REVIEW ON ESCHERICHIA COLI AND ITS PUBLIC HEALTH IMPACT

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SUMMARY : *Escherichia coli* is a significant public health concern due to its pathogenic strains, which can lead to severe foodborne illnesses. This review synthesizes current literature on *E. coli's* impact on public health, focusing on its transmission routes, pathogenicity, and the importance of food safety measures. It also examines the public health implications of E. coli, particularly its presence in food and water, and highlights the need for improved hygiene practices, the importance of hygiene and sanitation in preventing outbreaks. The aim of this review were focused on identifying the factors contributing to *E. coli* presence in food, understanding its pathogenicity, and assessing its environmental implications, evaluating the overall public health risks associated with E. coli infections and promoting food safety practices. Prevention and control is thorough hand washing and proper food handling, can significantly reduce the risk of infection, vaccination strategies and research into novel antimicrobial agents and alternative therapies is also gaining momentum, aiming to reduce reliance on traditional antibiotics while effectively managing infections. The treatment was by using alternative therapies, such as phage therapy, are being investigated to address antibiotic resistance and effectively target pathogenic strains. Research is also looking into the use of probiotics to restore healthy gut flora, potentially reducing the incidence of infections caused by pathogenic *E. coli*.

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1. INTRODUCTION

Escherichia coli is a rod-shaped, Gram-negative bacterium, and classified as a member of the family Enterobacteriaceae within the Gammaproteobacteria class. *Escherichia coli* is among one of the well-studied bacteria. *Escherichia coli* can grow rapidly under optimal growth conditions, replicating in ~20 min. Many gene manipulation systems have been developed using *E. coli* as the host bacterium, producing countless enzymes and other industrial products. Genome sequence analysis of *E. coli* was first reported in 1997. Since then, more than 4800 *E. coli* genomes have been sequenced. The fastgrowth characteristics of *E. coli* make it suitable to study the evolution of micro-organisms and a long-term experimental evolution study of *E. coli* involving more than 50 000 generations is ongoing (Tenaillon *et al*. 2016). Infection with *Escherichia coli* serotype is associated with a spectrum of illnesses including watery diarrhea, bloody diarrhea, and the hemolytic uremic syndrome, a potentially fatal condition characterized by acute renal failure (Griffin and Tauxe, 1991).

Escherichia coli is linked to foodborne illnesses, with pathogenic strains causing severe health issues like diarrhea and hemorrhagic colitis (Mulyati *et al*., 2024; Bairi *et al*., 2024). It is a diverse group of bacteria, with some strains causing severe gastrointestinal diseases. The increasing prevalence of pathogenic *E. coli* strains, particularly Verocytotoxigenic *E. coli* (VTEC), is a major cause of foodborne illnesses, leading to severe conditions like Hemorrhagic Uremic Syndrome in food sources, poses a significant risk to public health (Mulyati *et al*., 2024; Bairi *et al*., 2024).

Most strains of *E. coli* are harmless and even beneficial for digestion and immunity (Westendorf *et al*., 1917). However, some strains can cause serious illnesses, such as diarrhea, urinary tract infections, pneumonia, or blood infections. These strains are called pathogenic *E. coli* and they produce toxins that damage the cells of the body (Smith *et al.*, 2017). *Escherichia coli* is a gram-negative, rod-shaped, facultative anaerobe that can grow and reproduce in various environments and conditions (Jang *et al*., 2017). *Escherichia coli* significantly impacts public health, primarily through foodborne illnesses linked to contaminated meat and dairy products. In recent years, outbreaks linked to contaminated produce and undercooked meats have underscored the urgency of addressing these risks through enhanced surveillance and education initiatives. Furthermore, the role of environmental factors, such as water quality and agricultural practices, cannot be overlooked in mitigating the spread of these harmful strains. Effective monitoring and control measures are essential to mitigate these risks, including regular testing of food products and water sources (Kornacki and Marth, 1982).

Escherichia coli are naturally found in the human and animal microbiome, functioning as facultative anaerobes. They play a crucial role in the gastrointestinal environment, contributing to the overall microbial balance (Corcionivoschi *et al*., 2024). These bacteria assist in digestion, synthesize essential vitamins, and protect against pathogenic organisms, highlighting their importance in maintaining health. They also participate in the fermentation of undigested carbohydrates, producing short-chain fatty acids that serve as an energy source for colon cells and have anti-inflammatory properties (Lorenz and Donnenberg, 2009).

