Emerging Pathogens, Food Borne Illness and Trends

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Abstract

Foodborne pathogens, which include bacteria, viruses, fungi, and parasites, have been associated with a variety of problems in the public health domain, requiring stricter measures for safety in food. Bacterial pathogenesis which includes *Salmonella*, *Campylobacter*, *Vibrio*, and *Listeriamonocytogenes* is a common etiological agent in causing foodborne diseases. Viruses that cause foodborne diseases such as *Norovirus*, hepatitis A virus, and *Rotaviruses* are extremely common. Fungi diseases such as *Aspergillus*,*Penicillum*, *Fusarium* and *Alternaria* are pathogens that produce toxic metabolites called mycotoxins that contaminate food. Zoonotic parasitic pathogens like tapeworms, *Trichinella*and protozoa can be spread through the drinking contaminated water and food. The climatic change exacerbates contamination of food and water with microbes, thus posing a threat to both animal and human health. Detection methods include Next Generation Sequencing (NGS), immunological assays, Polymerase Chain Reaction (PCR), and a novel deduction method. These risks, however, are minimized by having 'Good Agricultural Practices' (GAPs), 'Hazard Analysis Critical Control Point' (HACCP) protocols, 'Good Manufacturing Practices' (GMPs) in the process.

Keywords: Foodborne**,** Pathogens, Climate change, Prevention, Detection

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Introduction

The use of microbial contamination on the global food supply can be driven by complex human-animal-plant-microorganism interactions (Hassan et al., 2023). Emerging novel pathogens, rising antimicrobial resistance, global pandemics and increased opportunistic infections push theevolution inthe landscape regarding foodborne pathogens (Tack et al., 2019). Food contamination results in about420,000 deaths and 600 million foodborne illnesses worldwide yearly according tostudies (Lee & Yoon, 2021). The foodborne pathogens are harmful that could be a bacteria, viruses, fungi or parasites and would be transferred through contaminated food and water that might precipitate illnesses and potentially severe health complications (Keerthana et al., 2022). The need for the identification of pathogens in food is therefore related to food safety (Aladhadh, 2023). Different methodologies for determining pathogens in food are, therefore, discussed in this chapter with great emphasis on sensible and reliable methods. Mitigating the novel foodborne pathogens demands enhanced surveillance, advanced diagnostics, and evidence-based prevention and control measures to protect public health (Shafique et al., 2022; Smith & Fratamico, 2018).

The world most common causes of foodborne illness are bacterial pathogens, with themost important of these including *Salmonella*, *Vibrioparahaemolyticus*, *Listeriamonocytogenes*, and other pathogens being the most significant (He et al., 2023).

1.1.1.*Salmonella*

Salmonella include more than 2,500 serotypes. It is therefore the *S. enteritidis*, *S. typhimurium*, and *S.newport*, that are the most common serotypes and have been reported by the 'Foodborne Diseases Active Surveillance Network' (FoodNet) sites in the US Centers for 'Diseases Control and Prevention' (CDC) over the years during 1996-2014 (Iftikhar et al., 2024; Powell et al., 2018).

1. Emerging Food Borne Pathogens, Illness and Trends

1.1. Bacterial Pathogens

1.1.2. *Campylobacter*

Campylobacteriosis, a zoonosis, is caused by *Campylobacter spp.*, such as *C. coli*, *C. lari*, *C. jejuni* and *C.fetus* (Khairullah et al., 2024). The *Campylobacter spp.* are thermophilic, having a growth temperature above 40°C (Yanestria et al., 2024). The *Campylobacter spp.* are nonsporing, gram-negative bacteria; they are sensitive to irradiation, disinfectants, and heat (Kim et al., 2021). The pathogenesis of this pathogen involves virulence factors, chemotaxis, and lethal distending toxins (Khairullah et al., 2024; Irfan et al., 2022).

