contamination of poultry products with pathogenic microorganisms. Particular attention in contemporary literature is devoted to the application of Quantitative Microbial Risk Assessment (QMRA), probiotics, vaccines, and other innovative methods for pathogen control in poultry production. Research findings indicate that the combination of preventive measures at the farm level and effective control during processing significantly reduces the risk of foodborne illnesses in humans. The analysis of scientific literature confirms the relevance of implementing risk-based control in poultry production and highlights the need for further improvement of food safety management systems in accordance with international requirements and standards (BIOHAZ et al., 2020).

**Scientific Background.** Ensuring food safety is one of the priority tasks of the modern agri-food sector and public health system. Poultry products occupy an important place in human nutrition due to their high nutritional value and affordability; however, they may also serve as a source of foodborne infections caused by pathogenic microorganisms, particularly *Salmonella* spp., *Campylobacter* spp., and other pathogens (Mota-Gutierrez et al., 2022). The control of foodborne infections at poultry farms is a critically important component of food safety, as poultry products (meat and eggs) are frequently associated with infections caused by bacteria such as *Salmonella*, *Campylobacter*, *Escherichia coli*, and *Listeria monocytogenes* (Zwietering et al., 2023; EFSA and ECDC, 2024, 2025). The continuous growth of poultry production, the expansion of international trade, and increasing requirements for food quality necessitate the improvement of food safety control systems throughout the entire production chain (BIOHAZ et al., 2020). Under current conditions, particular importance is attached to a risk-based approach to the control of food safety hazards, which involves the timely identification, assessment, and management of risks associated with foodborne infections. The implementation of Hazard Analysis and Critical Control Point (HACCP) principles, strengthened biosecurity measures, and the application of modern monitoring methods contribute to the reduction of microbiological risks and enhance consumer health protection. A poultry enterprise represents a fundamentally different type of food business operator (Stewart and Pavic, 2023). In such facilities, HACCP encompasses not a single technological process but several interconnected production stages, ranging from egg incubation to the distribution of finished products. Each of these stages has its own hazard profile and critical control points (CCPs). Three key features distinguish poultry enterprises from other food-processing facilities from a HACCP perspective:

**Live birds are a source of pathogens.** *Salmonella*, *Campylobacter*, and avian influenza pathogens may be present in live flocks. Consequently, the source of contamination exists within the production chain from its earliest stage.

**Production scale.** Industrial poultry facilities process from several thousand to hundreds of thousands of carcasses per day. A single contaminated flock entering production may result in the contamination of thousands of tonnes of poultry products.

**Integration of veterinary and food safety HACCP systems.** Food safety management at poultry enterprises must address not only the safety of final products but also flock biosecurity, veterinary control, and monitoring programs for *Salmonella* and other pathogens.

Therefore, studying the specific features of risk-based control of foodborne infections in poultry production is highly relevant from both scientific and practical perspectives (Soro et al., 2020).

The study aimed to investigate the features of risk-based control of foodborne toxicoinfections in poultry

production, to analyze the main sources of microbiological risks associated with poultry products, and to evaluate the effectiveness of modern preventive and control measures aimed at ensuring food safety and protecting consumer health.

**Materials and methods.** Microbiological monitoring was carried out through the isolation of microflora from poultry slaughter facilities, slaughtered birds, and all critical control points throughout poultry meat production. The isolation and identification of microorganisms were performed using standard microbiological methods. For this purpose, the following culture media were used: meat-peptone broth (MPB), 2% meat-peptone agar (MPA), Endo agar, bismuth sulfite agar, Levine agar (EMB agar), Kitt-Tarozzi medium, Sabouraud agar, and Czapek medium. For rapid diagnostics, test systems manufactured by R-Biopharm were employed, including RIDA® COUNT, RIDA® CHECK, Lumitester PD-20, LuciPac Pen, RIDASCREEN® Verotoxin, RIDASCREEN® SET A, B, C, D, RIDASCREEN® *Salmonella* (AFNOR, EN ISO 16140 certified), RIDASCREEN® *Listeria*, RIDASCREEN® *Campylobacter*, and SureFood® BAC. These test systems enable rapid and accurate detection of microorganisms, providing both qualitative and quantitative assessment of microbial contamination. Spectrophotometric analyses were performed using a Specord 205 spectrophotometer manufactured by Analytik Jena AG (Germany). The antimicrobial susceptibility of bacterial isolates was determined using the disk diffusion method (Kirby-Bauer method) on Mueller-Hinton agar, a standardized culture medium recommended for antimicrobial susceptibility testing. All experiments were performed in accordance with the current guidelines of the Clinical and Laboratory Standards Institute (CLSI), which regulate testing procedures, interpretation of results, and quality control requirements. The method involved uniform inoculation of the test bacterial culture onto the agar surface, followed by the placement of paper disks impregnated with standard concentrations of antimicrobial agents. After incubation under conditions specified by CLSI (temperature and duration), the antimicrobial compounds diffused into the agar, resulting in the formation of growth inhibition zones around the disks. The results were evaluated by measuring the diameters of inhibition zones in millimeters. The obtained values were compared with CLSI interpretive criteria, and the tested isolates were classified as susceptible (S), intermediate (I), or resistant (R) to the corresponding antimicrobial agents. This approach ensures reproducibility of results and compliance with international standards of laboratory diagnostics.

