ONE HEALTH SOLUTION FOR A SAFER PLATE: ADDRESSING CROSS-SPECIES PATHOGEN TRANSMISSION IN GLOBAL FOOD SYSTEMS

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REVIEW

Abstract
The spread of pathogens between species within global food systems presents a substantial challenge to food safety and public health, influenced by the interrelated aspects of human, animal, and environmental health. This review analyses the principal routes of pathogen transmission, including human-to-animal spillovers, animal-to-human infections, and environmental contamination. Additionally, the review emphasizes the significance of international collaboration, changes in legislation, and public education in ensuring a secure food supply. Implementing a One Health framework enables stakeholders to improve food safety, mitigate public health risks, and strengthen resilience against emerging threats in global food systems.

Keywords: foodborne pathogens, One Health, food safety, food security

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INTRODUCTION

The transmission of pathogens between species, commonly known as zoonotic transmission, poses a considerable challenge to global food safety and public health. This phenomenon takes place when pathogens transfer from animals to humans, occurring through multiple pathways such as direct contact, ingestion of contaminated food, or exposure to the environment. The consequences of this transmission are significant, potentially resulting in widespread outbreaks of foodborne illnesses that impact extensive populations. For example, pathogens like Salmonella and Campylobacter, commonly linked to animal products, account for millions of foodborne illnesses each year (Ejo et al., 2016; Abebe et al., 2020; Newell et al., 2010, Șonea, 2023a; Șonea, 2023b; Tudor, 2023; Gheorghe-Irimia, 2023). The intricate relationships among human, animal, and environmental health highlight the complexity of transmission dynamics, requiring a comprehensive approach to tackle the challenges presented by zoonotic diseases. The influence of pathogen transmission between species on food safety is complex and varied. It impacts not only the well-being of consumers but also introduces economic challenges for the food sector and public health frameworks. Foodborne pathogens can infiltrate the food supply chain at multiple stages, from production to consumption, and can be intensified by elements such as substandard hygiene practices, insufficient food processing, and environmental contamination (Shin et al., 2016; Carstens et al., 2022; Zhao et al., 2017). For instance, studies have found that contaminated raw meats, particularly poultry and beef, serve as major channels for Salmonella transmission, underscoring the necessity for rigorous food safety protocols across the food supply chain (Ejo et al., 2016; Bantawa et al., 2018; Heredia & García, 2018). Additionally, the rise of antibiotic-resistant strains of these pathogens introduces further complexity, complicating treatment options and heightening the severity of infections (Abebe et al., 2020; Nair et al., 2018). The interconnected nature of human, animal, and environmental health is presented in the One Health framework, which promotes a collaborative, multi-sectoral approach to address health challenges at the intersection of these domains. This framework acknowledges the interconnectedness of human, animal, and ecosystem health, highlighting that tackling health challenges in one domain can yield beneficial outcomes in others ("The European

Union One Health 2020 Zoonoses Report", 2021; Lahti et al., 2023). For example, zoonotic pathogens in livestock can have a direct effect on human health via foodborne diseases, and environmental factors like water quality and soil health can affect the prevalence of these pathogens in agricultural environments (Strawn et al., 2013; Gibb et al., 2020, Ayad et al., 2022; Nyachuba, 2010).

Additionally, improving food safety regulations and standards at the production level can reduce the risks linked to zoonotic pathogens, guaranteeing that food products are safe for consumption (Heredia & García, 2018; Newell et al., 2010; Ayad et al., 2022). The incorporation of modern technologies into food safety protocols represents a vital component of the One Health framework. Rapid detection methods for foodborne pathogens, including biosensors and molecular diagnostics, significantly improve the capacity to identify and respond to contamination events promptly (Yamada et al., 2016; Zhao et al., 2014).

The aim of this review is to explore the critical issue of cross-species pathogen transmission within global food systems and to highlight the role of the One Health approach in mitigating these risks.