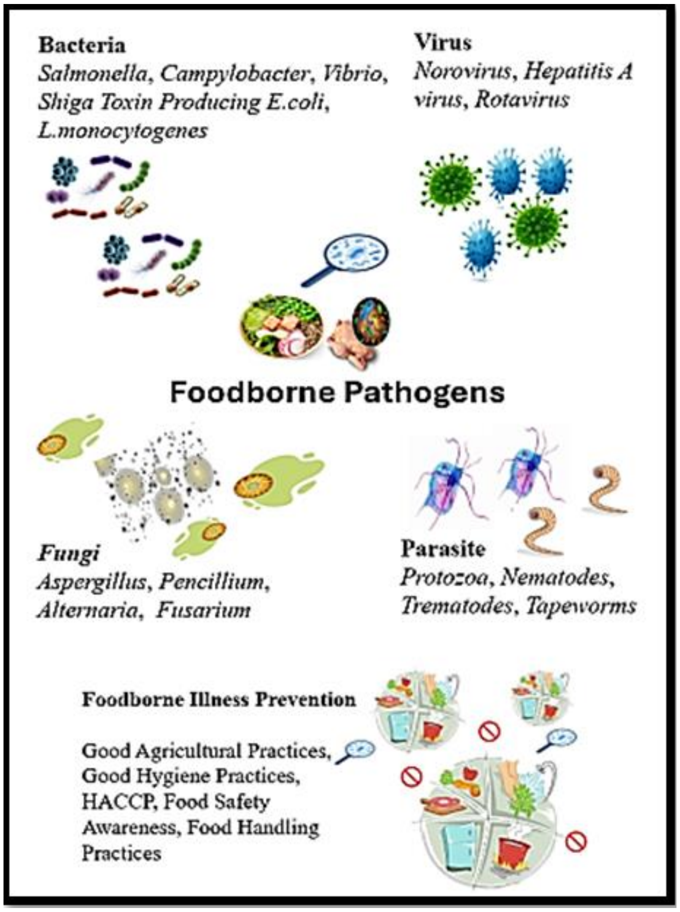

Fig. 1: Emerging Foodborne Pathogens.

1.1.3. *Vibrio parahaemolyticus*

Vibrio parahaemolyticus is a Gram-negative halophilic bacterium that lives in estuarine and marine environments (Wu et al., 2014). The virulent strains carry the toxigenic genes liketdh and trh hemolysis (Letchumanan et al., 2014). This gene is the essential virulence factor (Xu et al., 2014). The environmental isolates are mostly commensals, whereas only a few contain virulence genes (Igbinosa et al., 2021). Most of the food isolates are non-pathogenic and therefore are of negligible hazard to humans (Velazquez-Roman et al., 2012). The resistance genes of antibiotic in vibrio are mainly plasmid or chromosomal and thus favor horizontal and vertical gene transfer (Igbinosa et al., 2021). Isolates from the environment hardly cause diseases in marine animals and humans (Gutierrez-West et al., 2013).

1.1.4. *Shiga toxin-producing Escherichia coli*

STEC is one of the major foodborne pathogen causeingsevere human illness. The five most common serotypes of *STEC* are *O157*, *O103*, *O26, O145,* and*O111*(Douëllou et al., 2017; Griffin &Tauxe, 1991). *STEC O157:H7* is one of the previously recognized enteropathogensfor which infection is particularly associated with the outbreaks of 'HemolyticUremicSyndrome' and HC (Monoghan et al., 2012; Law, 2000). The shiga toxin (Stx), a vital virulence factor, is expressed by a lambdoid bacteriophage (Kim et al., 2020; Alotaibi& Khan, 2023).

1.1.5. *Listeria Monocytogenes*

Listeria monocytogenes is a facultative anaerobic gram positive bacterium, that the organism can grow at temperatures rangingfrom −0.4°C and 45°C, although it prefers optimal temperature at 37°C (Allerberger, 2003). The organism also tolerates to low water activity (aW< 0.90), and acidic to alkaline pH (4.6-9.5), and saline conditions up to about 20% (Bucur et al., 2018). The*L. monocytogenes* is ubiquitous, and is present in water,soil, and feed (Dhama et al., 2015) and survives at least 8 weeks within the environment (Rodríguez-Campos et al., 2018).