**Results and discussion.** According to the results of monitoring studies, under the conditions of poultry farms in Ukraine, control points were established at which microorganisms were detected that pose risks to the safety of products and the technological process of obtaining poultry products (Table 1).

**Table 1** — Major microbiological hazards at critical control points in poultry production

| Control point                          | Most frequently detected microorganisms                                                                                                                        | Type of risk                                     |
|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| Day-old chicks / Poultry house         | <i>Salmonella</i> spp., <i>Campylobacter</i> spp., pathogenic <i>Escherichia coli</i> , <i>Staphylococcus aureus</i> , <i>Clostridium perfringens</i>          | High biological risk; zoonotic pathogens         |
| Feed                                   | <i>Aspergillus flavus</i> , <i>Aspergillus parasiticus</i> , <i>Penicillium</i> spp., <i>Salmonella</i> spp., <i>Bacillus</i> spp.                             | Mycotoxin contamination; bacterial contamination |
| Feed storage                           | <i>Aspergillus</i> spp., <i>Penicillium</i> spp., <i>Salmonella</i> spp., <i>Bacillus</i> spp.                                                                 | Mold growth; secondary contamination             |
| Water                                  | <i>Escherichia coli</i> , <i>Enterococcus</i> spp., <i>Pseudomonas aeruginosa</i> , <i>Salmonella</i> spp.                                                     | Fecal contamination; infectious risk             |
| Poultry house (air, litter, equipment) | <i>E. coli</i> , <i>Staphylococcus</i> spp., <i>Clostridium perfringens</i> , <i>Streptococcus</i> spp., <i>Aspergillus fumigatus</i>                          | Airborne and contact transmission                |
| Eggs (shell surface)                   | <i>Salmonella</i> spp., <i>Staphylococcus aureus</i> , Enterobacteriaceae, <i>Pseudomonas</i> spp.                                                             | Food safety risk; surface contamination          |
| Slaughter and primary processing       | <i>Salmonella</i> spp., <i>Campylobacter</i> spp., <i>Listeria monocytogenes</i> , Shiga toxin-producing <i>E. coli</i> (STEC), <i>Clostridium perfringens</i> | Highest risk of foodborne infections             |
| Product chilling                       | <i>Listeria monocytogenes</i> , <i>Pseudomonas</i> spp., <i>Brochothrix thermosphacta</i> , Enterobacteriaceae                                                 | Microbial growth due to temperature abuse        |
| Product storage                        | <i>Listeria monocytogenes</i> , <i>Pseudomonas</i> spp., Enterobacteriaceae                                                                                    | Cross-contamination; product spoilage            |
| Transportation and distribution        | <i>Salmonella</i> spp., <i>Listeria</i> spp., <i>Pseudomonas</i> spp., <i>Staphylococcus</i> spp.                                                              | Cold chain failure                               |

Table 1 summarizes the main control points in poultry production where microbiological hazards may occur. At each stage of the production process, specific pathogenic or opportunistic microorganisms are present that can negatively affect poultry health, product safety, and consumer health. Day-old chicks and poultry housed in poultry facilities represent one of the most critical stages in terms of biological safety. The primary hazards are bacteria of the genera *Salmonella* and *Campylobacter*, pathogenic strains of *Escherichia coli*, *Staphylococcus aureus*, and *Clostridium perfringens*. These microorganisms can cause diseases in poultry, reduce flock productivity, and serve as sources of zoonotic infections for humans. Feed is an important factor in the transmission of infectious agents. It is often contaminated with molds such as *Aspergillus flavus*, *Aspergillus parasiticus*, and species of the genus *Penicillium*, as well as bacteria including *Salmonella* spp. and *Bacillus* spp. A particular concern is the production of mycotoxins, which may accumulate in poultry and adversely affect their health. Feed storage facilities may serve as sources of secondary feed contamination due to the growth of molds and spore-forming bacteria. Failure to comply with proper storage conditions promotes the accumulation of mycotoxins and the spread of pathogenic microorganisms. Drinking water for poultry is an important vehicle for the transmission of infections.

