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Emerging Foodborne Pathogens: Challenges and Strategies for Ensuring Food Safety

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Abstract: This review explores the challenges of emerging foodborne pathogens and the strategies employed to ensure food safety. The study conducted a comprehensive literature review to gather information on the latest trends in foodborne pathogens, their impact on public health, and the measures taken to mitigate their risks. Various scientific databases were utilized to identify relevant articles, research papers, and reports. The research findings highlight the emergence of new and re-emerging foodborne pathogens, such as *Salmonella, Campylobacter, Escherichia coli, Listeria monocytogenes,* and *norovirus*. These pathogens pose significant health risks and can lead to outbreaks and foodborne illnesses. The study examines the factors contributing to the emergence of these pathogens, including changes in food production, globalization, climate change, and antimicrobial resistance. Furthermore, the research explores the challenges faced in controlling and preventing the spread of these pathogens throughout the food supply chain. It examines issues related to contamination during production, processing, transportation, and consumption. The study also investigates the limitations of current detection methods and the need for improved surveillance systems to identify and respond to emerging pathogens effectively. In terms of strategies for ensuring food safety, the research highlights the importance of implementing preventive measures, such as good agricultural practices, proper sanitation, and hygiene protocols. It emphasizes the significance of robust food safety regulations and policies to enforce compliance across the industry. Additionally, the study explores the role of education and awareness campaigns in promoting safe food handling practices among consumers.

Keywords: foodborne pathogens; challenges; food safety; preventive measures

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1. Introduction

The prevalence of infections caused by microbes contaminating our food supply constantly reminds us of the intricate connections between humans, animals, plants, and microorganisms worldwide. The spectrum of foodborne infections has undergone significant changes over time, with established pathogens being controlled or eliminated while new ones emerge. Foodborne diseases continue to pose a significant burden, affecting approximately millions of people each year. Surprisingly, most of these disorders cannot be traced back to known viruses, implying that there are additional unidentified pathogens. Among the identified foodborne pathogens, newer ones are becoming more common, suggesting that our understanding of pathogens is improving, leading to better control (Tack *et al*., 2019). In addition to the emergence of new pathogens, other trends include global pandemics caused by certain foodborne pathogens, the rise of antimicrobial resistance, the identification of highly opportunistic pathogens that mainly affect high-risk groups, and the increasing occurrence of large-scale outbreaks. New pathogens can arise

due to changes in ecology or technology that connect potential pathogens to the food chain. They can also emerge through the transfer of mobile virulence factors, often via bacteriophages, although this is rarely observed. A better understanding of phage transmission among bacteria can illuminate the emergence of new pathogens in the future (Sofos, 2008).

New and emerging bacteria, toxins, and antimicrobial resistance pose a challenge to food safety, as they can cause outbreaks of illness that are difficult to diagnose and treat (Ruzickova *et al*., 2008). Food production and supply changes, such as increased imports, might raise the risk of food contamination and sickness. Changes in consumer preferences and habits, changes in consumer habits and preferences, such as increased demand for fresh produce and ready-to-eat meals, can lead to new challenges in food safety. Difficulty in establishing causal relationships, Because of underreporting and the difficulty in proving causal linkages between food contamination and disease, the burden of foodborne diseases on public health and economies has frequently been underestimated resulting in illness or death (Nicolas *et al.,* 2011). These challenges highlight the need for attempts to improve food safety and prevent the spread of foodborne pathogens.

The intricate and ever-evolving biological network within the human food supply suggests that we should anticipate the emergence of new pathogens, while significant progress has been made in recent years in enhancing food safety, much of it has focused on reducing contamination after harvesting. This has involved improving sanitation and process control in meat and poultry processing, as well as better management of processed foods to minimize food-borne pathogenic contamination. This study aims to examine prior studies and emphasize the introduction of new and re-emerging foodborne diseases, as well as the obstacles to ensuring food safety.

2. Pathogens outbreak

A case study conducted in the United States found that most foodborne illnesses were caused by norovirus, followed by nontyphoidal *Salmonella spp., Campylobacter spp,* and *Clostridium perfringens*. Food contaminated with 31 identified agents of foodborne disease caused 9.4 million illnesses, 55,961 hospitalizations, and 1,351 fatalities in the United States per year, according to this study. Norovirus caused most illnesses; Campylobacter spp., nontyphoidal Salmonella spp., norovirus, and T. gondi caused most hospitalizations; and *L. monocytogenes, nontyphoidal Salmonella spp., T. gondi*, and *norovirus* caused most deaths (Scallan *et al*., 2011).