Table 1: Emerging Foodborne Bacterial Pathogens: Trends and Characteristics

Bacterial Pathogens	Incident Rates & Outbreaks	Food Sources	Transmission Route	Symptoms
Salmonella	85% of food linked illness, 200 million -1billion worldwide infection with 155,000 deaths and 93 million cases of gastroenteritis (Castro-Vargas et al., 2020; Hung et al., 2017)	Animal origin foods (Sun et., 2021; Wessels et al., 2021; Whiley & Ross, 2015), Cross Contamination (Yeh et al., 2017), Fruits &Vegetables contaminated with animal fecal (Kore et al., 2017)	Contaminated food	Influenza-like symptoms includevomiting, nausea, diarrhea and abdominal pain (Crump et al., 2015).
Campylobacter	8.4% of total global cases of diarrhea (Igwaran &Okoh, 2019)	Animal Products (Agumah et al., 2024; Chlebicz&Śliżewska, 2018)	Contact with infected animals, contaminated food & water (Goddard et al., 2022)	Bloody/watery diarrhea, vomiting, fever (Guo et al., 2023)
Vibrio	-	Seafood (Aladhadh,2023)	Contaminated seafood (Aladhadh, 2023)	Acute gastro-enteritis (Igbinosa et al., 2021)
STEC	Sporadic cases or large scale outbreaks (Karmali, 2004), life threatening (Levine et al., 1992; Tarr et al., 2005)	Contaminated food or water (Nataro&Kaper, 1998), animal intestinal tract (Balière et al., 2015)	fecal-oral route, contact with contaminated food, human, water surfaces (Nataro&Kaper, 1998)	hemorrhagic colitis, diarrhea and bloody diarrhea (Levine et al., 1992; Tarr et al., 2005)
L. Monocytogenes	Listeriosis, with worldwide 20-30% mortality rate (Buchanan et al., 2017)	Food Processing & Post processing environment (Ferreira et al., 2014)	Consumption of contaminated food (Harter et al., 2017)	Muscle aches, nausea, fever vomiting, diarrhea, severe cases exhibiting headache, convulsions (Osek et al., 2022).

1.2. Viral Pathogens

1.2.1. *Noroviruses*

The*Noroviruses* have been identified as the leading etiologic agents of foodborne disease and acute non-bacterial gastroenteritis in all over the world (Atmar & Estes, 2006). The *Noroviruses* (NoVs) are divided into five genogroups by phylogenetic analysis of the viral capsid (VP1) gene, with further subdivision into genetic clusters known as genotypes (Zheng et al., 2006). The *Noroviruses* are non-enveloped, icosahedral viruses, 23-40 nm in diameter, with a capsid consisting of minor VP2 protein and major VP1 protein (60k Dalton). The genome is a positive-sense, single-stranded RNA, 7-8 kb in length, non-segmented, and polyadenylated at the 3'-terminal (Ushijima et al., 2014).

1.2.2. *Hepatitis A*

The *Hepatitis A virus*is a positive-sense singlestranded RNA virus. This virus belongs to the genus *Hepatovirus* in the family *Picornaviridae* (Sander et ., 2018; Lefkowitz et al., 2017). The *HAV* virus can be further separated into six genotypes, three of which affect humans (I, II & III) and three that affect nonhuman primates (IV, V & VI). It is formed as a 27-32 nm diametervirion or spherical particle (Vaughan et al., 2014).

1.2.3. *Rotavirus*

The *Rotaviruses* are highly endemic, causing almost every child in the world to become infected by 3-5 years of age (Velázquez et al., 1996). The *rotaviruses* are non-enveloped, having double-stranded RNA (dsRNA) viruses with a triple-layered capsid and 11-segmented dsRNA genome encoding six structural and six non-structural proteins (Gurwith et al., 1981).