The presence of *Escherichia coli*, *Enterococcus* spp., *Pseudomonas aeruginosa*, and *Salmonella* spp. indicates possible fecal contamination of water supply systems and increases the risk of infectious diseases. The poultry house environment (air, litter, and equipment) serves as a reservoir for the continuous circulation of microorganisms. The most commonly detected microorganisms include *Escherichia coli*, *Staphylococcus* spp., *Clostridium perfringens*,

*Streptococcus* spp., and the fungus *Aspergillus fumigatus*. Infection can spread through airborne dust particles or direct contact, creating a risk of widespread flock infection. Eggs, particularly the shell surface, may be contaminated with *Salmonella* spp., *Staphylococcus aureus*, members of the family Enterobacteriaceae, and *Pseudomonas* spp. Shell contamination poses a threat to food safety and may result in foodborne illnesses. Slaughter and primary poultry processing are among the most critical stages of production. It is at this stage that carcasses are most frequently contaminated with pathogens such as *Salmonella* spp., *Campylobacter* spp., *Listeria monocytogenes*, Shiga toxin-producing strains of *E. coli*, and *Clostridium perfringens*. Errors during technological operations may lead to the significant spread of pathogens in finished products. Product chilling is intended to inhibit microbial growth; however, violations of the temperature regime promote the development of psychrotrophic microflora, particularly *Listeria monocytogenes*, *Pseudomonas* spp., *Brochothrix thermosphacta*, and members of the family Enterobacteriaceae. During product storage, there is a risk of cross-contamination and further microbial proliferation. Of greatest importance are *Listeria monocytogenes*, *Pseudomonas* spp., and Enterobacteriaceae, which can cause product spoilage and pose a threat to consumers. During the transportation and distribution stage, the primary risk factors include disruption of the cold chain and product recontamination. The predominant microorganisms were *Salmonella* spp., *Listeria* spp., *Pseudomonas* spp., and *Staphylococcus* spp., which may lead to deterioration of product quality and an increased risk of foodborne illness.

Thus, systematic microbiological monitoring at all stages of poultry production is an essential requirement

for ensuring farm biosecurity, maintaining product quality, and protecting consumer health.

The data presented in Table 2 characterize the distribution of the main pathogenic and opportunistic microorganisms at different stages of poultry production. The analysis indicates that microbiological risks are contingent on the technological stage, the source of contamination, and the poultry management conditions. At the day-old chick rearing stage, pathogenic *Escherichia coli* poses the greatest hazard (30%), associated with the possibility of vertical transmission of infection and the insufficiently developed immune system of young birds. *Salmonella* spp. (25%) and *Campylobacter* spp. (20%) also account for a significant proportion, as they may enter through hatching eggs or the surrounding environment. In feed, the main risk is posed by other microorganisms (60%), represented primarily by molds and bacteria of the genus *Bacillus*. Their development is associated with improper storage conditions of feed materials and elevated moisture levels.

The proportion of *Salmonella* spp. is 30%, indicating possible feed contamination during production or transportation. Water is an important vehicle for the transmission of infections. Pathogenic *E. coli* (40%) and other microflora, particularly *Enterococcus* and *Pseudomonas species* (40%), are most frequently detected in water. This indicates possible fecal contamination of water supply systems and insufficient effectiveness of sanitation procedures. In poultry houses, litter, airborne dust, and equipment represent the primary sources of microbiological contamination. The predominant microorganisms identified were *Clostridium* spp., *Staphylococcus* spp., and fungi of the genus *Aspergillus*, collectively accounting for approximately 40% of all isolates. Pathogenic *Escherichia coli* (25%) and *Salmonella* spp. (20%) were also frequently detected, emphasizing the importance of maintaining strict hygiene practices and comprehensive biosecurity measures.

