THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
Popular Article
June, 2026 Vol.6(6), 1680-1686

Escherichia coli as a foodborne pathogen: a mini review

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doi.org/10.5281/ScienceWorld.20776959

Abstract

Foodborne diseases are critical public health issues caused by the consumption of microbes-contaminated food and water. *Escherichia coli* is one of among foodborne bacteria. Although most of strains of *E.coli* are harmless, pathogenic strains such as ETEC, EPEC, EHEC/STEC, EIEC, and EAEC cause serious illnesses such as diarrhea, bloody diarrhea, urinary tract infections, septicemia, and hemolytic uremic syndrome. The pathogenicity of *E. coli* is determined by presence of various virulence factors responsible for adhesion, enterotoxins, shiga toxins, hemolysin, capsule formation, and biofilm formation. Currently, antimicrobial resistance, especially MDR and ESBL-producing *E. coli*, has become a serious global concern. STEC infections and outbreaks have been reported worldwide, including in India, primarily associated with contaminated meat, milk, vegetables, water, and poor sanitation. Traditional immunological, molecular, and rapid automated techniques are now being used to identify foodborne pathogens. Food hygiene, proper sanitation, effective surveillance systems, and judicious use of antibiotics are essential for the prevention and control of foodborne diseases.

Key words: Foodborne diseases, *Escherichia coli*, STEC and Virulence factors

Introduction

Foodborne diseases are infections caused by the consumption of contaminated food and water, and considered as serious public health issue worldwide. Foodborne diseases affect millions of people each year. Foodborne illnesses reported to have more severe effects in children, the elderly and immune-compromised individuals. Foodborne pathogens are microorganisms, include bacteria, viruses, parasites, and fungi that enter the body through

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contaminated food and cause infections in host. Poor sanitation, contaminated water, improper food processing, improper storage, and unsanitary way of food handling are the main causes of foodborne illnesses. Major foodborne pathogens include *Salmonella* spp., *Staphylococcus aureus*, *Listeria monocytogenes*, *Campylobacter jejuni*, and *Escherichia coli*. All these microbes mostly responsible for gastrointestinal infections and food poisoning. Foodborne pathogens can survive in food for longer period and multiply exponentially under suitable temperature, produce toxins, survive for long periods in contaminated food, and spread rapidly during favorable condition. Some pathogens can survive low temperature of refrigerator, while others produce heat-resistant toxins.

Escherichia coli as a foodborne pathogen

Escherichia coli (*E. coli*) are important bacteria belong to the *Enterobacteriaceae* family. It was first described by Theodor *Escherich*. It is a major component of the intestinal microflora. Although, most strains are harmless, but some pathogenic strains cause diseases. Morphologically, *E. coli* is a Gram-negative, rod-shaped (approximately 2–6 µm in length), facultative anaerobic, non-spore-forming, and motile bacterium. It forms pink colonies fermenting lactose on MacConkey agar. The pathogenic strain *E. coli* O157:H7 is identified as colorless colonies on Sorbitol MacConkey (SMAC) agar as it unable to ferment sorbitol. *E. coli* is distributed ubiquitously in soil, water, sewage, and various foods. It enters the food chain through contaminated water, animal feces, raw or undercooked meat, unpasteurized milk, contaminated vegetables, and unhygienic food handling, causing foodborne infections.

Virulence determinants and pathotypes of *E. coli*

The pathogenicity of *Escherichia coli* (*E. coli*) express various virulence factors facilitating adherence to host cells/tissues, multiply inside host, evade the host immune system, and toxins. The major virulence factors are:

i. Adhesins (Fimbriae/Pili): These help the bacterium adhere to intestinal epithelial cells.

ii. Colonization factors: They help in colonization in host and establish infection in the intestine.

iii. Enterotoxins: Heat-labile toxin (LT) and heat-stable toxin (ST) increase secretion of water and electrolytes and cause diarrhea.

iv. Shiga toxins (Stx1, Stx2): Shiga toxins cause severe damage by inhibiting protein synthesis in cells and can cause Hemolytic Uremic Syndrome (HUS).

v. Hemolysin: A toxin that lyse red blood cells in host body.

vi. Capsule (K antigen): responsible for evasion of host immune system and phagocytosis.