Escherichia coli presence in food is influenced by factors such as food handler hygiene and environmental conditions. The bacterium's zoonotic strains, particularly Verocytotoxigenic *E. coli* (VTEC), are critical public health concerns due to their potential to cause severe illness (Bairi *et al*., 2024; Mohamed and Habib, 2024). Effective surveillance systems and public awareness campaigns are vital in preventing transmission and ensuring timely intervention during outbreaks. The rising global population and meat consumption create challenges for food safety, necessitating a focus on the risks associated with *E. coli* contamination in food products. To address these challenges, it is essential to enhance monitoring systems and invest in research that explores innovative methods for detecting and mitigating *E. coli* in agricultural settings (Phillips, 1999).

Escherichia coli encompasses a diverse range of strains, some of which are pathogenic and responsible for significant health issues. Understanding its pathogenesis, prevention, control, and treatment is crucial for public health. *E. coli* is a diverse group of bacteria, with certain strains posing severe health risks. The rise of antibiotic-resistant strains, such as carbapenem-resistant *E. coli* (CREC), further complicates public health responses (Li *et al*., 2024). These strains can lead to increased morbidity and mortality, necessitating urgent action from health authorities and policymakers to address the underlying causes of contamination. Contamination Sources: Cattle are primary reservoirs for VTEC, and their fecal shedding can contaminate food, water, and the environment. Contaminated meat and dairy products are common transmission routes (Doyle and Erickson, 2012). The epidemiology of Escherichia coli reveals significant public health implications due to its diverse pathogenic strains and increasing antimicrobial resistance. *E. coli* is a leading cause of foodborne illnesses, particularly through zoonotic transmission from contaminated meat and dairy products (Bairi *et al*., 2024; Onwumere-Idolor *et al*., 2024).

According to the World Health Organization, Shiga toxin-producing E. coli (STEC) causes about 2.8 million cases of diarrhea and 3,000 deaths every year worldwide (Rivas *et al*., 2015). The United States Food and Drug Administration (FDA) reported that previous United States outbreaks of pathogenic *E. coli* have involved leafy greens, sprouts, raw milk and cheeses, and raw beef and poultry (Marler, 2011). According to the FDA, some of the foods that have been linked to *Escherichia coli* outbreaks in the past include leafy greens, sprouts, raw milk and cheeses, and raw beef and poultry. These foods can become contaminated by contact with animal feces during harvesting, processing, or storage, or by cross-contamination with other foods or utensils. To prevent *E. coli* infection, the FDA advises consumers to wash their hands and produce before eating, cook meat and poultry thoroughly, avoid raw milk and unpasteurized cheeses, and refrigerate leftovers promptly. Public Education and Monitoring: The introduction stresses the importance of educating the public about the risks associated with improper meat handling and contamination. It also highlights the necessity of monitoring and surveillance of meat quality in local markets to ensure food safety, underscoring the critical need to manage *E. coli* contamination effectively to protect public health (Bairi *et al*., 2024).

Writing a review on Escherichia coli and its public health impact is crucial due to its significant role in foodborne illnesses and antimicrobial resistance. *E. coli*, particularly pathogenic strains like Verocytotoxigenic *E. coli* (VTEC), poses severe health risks, including Hemorrhagic Uremic Syndrome, primarily through contaminated meat and dairy products (Bairi *et al*., 2024). The misuse of antimicrobials in agriculture has led to the emergence of extended-spectrum beta-lactamase (ESBL)-producing E. coli, complicating treatment options and threatening public health (Ribeiro *et al*., 2024). Furthermore, factors such as poor food sanitation and hygiene practices contribute to *E. coli* prevalence in food (Mulyati *et al*., 2024). Understanding the mechanisms of *E. coli* attachment to meat can inform better food safety practices (Corcionivoschi *et al*., 2024). Lastly, the situation in the Arab countries highlights the urgent need for comprehensive surveillance and control measures against harmful *E. coli* strains in the food supply (Mohamed and Habib, 2023).