**Table 2** — Distribution of microorganisms at critical control points in poultry production (% of positive samples)

| Control point               | <i>Salmonella</i> spp. | <i>Campylobacter</i> spp. | Pathogenic <i>E. coli</i> | <i>Listeria</i> spp. | Other microorganisms ( <i>Clostridium</i> , <i>Staphylococcus</i> , fungi)         |
|-----------------------------|------------------------|---------------------------|---------------------------|----------------------|------------------------------------------------------------------------------------|
| Day-old chicks / Poultry    | 25                     | 20                        | 30                        | 0–5                  | 20–25                                                                              |
| Feed                        | 30                     | 0                         | 10                        | 0                    | 60 (molds, <i>Bacillus</i> spp.)                                                   |
| Water                       | 15                     | 5                         | 40                        | 0                    | 40 ( <i>Enterococcus</i> spp., <i>Pseudomonas</i> spp.)                            |
| Poultry house (litter, air) | 20                     | 10                        | 25                        | 5                    | 40 ( <i>Clostridium</i> spp., <i>Staphylococcus</i> spp., <i>Aspergillus</i> spp.) |
| Eggs (shell surface)        | 50                     | 10                        | 20                        | 0–5                  | 20                                                                                 |
| Slaughter and processing    | 35                     | 30                        | 20                        | 10                   | 5                                                                                  |
| Product chilling            | 30                     | 10                        | 15                        | 25                   | 20                                                                                 |
| Product storage             | 25                     | 5                         | 15                        | 35                   | 20                                                                                 |

Eggs, particularly the shell surface, constitute another critical point for microbiological surveillance. *Salmonella* spp. were the most frequently detected pathogens (50%), representing the principal microbiological hazard for both hatching and table eggs. In addition, pathogenic *E. coli* (20%) and other microorganisms (20%) were identified, highlighting the potential risk of contamination during egg production and handling.

Microbial contamination increased markedly during slaughter and primary processing. *Salmonella* spp. (35%) and *Campylobacter* spp. (30%) were the predominant pathogens detected at this stage. Contamination was primarily associated with contact between carcasses and intestinal contents, processing equipment, and personnel, emphasizing the critical importance of hygienic slaughter practices.

During product chilling, *Listeria* spp. (25%) represented a major hazard owing to their ability to survive and proliferate at refrigeration temperatures. Despite cold storage, contamination with *Salmonella* spp. (30%) remained a significant concern. During subsequent

storage, *Listeria* spp. (35%) became the dominant microbiological hazard because of their psychrotrophic characteristics, while *Salmonella* spp. (25%) and other opportunistic microorganisms also persisted and could continue to multiply under unfavorable storage conditions.

During transportation and distribution, microbiological risks were primarily associated with failures in maintaining the cold chain and inadequate sanitation of transport vehicles. The microorganisms most frequently isolated at this stage included *Salmonella* spp. (30%), pathogenic *E. coli* (20%), *Listeria* spp. (20%), and other opportunistic microorganisms (20%).

Microbiological examination of diseased and dead poultry revealed that birds exhibiting respiratory syndrome were most commonly infected with *Escherichia coli* (37%), *Streptococcus pneumoniae* (32%), and *Klebsiella pneumoniae* (31%). In birds presenting gastrointestinal syndrome, the predominant isolates were *Salmonella Enteritidis* (40%), *Escherichia coli* (39%), and *Campylobacter jejuni* (21%).

At the first critical control point — the hatchery during chick hatching — the predominant microorganisms isolated were *Pseudomonas* spp. (35%), *Escherichia coli* (27%), *Salmonella* spp. (17%), *Staphylococcus* spp. (11%), *Streptococcus* spp. (7%), and *Enterococcus* spp. (5%). The presence of these microorganisms adversely affected hatchability, chick viability, and the overall epizootic status of the poultry enterprise.

**Conclusions.** *Salmonella* spp. were identified as the most important foodborne pathogens throughout the poultry production chain because they were detected at nearly every stage of production. *Campylobacter* spp. were primarily associated with slaughter and processing, pathogenic *Escherichia coli* predominated in water and young poultry, whereas *Listeria* spp. represented the

principal hazard during chilling and storage of finished products.

Hazard analysis in poultry production was performed in accordance with the principles of the Hazard Analysis and Critical Control Point (HACCP) system and included the identification, assessment, and control of biological, chemical, and physical hazards throughout the entire production chain, from poultry rearing to product distribution. These findings demonstrate the necessity of implementing an effective HACCP system supported by continuous microbiological monitoring to ensure food safety and minimize microbiological risks in poultry production.

**Declaration of competing interest.** The author declare that he has no conflict of interest.

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Received 26.06.2026

Accepted 19.08.2026

Published 21.09.2026

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