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vii. Lipopolysaccharide (LPS/O antigen): These are endotoxins, cause inflammation and fever.

viii. Flagella (H antigen): Flagella antigen provides motility, allowing the bacterium to spread infection among hosts.

ix. Type III secretion system (T3SS): Allows virulence proteins to enter host cells.

x. Intimin and Invasins proteins: Intimin facilitates attachment to intestinal cells of host and invasion helps in entry into host tissues. Both virulence factors are central to attaching and effacing of enterohaemorrhagic *E.coli* in host.

xi. Biofilm formation: *E. coli* can survive adverse conditions and antimicrobial agents by forming a biofilm.

xii. Siderophores/ Iron acquisition systems: The virulence factors associated with this system aids in growth and survival by acquiring iron from the host.

xiii. Serum resistance factors: The factors help to evade the complement system.

xiv. Plasmid-mediated virulence genes: Many virulence traits are controlled by plasmids.

Due to these virulence factors, pathogenic *E. coli* can cause gastrointestinal infections, urinary tract infections, septicemia, and foodborne outbreaks.

Pathogenic *Escherichia coli* types

***E.coli* pathotypes**	**Syndromes/ Diseases**	**Associated important virulence factors**
Enterotoxigenic *E. coli* (ETEC)	Watery diarrhea, traveler's diarrhea	Heat-labile (LT), Heat-stable (ST) toxins, Colonization factor antigens (CFA/II, CFA/I)
Enteropathogenic *E. coli* (EPEC)	Infantile diarrhea	Intimin (*eae*) protein, Bundle-forming pilus (BFP)
Enterohemorrhagic*E.coli* / Shiga toxin-producing *E. coli*	Bloody diarrhea, Hemolytic Uremic Syndrome (HUS)	Shiga toxins (Stx1 and Stx2), Intimin (*eae*) protein, α-Hemolysin (Hly),
Enteroinvasive *E. coli* (EIEC)	Dysentery-like diarrhea	Aerobactin, Invasion plasmid antigen (IPA)

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Entero-aggregative *E. coli* (EAEC)	Persistent diarrhea	Aggregative adherence fimbriae I, Low molecular weight heat-stable toxins
Diffusely Adherent *E. coli* (DAEC)	Childhood diarrhea	Diffuse adherence adhesins
Uropathogenic *E. coli* (UPEC)	Urinary tract infections (UTIs)	P fimbriae, hemolysin, iron acquisition systems
Neonatal meningitis-associated *E. coli* (NMEC)	Neonatal meningitis, sepsis	K1 capsule, serum resistance
Avian Pathogenic *E. coli* (APEC)	Poultry infections (colibacillosis)	Adhesins, toxins, serum resistance

Global and Indian status of STEC infections and outbreaks

Shiga toxin-producing *Escherichia coli* (STEC) are currently a major foodborne pathogen, posing a serious challenge to global public health. More than 1,000 STEC outbreaks have been reported in over 30 countries worldwide. Globally, *E. coli* O157:H7 is the most prevalent and clinically significant STEC serotype, causing major outbreaks in several countries, including the United States, Canada, Japan, the United Kingdom, and Germany. The 1996 outbreak caused by *E. coli* O157:H7 in Sakai City, Japan, is considered one of the largest STEC outbreaks to date, affecting approximately 8,000 people. Additionally, several severe cases of hemolytic uremic syndrome (HUS) were reported during an outbreak related to *E. coli* O104:H4 in Germany in 2011.Major sources of STEC infection include contaminated meat, dairy products, green leafy vegetables, sprouts, and contaminated water. In addition to O157:H7, other pathogenic serotypes of *E.coli* such as O26, O111, O103, O121, O145, and O45 have also been associated with outbreaks in various regions of the world.