PATHOGEN TRANSMISSION ACROSS FOOD SYSTEMS

Human-to-Animal Pathogen Transmission

The transmission of pathogens from animals to humans, known as zoonotic spillovers, has been intensified by agricultural practices and food production systems. Intensive farming, marked by elevated animal density and restricted confinement, fosters conditions that promote the emergence and proliferation of zoonotic pathogens. The intensification of livestock farming has been associated with the emergence of diseases like Q fever, which is caused by *Coxiella burnetii* and is linked to regions with high livestock density (Smit et al., 2012; Freidl et al., 2017). The confined spaces in which animals are housed promote the spread of pathogens, affecting not only livestock but also humans, especially farm workers and those living nearby. Moreover, the ecological consequences of these methods, including the emission of pathogens into the atmosphere via ventilation systems, heighten the likelihood of zoonotic transmission to both wild and domestic animals (Jones et al., 2013). The misuse of antibiotics and intensive farming practices significantly contribute to the amplification of pathogens due to human activities. The excessive use of antibiotics in livestock can result in the emergence of antibiotic-resistant strains of pathogens, presenting considerable threats to human health (Stevenson, 2023). The prevalence of Methicillin-resistant *Staphylococcus aureus* (MRSA) has been associated with intensive pig farming, where the close proximity of animals and the frequent use of antibiotics foster optimal conditions for the selection and dissemination of resistant strains (Kalupahana et al., 2019). Furthermore, the transportation of animals for commercial purposes or slaughter can promote the dissemination of these resistant pathogens across different areas, thereby complicating control measures (Murray et al., 2023).

Animal-to-Human Transmission

Pathogens are frequently transmitted to humans via the ingestion of contaminated food items, especially those sourced from livestock. For example, *Salmonella* ranks among the most common foodborne pathogens, causing millions of infections each year, with contaminated poultry and eggs identified as major sources (Zhai et al., 2018). In a similar vein, *Campylobacter*, frequently present in poultry, stands out as a primary contributor to bacterial gastroenteritis on a global scale (Zhai et al., 2018). The spread of these pathogens is frequently enabled by insufficient food processing and handling methods, which may result in cross-contamination during food preparation (Zhai et al., 2018). The transmission of zoonotic pathogens is significantly influenced by risk factors present in animal husbandry and food processing. Intensive farming practices, characterised by the confinement of animals in close proximity, heighten the risk of pathogen transmission among the animals and, consequently, to humans (Coker et al., 2011). Furthermore, inadequate biosecurity protocols on farms may result in the introduction and ongoing presence of pathogens among livestock populations (Coker et al., 2011; Espinosa et al., 2020, Heijne et al., 2018). Moreover, the transportation of livestock for commercial purposes or slaughter can promote the dissemination of pathogens between areas, hindering control measures and elevating the likelihood of outbreaks (Murray et al., 2023).

Environmental Transmission Pathways

The contamination of the environment through animal and human waste serves as a crucial route for the spread of zoonotic pathogens. The runoff from agricultural fields, especially those with intensive livestock operations, has the potential to introduce pathogens into water sources, soil, and crops (Jones et al., 2013; Sundberg et al., 2014). Contamination can arise through multiple mechanisms, including the use of manure as fertiliser, which may contain pathogens like *E. coli* and *Salmonella* (Jones et al., 2013; Sundberg et al., 2014). The existence of these pathogens in the environment presents a threat not just to agricultural output but also to public health, since contaminated water and crops can result in foodborne illnesses in humans (Jones et al., 2013; Sundberg et al., 2014). The significance of antimicrobial residues and resistant pathogens in environmental contamination is becoming increasingly acknowledged as a vital public health issue. Antibiotic use in livestock farming results in the excretion of antimicrobial residues into the environment, which contributes to the emergence of antibiotic-resistant bacteria (Xiong et al., 2015). The persistence of these resistant pathogens in the environment presents significant risks to the health of both animals and humans (Xiong et al., 2015).