1.1. **Objectives**

- To identify factors in food contamination to investigate personal hygiene of food handlers, food sanitation practices, and

environmental conditions that contribute to *E. coli* presence.
- To assess pathogenic strains to describe the virulence factors and antibiotic resistance of extraintestinal pathogenic *E. coli* (ExPEC).
- To understand the public health implications of E. coli infections, particularly from zoonotic strains like Verocytotoxigenic *E. coli* (VTEC).
- To promote Food Safety and advocate improved hygiene practices and monitoring in food production to mitigate *E. coli* contamination.

2. *ESCHERCHIA COLI* AND ITS PUBLIC HEALTH IMPACT

2.1. **Overview of zoonotic *Escherichia coli***

Zoonotic *Escherichia coli* represent a significant public health concern due to its potential to cause severe foodborne illnesses. Various strains, particularly Verocytotoxigenic *E. coli* (VTEC), are linked to outbreaks and can lead to serious conditions such as Hemorrhagic Uremic Syndrome (Bairi *et al*., 2024). The primary reservoirs for these pathogens include cattle, which can contaminate food and water through fecal shedding (Bairi *et al*., 2024).
Zoonotic transmission of *E. coli* can be transmitted from animals to humans through contaminated food, water, and direct contact with animals (Abey *et al*., 2024). Studies indicate that approximately 8% of human extraintestinal infections are attributed to foodborne zoonotic *E. coli* strains (Liu *et al*., 2023). Inadequate cooking of meat, especially ground beef, and improper handling of fresh produce are common pathways for infection, highlighting the importance of food safety practices in preventing outbreaks (Hogg *et al*., 2009).
Antimicrobial resistance of many zoonotic *E. coli* strains exhibit multidrug resistance, complicating treatment options (Abey *et al*., 2024). Extended-spectrum β-lactamase (ESBL) producing strains have been identified in both pets and livestock, highlighting the need for surveillance (Soares *et al*., 2022).
Public health implications of the close interaction between humans and animals increases the risk of zoonotic transmission, necessitating improved hygiene practices in food handling and animal husbandry (Soares *et al*., 2022; Saidenberg *et al*., 2022). While zoonotic *E. coli* poses significant risks, ongoing research is essential to understand its transmission dynamics and develop effective control measures.

2.2. **Etiology of zoonotic *Escherichia coli***

The etiology of zoonotic Escherichia coli primarily involves pathogenic strains that can be transmitted from animals to humans, leading to various diseases. The most significant zoonotic group is Shiga toxin-producing *E. coli* (STEC), particularly *E. coli* O157, which is associated with severe human illnesses such as hemorrhagic colitis and hemolytic uremic syndrome (Wasteson, 2002; Caprioli *et al*., 2005).
Pathogenicity groups are STEC which is the primary zoonotic concern, with cattle as the main reservoir. These strains produce shiga toxins, which are crucial for their virulence (Caprioli *et al*., 2005). Extraintestinal pathogenic *E. coli* (ExPEC) which includes strains that can cause urinary tract infections and other systemic diseases. Poultry and other farm animals are recognized reservoirs for these pathogens (Bélanger *et al*., 2011; Mitchell *et al*., 2015).
Transmission pathways are foodborne transmission that of contaminated meat and dairy products are common sources of STEC infections in humans (García *et al*., 2010; Mitchell *et al*., 2015). Environmental exposure when contact with animal feces or contaminated water can also facilitate transmission (Caprioli *et al*., 2005). While zoonotic *E. coli* poses significant health risks, understanding its transmission dynamics and reservoirs is crucial for effective prevention strategies. However, the complexity of its ecology in animal populations remains an area requiring further research.

2.3. Epidemiology of E. coli

Escherichia coli is a major public health concern because it can cause outbreaks of disease that affect many people and have serious consequences (Yang *et al*., 2017). The centers for disease control and prevention estimates that Shiga toxin-producing *E. coli* (STEC) causes about 265,000 illnesses, 3,600 hospitalizations, and 30 deaths in the United States each year (Collier *et al*., 2014). *Escherichia coli* infections can occur through ingestion of contaminated food or water, contact with infected animals or their feces, or contact with infected individuals or their feces (Locking *et al*., 2001). The risk of infection can vary depending on the type and amount of *E. coli* ingested the susceptibility and immune status of the host, and the presence of other factors that may facilitate or inhibit the infection. Prevalence in Children: enterotoxigenic *E. coli* (ETEC) infections account for significant morbidity, with a 73 per 100 child-years incidence rate in Lima, Peru (Pajuelo *et al*., 2024). This highlights the urgent need for targeted interventions and public health strategies to mitigate the impact of these infections, particularly in vulnerable populations.