STEC outbreaks in India are relatively underreported, although cases have been reported from various states. Most infections have been linked to contaminated food, drinking water, inadequate sanitation, and animal-based foods. Various studies have confirmed the presence of STEC in raw milk, meat, vegetables, and street food. Severe symptoms such as diarrhea, bloody diarrhea, and HUS have also been observed in children. Limited surveillance systems, inadequate molecular diagnostic facilities, and a lack of awareness have prevented a full assessment of the true prevalence of STEC infections in India. However, rapid

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urbanization, increased food processing, and sanitation problems are making STEC an emerging public health challenge in India.

Antimicrobial Resistance (AMR) in *E. coli*

Antimicrobial resistance (AMR) is a condition in which *E. coli* develops resistance to antibiotics. Excessive and inappropriate uses of antibiotics are major cause of AMR. Resistance genes in *E. coli* can be transferred from one bacterium to another through mobile genetic elements *i.e*. plasmids, transposons, and integrons. Multidrug-resistant (MDR) *E. coli* strains have been isolated from various samples by many research groups and found to become resistant to many antibiotics such as penicillin, cephalosporins, fluoroquinolones, and aminoglycosides. Extended Spectrum Beta-Lactamase (ESBL)-producing *E. coli* are particularly important because they can inactivate many beta-lactam antibiotics. Carbapenem-resistant *E. coli* strains are also currently a global concern. AMR complicates treatment and can increase the severity and mortality of infections.

Detection of pathogenic *E.coli*

Conventional, immunological, molecular, and automated methods are used to identify pathogenic *E. coli* strains. Conventional methods involve isolating *E. coli* on selective and differential media, such as MacConkey Agar, EMB Agar, and Sorbitol MacConkey Agar (SMAC), followed by confirmation by Gram staining and set of biochemical tests such as indole, methyl red, voges-proskauer, citrate (collectively called as IMViC test) and triple sugar iron (TSI).Immunological techniques include ELISA and latex agglutination tests to identify specific serotypes and toxins. Molecular methods such as PCR, multiplex PCR, real-time PCR, DNA sequencing, and whole genome sequencing (WGS) are capable of rapid, sensitive, and accurate identification of pathogenic *E. coli*. These techniques primarily detect virulence genes such as *stx1*, *stx2*, *eaeA*, and *hlyA*. Recently, the use of advanced automated technologies such as MALDI-TOF MS, biosensors, and VITEK 2 compact have been increasingly used rapid and reliable identification of pathogenic *E. coli*. All these methods play an important role in food safety surveillance, outbreak investigation, clinical diagnosis, and public health monitoring.

Management of *E. coli* causing foodborne illnesses

Management of *E. coli*-related foodborne illnesses involves early diagnosis, appropriate treatment, and infection prevention. In most cases, treatment is supportive, with adequate fluids, ORS, and electrolyte balance being crucial. In severe cases, hospitalization and intravenous fluids may be necessary. Antibiotics may be used in some non-STEC infections based on medical advice and antimicrobial susceptibility testing. However,

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antibiotics are generally avoided in STEC infections because they may increase the risk of HUS. Disease prevention requires thorough cooking, the use of safe drinking water, regular hand washing, separation of raw and cooked foods, and adherence to food safety measures such as good manufacturing practices (GMPs), good hygienic practices (GHPs) and hazard analysis and critical control point (HACCP) systems GHP. Additionally, regular surveillance and rapid outbreak investigation play a crucial role in infection control.

Conclusion

Foodborne diseases remain a serious public health problem globally, affecting human health, food security, and economic conditions. *Escherichia coli* are considered as important foodborne pathogens due to its diverse pathogenic species, virulence factors, and increasing antimicrobial resistance. STEC infections and outbreaks have been linked to contaminated food, water, and poor sanitation worldwide and in India. The increasing incidence of MDR, ESBL-producing, and carbapenem-resistant *E. coli* has made treatment more difficult and expensive. Conventional, immunological, molecular, and automated techniques play important role in the rapid and accurate identification of foodborne pathogens. However, occurrence of foodborne diseases can be controlled through food safety, hygiene, effective surveillance systems, public awareness, and appropriate use of antibiotics.

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