Numerous outbreaks of foodborne diseases and pathogens have been associated with fresh produce in Florida. Some documented incidents are briefly outlined in a study (Hammond *et al*., 2001) A case study in Ontario, Canada, discovered evidence of foodborne outbreaks linked to pizza. The most often reported pathogen associated with the outbreaks was *norovirus* (Smith *et al*., 2004). The CDC maintains a list of multistate foodborne outbreaks for which they led the investigation and issued outbreak notices since 2006. The list includes outbreaks related to frozen strawberries, hepatitis A, leafy greens, Listeria monocytogenes, and alfalfa sprouts. Reducing the number of foodborne diseases and pathogen emergence/reemergence necessitates global collaboration among government agencies, the food industry, and other stakeholders. To combat new foodborne diseases, more sensitive and rapid surveillance, improved laboratory identification and subtyping procedures, and efficient prevention and control will be required. (Smith and Fratamico, 2018).

A case study conducted during a Special Operations Forces deployment to South America revealed that foodborne illness was most likely caused by inappropriate food storage, inadequate kitchen sanitation, and holding. (McCowen and Grzeszak, 2010).

Table 1. Different food-borne pathogens and their prevention, the disease they cause, and diagnostic techniques.

Microorganism specie	Host	Disease caused by microorganisms	Detection methods	Prevention	References
S. Typhi	Humans	Typhoid, fever, and septicemia	Chemically altered oligonucleotides are employed in the detection technique, flanked at the 5' end by a fluorophore (FAM) and a quencher (TQ2) at the 3' end. Nuclease causes the oligonucleotide probes to degrade, while FAM functions as a reporter molecule to monitor fluorescence to record the activity. Use yeast as a preventative agent against typhoid, paratyphoid, and NTS (non-typhoid Salmonella).	Don't eat raw or barely cooked eggs or meat, wash raw fruits and vegetables well, refrigerate food properly, properly pasteurize your food product before use, avoid splashes from raw meat on other surfaces, wash your hands with soap after touching animals, keep your kitchen clean and maintain hygienic conditions	(Aziz *et., al* 2023)
S. paratyphi	Humans	Bacteremia and fever			
S. Typhimurium	Humans, Mice Bovines, Chicken, Equine, and Ovines	Diarrhea, and fever			
S. enteritidis	Humans, mice, and chicken	Septicemia, gastroenteritis, and fever			
S. Dublin	Bovines, swine, and ovines	Abortion, septicemia, fever, and gastroenteritis			
S. derby	Swine and birds	Bacteremia, diarrhea, and fever			
S. gallinerum	Chicken	Gastroenteritis, and septiciemia			
S. abortosovis	Ovines	Septicemia, and abortion			
S. abortusequi	Equines	Abortion			
S. choleraesuis	Swine	Fever, and bacteremia			
Norovirus	Oysters	Diarrhea, vomiting, stomach flu, stomach bug	PCR (RT-qPCR) technique, and new generation	Proper handling of food, hand	(Sun *et., al* 2023)

			molecular detection technology CRISPR/Cas	washing for 30 seconds before eating, NTP (non-thermal plasma) methods, such as HHP (high hydrostatic pressure), irradiation treatment, and plasma treatment, have good *Norovirus* removal effects,	
Listeria monocytogenes	Animals	Necrosis, abortion and stillbirth, encephalitis, endocarditis and have a high mortality rate	The USDA-FSIS (United States of Agriculture-Food Safety and Inspection Service) technique, the ISO 11290-1 method, and the FDA-BAM (Food and Drug Administration-Bacteriological and Analytical Methods) method (one broth method) can all be used to isolate and detect Listeria monocytogenes from various food samples (two enrichment steps needed)	Washing your hands before cooking, antibiotic treatment	(Ravindhiran *et., al* 2023)

Campylobacter jejuni	Cattles, poultry	Abdominal pain, fever, nausea, gastroenteritis	Biochemical and molecular tests, including PCR, DNA assay	Reduction of pathogenic food contamination, hygiene measures, keeping raw poultry away from other foods, and Cleaning all cutting boards, countertops, and utensils with soap and hot water after preparing any type of raw meat.	(Heimesaat *et., al* 2023) (Peruzy et al., 2020)
Campylobacter coli	Pork	Human diarrhea, fever, vomiting			
Enterotoxigenic E. Coli (ETEC)	Humans, cattle	Traveler's diarrhea, chronic childhood diarrhea (in developing countries)	-	Proper handling of food products, and washing before use, Vulnerable populations (such as small children and the elderly) should avoid the consumption of raw or undercooked meat products, raw milk, and products made from raw milk.	(Oliveira *et., al* 2023) (Ajayi et al., 2016)
Enteropathogenic E. coli (EPEC)	Humans, pigs	Infant diarrhea			
Enteroinvasive E. coli (EIEC)	Humans	Dysentery, fever, nausea, and abdominal cramps			
Enterohemorrhagic E. coli (EHEC)	Humans, chickens	Hemorrhagic colitis (HC), vomiting, hemolytic uremic syndrome (HUS)			

2.1. Factors involved in the emergence and reemergence of food-borne pathogens.

The following factors are directly involved in increasing food-borne infections:

Table 2. Factors Related to Increase in Foodborne Illness and the Emergence/ Re-Emergence of Foodborne Pathogens.