Some of the risk factors associated with *E. coli* infections include: eating raw or undercooked meat, especially ground beef; drinking raw or unpasteurized milk or juice; eating raw or unwashed fruits and vegetables, especially sprouts; drinking or swimming in contaminated water; traveling to areas with poor sanitation and hygiene; having contact with farm animals or their feces; having contact with people who have diarrhea or who do not wash their hands properly; being young, elderly, pregnant, or immunocompromised; and taking antibiotics or antacids that may alter the intestinal flora (WHO, 2022; Bacteria and Viruses, 2023). Zoonotic Transmission: Contamination of beef with *E. coli* O157 and other strains at processing points is a critical public health concern, with a 13.8% prevalence noted in Nigeria (Onwumere-Idolor *et al*., 2024). Increased Surveillance: Enhanced monitoring of food sources and improved hygiene practices are essential to mitigate the risks associated with these pathogens.

Escherichia coli infections can affect anyone, but some populations (e.g., children, elderly, immunocompromised individuals) are more vulnerable to severe outcomes and complications (Esme *et al*., 2019). These include: children under 5 years of age, who are more likely to develop Hemolytic Uremic Syndrome (HUS) and kidney failure; elderly people over 65 years of age, who may have weaker immune systems and underlying health conditions; pregnant women, who may experience miscarriage, premature delivery, or stillbirth; and immunocompromised individuals, who may have reduced ability to fight off infections Hemolytic Uremic Syndrome (HUS). These populations should take extra precautions to avoid exposure to *E. coli* and seek medical attention promptly if they experience symptoms of infection. Antimicrobial Resistance: The rise of multidrug-resistant *E. coli* strains, particularly ST131, highlights the urgent need for monitoring and intervention strategies (Holland *et al*., 2020). Emerging Research: Recent studies suggest that environmental factors, such as climate change and urbanization, may further exacerbate the spread of these resistant strains, necessitating a comprehensive approach to public health policy (Al-Otaibi and Bukhari, 2017).

2.4. Environmental factors influencing the growth and survival of *Escherichia coli*

The growth and survival of *E. coli* in natural environments can be influenced by both biotic and abiotic factors (Rochelle-Newall *et al*. 2015). Abiotic factors include temperature, water and nutrient availability, pH, and solar radiation. Biotic factors include the presence of other micro-organisms, and the ability of *E. coli* to acquire nutrients, compete with other micro-organisms and form biofilms in natural environments. These factors are discussed in detail below:

2.4.1. Temperature

Temperature is probably the most important factor influencing *E. coli* survival and growth in the environment. While temperature is stable and optimal for *E. coli* growth (36–40°C) in the intestinal tract of warm-blooded animals, temperature in natural environment is generally low (<30°C). *Escherichia coli* can grow in soil at temperatures >30°C, although their death rate is faster in warm (>30°C) than cold (<15°C) temperatures (Ishii *et al*. 2006, 2010). For example, *E. coli* survived for over 6 months in sun-dried algal mats stored in airtight plastic bags at 4°C (Whitman *et al*. 2003), indicating that *E. coli* have the ability to survive long term under temperature conditions lower than that in host bodies.

2.4.2. Water availability

Natural or substrate-induced (salt or sugar) low water activity (or potential) controls what microbes have the potential to grow given that all other factors are in acceptable tolerance ranges. Desiccation is one of the common stresses to bacteria in natural environments (Evans and Wallenstein 2012). Rehydration can cause an anoxic environment around the cells (van Elsas *et al*. 2011); therefore, *E. coli* and other bacteria need to adjust their membranes and gene regulation to adapt to the desiccation and rehydration cycles (Evans and Wallenstein 2012). *E. coli's* presence in water sources indicates fecal contamination, raising public health alarms regarding water quality (Jang *et al*., 2017).