Table 2: Emerging Foodborne Viral Pathogens: Trends and Characteristics

Viral Pathogens	Incident Rates & Outbreaks	Food Sources	Transmission Route	Symptoms
Norovirus	200,000 deaths per year in children under five years old in developing countries, affect all age groups (Patel et al., 2008)	Ready-to-eat foods, shellfish, berries, and leafy greens, often contaminated by food handlers, washing water, or environmental sources (Ushijima et al., 2014).	fecal-oral route, via person-to-person spread (88%), contaminated food (10%), or water (1.5%) (Kroneman et al., 2008), Histo-blood group antigens (HBGAs) serve as receptors for attachment and entry & permissive cells (Debbink et al., 2012; Tan & Jiang, 2011).	Altered enzyme activity in infected cells (Flynn &Saif, 1988)
HepatitisA	primary causative agents of foodborne viral outbreaks (Urbanus et al., 2009)	Green-leaf salads, berries, bivalve molluscan shellfish (Kokkinos et al., 2009).	person-to-person via the fecal-oral route (Urbanus et al., 2009)	Malaise, fever, jaundice, nausea abdominal discomfort, loss of appetite (Nemes et al., 2023)
Rotavirus	5-10% of community-acquired cases, 15-20% of outpatient cases, and 30-50% of inpatient cases (Tate et al., 2016)	Fecal Contamination of food (Sadiq& Khan, 2024)	fecal-oral route, with close person-to-person contact (Crawford et al., 2017), infects mature enterocytes and enter endocrine cells in the small intestine (Lundgren & Svensson, 2001;)	Inflammation (Lundgren & Svensson, 2001; Morris & Estes, 2001), vomiting, malaise, fever, and non-bloody diarrhea (Crawford et al., 2017)

1.3. Fungal Pathogens

Fungi like *Aspergillus, Fusarium, Penicillum* and *Alternaria* produce toxic metabolites called mycotoxins that contaminate food (Pandey et al., 2022). Important mycotoxins are ochratoxin A, aflatoxins, and trichothecenes. Mycotoxin exposure affects animal and human health making food unsafe and less marketable (Soares Mateus et al., 2021). Fungi also affect wheat during transport and storage and produce toxins like Fusarenon X-glucoside (Nakagawa et al., 2011). Today 30-50% of food commodities are lost at pre-harvest and post-harvest stage in the world's food security (Kim et al., 2020; Pandey et al., 2023).

Table 3: Emerging Foodborne Fungal Pathogens: Trends and Characteristics

Fungal Pathogens	Incident rates & Outbreaks	Food Sources	Transmission Route	Symptoms
Aspergillus, *Fusarium*, *Penicillum*, and *Alternaria* (Pandey et al., 2022)	Global security threat of 30-50% loss of food commodities (Pandey et al., 2023), daily Over 5 billion people are exposed to mycotoxins (Khodaei et al., 2021).	Toxins in fruits & pulses (Pandey et al., 2023), grains (Siruguri et al., 2012), Coffee (Richard et al., 1999)	Mycotoxin consumption (Soares Mateus et al., 2021)	Gastroenteritis, food poisoning, Localized infections (Aladhadh, 2023)

1.4. Parasitic Pathogens

Parasitic pathogens are zoonotic in nature. These parasitic pathogens can be spread through contaminated water and food. The foodborne parasites mainlyincludes *Clonorchissinensis*,tapeworms, *Trichinella*, trematodes, protozoa such as *Toxoplasma gondii*, *Giardia lamblia*, and *Cryptosporidium*according to the mode of transmission and life cycle of the parasite (Pozio, 2020).

2. Effects of Climate Change on food Pathogens

The climatic change enhances the microbial contamination in water and food leading to a menace to the health of animals and humans and compromising food security (War et al., 2022). Rising temperatures and modified patterns of precipitation drive disease spread, increasing the prevalence of bacterial, pathogenic and viral contamination in water and food (Singh, 2022). Warmer temperatures boost Salmonella growth and survival (Awad et al., 2024), and flooding boosts microbial contamination, including *Salmonella*, within water sources (Dzodzomenyo et al., 2022). The climatic change includes increased heat waves and storms that affect the survival and spread of Campylobacter and other foodborne pathogens (Sterk et al., 2016). *Noroviruses* are extremely resistant and can survive a temperature range of freezing to 60 °C, persist on surfaces, and foods that enable rapid spread through secondary transmission by means of food handlers or family members (Glass et al., 2009). The climatic change affects transmission of parasites: warming temperatures kill eggs, while rising flooding and excessive rains increase infections in humans with *Fasciola spp.* (Pozio, 2020).