Factors	What impact do they have?	References
Human behavioral adjustment	The liberation of sexual practices, growing demand for childcare beyond the household, substance abuse, alterations in food distribution, and shifts in transportation practices.	(Church, 2004)
Urbanization	Rapid urbanization can lead to crowded living conditions and challenges in maintaining proper food safety measures or unchaotic urbanization is commonly linked to substandard housing and lack of essential services, such as water and sanitation which provide optimal conditions for the expansion of the vector population.	(Chala & Hamde, 2021)
Climate change	Altered weather patterns and temperature fluctuations can impact the prevalence and distribution of foodborne pathogens. Due to climate change, food production will occur under modified climatic conditions but the interface between climate change and the food system is complex. For example, the shifting climate patterns might result in changes to the flooding of agricultural areas, posing a risk of introducing infections entering the food chain when consuming affected produce in its raw form.	(Lake & Barker, 2018)
International travel	The movement of people and food products across borders can contribute to the spread of foodborne pathogens. Migration and international travel are determinants in the transmission of food-related illnesses.	(Käferstein *et al*., 1997)
Pathogen evolution	Antimicrobial resistance and increased disease-causing potential.	(Smoot & Cordier, 2009)
	Adaptation of pathogens to novel environments, stress conditions, and antimicrobials.	(Smith & Fratamico, 2018)
Changes in consumer behavior	Busy lifestyles and a demand for convenience can lead to increased consumption of pre-packaged and ready-to-eat foods, sometimes associated with a higher risk of contamination. Moreover, the methods by which individuals transmit microorganisms to each other and themselves include actions like coughing and sneezing. The failure to wash hands before, during, and after handling food undeniably plays a role in distributing foodborne infections and intoxications.	(Collins, 1997)

3. Challenges and strategies to ensure food Safety.

Food safety and the prevention of foodborne diseases are key concerns in the food industry. Changes in food production techniques, the impact of globalization, climate change, and the development of antibiotic resistance are all factors leading to the introduction of food-borne pathogens. Contamination is a serious problem at all phases of the food supply chain, including manufacturing, processing, transportation, and consumption. Pathogens can enter the food supply chain at any of these steps, posing potential health risks (Ajayi *et al*., 2016).

To overcome these difficulties, it is critical to establish preventive measures and effective methods. Adopting and maintaining appropriate agricultural practices, such as tight

hygiene regulations, thorough sanitation procedures, and effective pest control, can assist in reducing contamination throughout production. Good manufacturing practice (GMP) implementation in the food industry, including enhanced food products, storage, shipping, and handling techniques, as well as the implementation of food safety training programs, particularly for workers in the food industry and personnel in restaurants or distribution centers, should be given careful thought. To ensure the safe manufacturing of food, the Hazard Analysis Critical Control Point (HACCP) system should be implemented in all food processing processes, including raw material processing, storage, and transportation (Shamloo *et al.*, 2019). Additionally, educating customers about proper food handling procedures and raising awareness of food safety measures are critical in preventing contamination during consumption. The food business may aim to provide robust food safety standards and protect public health by addressing these difficulties and applying relevant methods.

4. Results and Discussion

The study identified a range of emerging foodborne pathogens, including *Salmonella, Campylobacter, Escherichia coli, Listeria monocytogenes*, and norovirus. These pathogens pose significant health risks and can lead to outbreaks and foodborne illnesses. Factors contributing to their emergence include changes in food production, globalization, climate change, and antimicrobial resistance. The findings highlight the need for effective control and prevention measures throughout the food supply chain. Challenges in this regard include contamination during production, processing, transportation, and consumption. The study also revealed limitations in current detection methods, emphasizing the necessity for improved surveillance systems to identify and respond to emerging pathogens promptly. To ensure food safety, the research emphasizes the importance of implementing preventive measures such as good agricultural practices, proper hygiene, and robust food safety regulations. These measures can help mitigate the risks associated with emerging foodborne pathogens and protect public health.

In conclusion, this study provides valuable insights into the challenges posed by emerging foodborne pathogens and offers recommendations for strategies to ensure food safety. Further research and collaborative efforts are needed to address these challenges effectively and safeguard the well-being of consumers.

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