2.4.3. Nutrient availability

The availability of nutrients such as carbon, nitrogen and phosphorus is also an important factor influencing *E. coli* survival and growth in the environment. Natural environments are generally low in readily available nutrients compared with the intestinal tract of warm-blooded animals. *Escherichia coli* is versatile in energy acquisition and can degrade various kinds of carbon substrates, including aromatic compounds (Díaz *et al*. 2001)

2.4.4. pH

Environmental pH can also influence the survival and growth of *E. coli* in soil, and the level of pH resistance varies by strains (van Elsas *et al*. 2011). *Escherichia coli* serotype O157:H7 strains showed superior survival at low pH, as compared to non-O157 *E. coli* strains (Lin *et al.* 1996). Similar to acidophiles, some *E. coli* O157:H7 strains can survive better at low pH than at relatively high pH (van Elsas *et al*. 2011). Therefore, specific *E. coli* strains could survive selectively, influenced by local pH of the environment.

2.4.5. Solar radiation

Solar radiation is the most effective abiotic factor causing death of fecal indicator bacteria (FIB) in environmental waters. The inactivation process of fecal indicator bacteria (FIB) by sunlight involves three major mechanisms utilizing photobiological, photooxidative and photochemical pathways. Solar radiation, especially those in the lower wavelengths (i.e. ultraviolet (UV) light) can directly cause DNA damage (photobiological mechanism) and oxidation of cellular contents (photooxidative mechanism), but these mechanisms are effective only at depths to which sunlight reaches (e.g. upper surface water) (Whitman *et al*. 2004).

2.4.6**.** Presence of other micro-organisms

Escherichia coli interacts with other micro-organisms in all natural habitats. *Escherichia coli* can be predated by protozoa and lysed by phages. These two biological mechanisms have been reported to be responsible for up to 70% of the fecal indicator bacteria (FIB) removal over 120 h in river water (Korajkic *et al*. 2014). *Escherichia coli* also needs to compete with indigenous micro-organisms for limited nutrient sources, and defend themselves from antagonism in the environment.

2.4.7**.** Ability to form biofilms

Biofilms formed by *E. coli* on surfaces in aquatic environments, such as sediments, is a well-known factor contributing to the persistence of *E. coli* in natural environments (Lee *et al*. 2006). Biofilms protect the bacteria from hostile environmental conditions such as ultraviolet UV radiation, desiccation, protozoan predators, and chemicals including antibiotics and disinfectants (McDougald *et al*. 2012).

3. **PUBLIC HEALTH IMPACT**

Vulnerable populations are more susceptible to severe *E. coli* infections. *Escherichia coli* infections can affect anyone, but some populations (e.g., children, elderly, immune compromised individuals) are more vulnerable to severe outcomes and complications (Esme *et al*., 2019). These include: children under 5 years of age, who are more likely to develop hemolytic uremic syndrome (HUS) and kidney failure; elderly people over 65 years of age, who may have weaker immune systems and underlying health conditions; pregnant women, who may experience miscarriage, premature delivery, or stillbirth; and immunocompromised individuals, who may have reduced ability to fight off infections (Hemolytic uremic syndrome (HUS)). These populations should take extra precautions to avoid exposure to *E. coli* and seek medical attention promptly if they experience symptoms of infection.

Extended-Spectrum Beta-Lactamase (ESBL) production is of importance not only in the nosocomial and long-term care perspectives but, also, for community-onset infections, with increasing reports of the latter. The transmission of ESBL-producing bacteria may occur from human to human, or from animal sources to humans via the food chain (Falagas and Karageorgopoulos, 2009). The clinical impact of infections by ESBL-producing *E. coli* strains has mainly been studied in hospitalized patients. These infections present a higher mortality rate associated with a delay in implementing an appropriate antimicrobial therapy, since empirically prescribed antibiotics may not be effective in this case (Falagas and Karageorgopoulos, 2009). In a study in Europe (Cassini *et al*., 2019) ESBL-producing *E. coli* infections were estimated to be in the order of 300,000 and to have caused 9000 attributable deaths. Besides, infections with ESBL-producing bacteria have been associated with longer hospital stays and with an increased burden on the health services (Schwaber and Carmeli, 2007).