Table 4: Emerging Foodborne Parasitic Pathogens: Trends and Characteristics

Parasites	Incident rate & Outbreaks	Food Sources	Transmission route	Symptoms
Protozoa, Nematodes (Chávez-Ruvalcaba et al., 2021)	48% of parasitic diseases are foodborne (Torgerson et al., 2015)	Fecal contaminated or contaminated fruits, vegetables, meat, milk (Chávez-Ruvalcaba et al., 2021)	Contaminated food / water (Chávez-Ruvalcaba et al., 2021)	Abdominal & intestinal diseases (Chávez-Ruvalcaba et al., 2021)

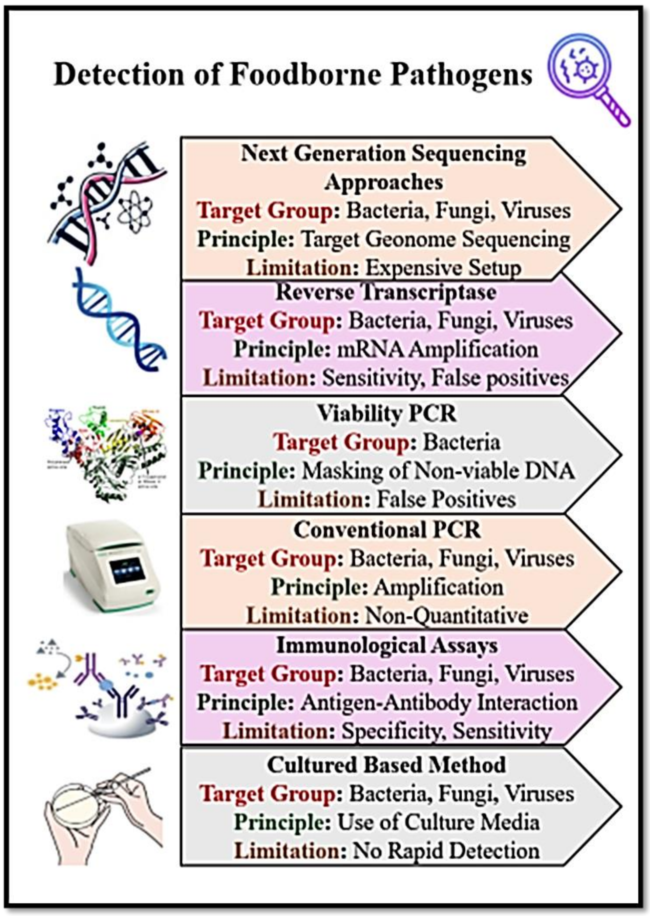

Fig. 2: Conventional and Modern Methods for Foodborne Pathogens Detection (Aladhadh, 2023; Foddai& Grant, 2020).

3. Methods for Detection of Foodborne Pathogens

The foodborne pathogenic detection in food matrices with high accuracy and reliability is of critical importance for food safety monitoring. Nevertheless, this task is a considerable challenge because of some of its constraints including interference from matrix components, low target pathogenic concentrations, nonpathogenic microorganism species and recovery complications of microbes from food samples (Aladhadh, 2023). For this reason, a number of analytical methods have been established to both detect and identify foodborne pathogens (Foddai& Grant, 2020; Saravanan et al., 2020). These methods include thetraditional culture-based techniques, nucleic acid-based methods such as Polymerase Chain Reactions (PCR), immunological assays, and the Next Generation Sequencing (NGS) methods (Aladhadh, 2023).

4. Prevention of food borne pathogens

The foodborne pathogens are a risk to health in public places and should be prevented with quality control over the food with much caution. There are several vectors through which pathogens enter the food chain, including agricultural runoff, cross-contamination, and poor sanitation (Ajayi, 2024). Implementation of 'Good Agricultural Practices' (GAPs), 'Hazard Analysis Critical Control Point' (HACCP) protocols and 'Good Manufacturing Practices' (GMPs)will help in the elimination of such risks. The best way of avoiding food contamination include proper storage, food handling, and transportation procedure for food. The optimal handling practices and awareness of food safety can also be enhanced through training programs and education for food handlers and consumers (Hassan et al., 2023).

Conclusion

The global food-borne pathogens like bacterial, parasitic, viral and fungal pathogens are very serious health risk globally. A holistic approach would include evidence-based detection methodologies, surveillance, and prevention strategies. Improving agricultural practices, good manufacturing practices, sanitation, and hygiene through sustainable agriculture and climate-resilient food systems can help to reduce foodborne illnesses. Strong actions on effective control measures andsafety of food would effectively reduce the prevalence of foodborne pathogen and ultimately foodborne illness. Improved health and well-being in the world would call for effective mitigation. Deploying such measures would significantly reduce the cases of foodborne diseases all over the world significantly every year and protect generations for good.

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