THE ROLE OF THE ONE HEALTH APPROACH

Integration Across Sectors

The One Health approach highlights the necessity of cooperation between human health, veterinary, and environmental sectors to address the intricate health issues that emerge at the convergence of these areas. This integration is essential for the effective management of zoonotic diseases, which frequently necessitate coordinated responses across various disciplines. The PREDICT project, initiated by the United States Agency for International Development (USAID), serves as a prime example of a One Health initiative focused on monitoring potential spillovers of pathogenic viruses from animals to humans (Ajayi et al., 2021). This project has deepened our comprehension of viral evolution and showcased the effectiveness of interdisciplinary collaboration in mitigating future pandemics. Global initiatives have been established to address the challenges of food safety through a comprehensive approach. For instance, the European Union has implemented a One Health framework that combines data from human health, animal health, and environmental monitoring to tackle foodborne pathogens (Zanet et al., 2022). This initiative has enabled the establishment of coordinated surveillance systems that allow for the identification and management of zoonotic diseases, thus enhancing food safety and public health results. Furthermore, the combination of veterinary and public health surveillance systems has demonstrated an ability to improve the identification of emerging pathogens.

Surveillance and Early Detection

The One Health approach encourages the development of comprehensive surveillance networks that include data from human, animal, and environmental health domains. The MediLabSecure project aims to improve pathogen detection and surveillance for arboviral infections by fostering a One Health collaboration, highlighting the necessity for integrated systems capable of addressing emerging infectious diseases (Mikaty et al., 2022). Coordinated efforts are essential for the early identification and swift action against potential health threats. The application of genomic tools and the exchange of data among various sectors play a vital role in the efficiency of surveillance systems. Genomic surveillance facilitates the identification of pathogen strains and their transmission pathways, offering important insights into disease dynamics (Gardy & Loman, 2017). The utilisation of high-throughput sequencing technologies has enhanced our capacity to monitor the dissemination of antibiotic-resistant bacteria, which is vital for public health initiatives (Bianconi, 2023). Moreover, combining genomic data with epidemiological insights can deepen our comprehension of pathogen evolution and enable prompt reactions to outbreaks (Vashisht, 2023). This genomic approach, guided by a comprehensive perspective, presents substantial potential for enhancing global health security.

Sustainable Agricultural Practices

Implementing strategies that emphasise environmental well-being allows farmers to reduce the threats posed by zoonotic diseases. For example, methods like crop rotation, organic farming, and integrated pest management can decrease dependence on

chemical inputs and lower the likelihood of pathogen contamination in food products (Ajayi et al., 2021). The implementation of these sustainable practices enhances public health while simultaneously strengthening agricultural systems against climate change and various environmental challenges. Alternatives to antibiotics in livestock production, including probiotics and vaccines, are gaining recognition as vital elements of sustainable farming practices. The excessive application of antibiotics in livestock management has been associated with the rise of antibiotic-resistant pathogens, presenting considerable threats to human health (Stevenson, 2023). Implementing probiotic treatments and vaccination programs allows farmers to improve animal health and minimise antibiotic use, which in turn reduces the chances of resistance development (Ajayi et al., 2021). The application of vaccines in poultry has demonstrated a significant reduction in the occurrence of *Salmonella* infections, leading to enhanced food safety outcomes (Zanet et al., 2022).

CONCLUSIONS

In summary, the One Health approach offers a holistic framework for tackling the intertwined issues of human, animal, and environmental health. Through the promotion of cross-sector collaboration, the enhancement of surveillance systems and the advocacy for sustainable agricultural practices, various stakeholders can unite to address the risks linked to zoonotic diseases and advance public health outcomes. The incorporation of genomic tools and the sharing of data significantly improve our capacity to address emerging pathogens, leading to a more robust and secure global health environment.

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