The other important factor in predicting the public health significance of antimicrobial resistance of commensal *E. coli* is, that their resistance genes could be efficiently transferred in vivo to pathogenic strains of *E. coli* or to Salmonella and vice versa as indicated by molecular epidemiological data (Nógrády *et al*., 2006; Szmolka *et al*., 2011). This can be explained by assuming that the Multidrug Resistance (MDR) population of *E. coli* is not only becoming dominant in the intestine but as a result of possible antimicrobial interference and host response will start disseminating its versatile mobile genetic vectors, most often conjugative plasmids for antimicrobial resistance, or for increase fitness or virulence (Bonnet *et al*., 2009).

People with gastrointestinal tract and gastric problems may have lower levels of stomach acid, which is a natural defense against *E. coli* and other bacteria. Antacid or peptic ulcer medications can further reduce the acidity of the stomach, making it easier for *E. coli* to survive and cause infection (Peptic ulcer—symptoms and causes—Mayo Clinic, 2022; Helicobacter pylori, 2023). Some studies have suggested that people who use proton pump inhibitors (PPIs), a type of medication that blocks acid production in the stomach, may have a higher risk of developing *E. coli* infections, especially STEC infections (Jaynes and Kumar, 2019). This may be due to the altered gastric pH, the reduced bacterial diversity in the gut, or the increased susceptibility to foodborne pathogens.

Escherichia coli infections lead to substantial economic costs and morbidity health burdens globally, with rising antibiotic resistance complicating treatment, with billions spent annually on treatment (Pokharel *et al*., 2023). Efforts to enhance surveillance and rapid response systems are crucial in mitigating these impacts, ensuring timely interventions and better resource allocation during outbreaks. Pathogenic Strains: Certain *E. coli* strains, such as O157:H7, are known to cause severe gastrointestinal diseases, leading to significant morbidity and mortality. Zoonotic Risks: The introduction also discusses the zoonotic potential of *E. coli*, particularly from chicken products to humans. The risk associated with extraintestinal pathogenic *E. coli* (ExPEC) is highlighted, as it is suspected to be present in poultry, although the full extent of this risk is not completely understood (Review of *Escherichia coli* Infection of Veterinary Importance, 2022).

Environmental Persistence: *E. coli* can persist in various environments, raising concerns about its potential to contaminate water sources and food supplies, thereby posing risks to public health. Indicator Limitations: The naturalization of *E. coli* in ecosystems challenges its effectiveness as a fecal indicator, necessitating more comprehensive monitoring strategies to safeguard public health.

3.1. Environmental concerns

Escherichia coli's presence in water sources indicates fecal contamination, raising public health alarms regarding water quality (Jang *et al*., 2017). Efforts to improve wastewater treatment and implement better agricultural practices are essential to reduce runoff and protect water supplies, while also fostering community engagement in monitoring local water quality.

3.2. Foodborne Illness

Escherichia coli is frequently transmitted through contaminated food and water, with cattle being a primary reservoir (Bairi *et al*., 2024). Efforts to mitigate this risk include stricter regulations on meat processing, increased testing for pathogens in food products, and public awareness campaigns that emphasize the importance of cooking meat thoroughly and washing hands after handling raw foods. Contamination often arises from poor hygiene practices among food handlers and inadequate food sanitation, leading to the spread of *E. coli* in food supplies (Caprioli *et al*., 2014; Luna-Guevara *et al*., 2019)

Factors such as poor hygiene among food handlers and inadequate food sanitation practices significantly increase the risk of *E. coli* contamination in food (Mulyati *et al*., 2024). In the Arab region, limited data on *E. coli* prevalence in food highlights the need for better surveillance (Mohamed and Habib, 2023). Moreover, public awareness campaigns aimed at educating consumers about safe food handling practices are essential to mitigate these risks and promote a culture of food safety.

3.3. **Antimicrobial resistance**

Extended-Spectrum Beta-Lactamase (ESBL)-producing *E. coli* poses a significant threat, with genetic similarities found between animal and human strains (Ribeiro *et al*., 2024). These developments underscore the urgency for implementing stricter regulations and promoting responsible antibiotic use in both agricultural and clinical settings.

The rise of multidrug-resistant *E. coli* strains complicates treatment options, necessitating preventive measures like vaccination (Pokharel *et al*., 2023). Additionally, research into alternative therapies and the development of new antibiotic is crucial to combat this growing threat, alongside promoting responsible antibiotic use in both human medicine and agriculture. The emergence of antimicrobial-resistant *E. coli* strains further complicates public health responses (Ribeiro *et al*., 2024). The emergence of carbapenem-resistant *E. coli* (CREC) in healthy population raises concerns about antibiotic resistance, complicating treatment options and increasing public health risks (Li *et al*., 2024). In response, health authorities must prioritize research and monitoring efforts to track the spread of CREC, while also implementing stricter regulations on antibiotic use in both human medicine and agriculture (Szmolka and Nagy, 2013).

3.4. **Pathogenicity**

Pathogenic Strains: *E. coli* comprises various strains, with pathogenic types like Verocytotoxigenic *E. coli* (VTEC) is a major concern, causing severe gastrointestinal diseases, including Hemolytic Uremic Syndrome and diarrhea. Cattle are primary reservoirs, contributing to contamination of food and water sources (Bairi *et al*., 2024). Research indicates that VTEC can be transmitted through various routes, including contaminated water and direct contact with infected animals, highlighting the need for comprehensive strategies to reduce exposure and improve food safety standards. The bacterium can contaminate food and water, primarily through animal reservoirs, particularly cattle (Mohamed and

Habib, 2023). A research into innovative agricultural techniques and the development of rapid testing methods can enhance our ability to detect and respond to potential outbreaks swiftly. One of the most common and dangerous types of pathogenic *E. coli* is called Shiga toxin-producing *E. coli* (STEC) (Paton, 1998).

Pathogenic *E. coli* strains utilize various virulence factors, including adhesins, toxins, and biofilm formation, to establish infections in humans. Uropathogenic *E. coli* (UPEC) is particularly notable for causing urinary tract infections (UTIs) due to its ability to transition from the intestinal tract to the urinary system (Kot, 2017). Quorum sensing mechanisms also play a role in regulating virulence factor expression (Mayer *et al*., 2023). In addition, enterotoxigenic *E. coli* (ETEC) is a leading cause of traveler's diarrhea, employing heat-labile and heat-stable toxins to disrupt intestinal function and promote fluid secretion. These diverse pathogenic strategies highlight the adaptability of *E. coli* and underscore the need for targeted interventions to mitigate its impact on global health. Research into vaccines and novel therapeutic approaches is ongoing, aiming to reduce the incidence of infections caused by these strains and improve treatment outcomes for affected individuals. While many *E. coli* species are harmless, certain strains can become opportunistic pathogens. These pathogenic strains are responsible for severe infections in humans, particularly the enterotoxigenic, enteroinvasive, enteropathogenic, and enterohemorrhagic *E. coli* (Corcionivoschi *et al*., 2024).

Escherichia coli includes not only commensal strains but also pathogenic ones that cause a variety of human diseases resulting in more than 2 million deaths each year (Kaper *et al.* 2004). *E. coli* is, however, a particularly complex species, having diversified into pathogenic strains. Based on the type of virulence factor present, and the host's clinical symptoms, *E. coli* strains are classified into pathotypes of zoonotic intestinal pathogenic *E. coli* (IPEC) or extraintestinal pathogenic *E. coli* (ExPEC) (Lindstedt *et al*., 2018). There are six well-studied intestinal pathotypes of *E. coli*, including Shiga toxin-producing *E. coli* (STEC), enteropathogenic *E. coli* (EPEC), enterotoxigenic *E. coli* (ETEC), enteroaggregative *E. coli* (EAEC), diffusely adherent *E. coli* and enteroinvasive *E. coli*, including Shigella strains. These strains are classified by virulence properties and pathogenicity mechanisms causing gastrointestinal diseases such as diarrhoea (Nataro and Kaper 1998; Kaper *et al*. 2004; Alizade *et al.*, 2019). Food poisoning outbreaks have been particularly associated with Verocytotoxigenic *E. coli* (VTEC) and, to a lesser extent, enteropathogenic *E. coli* (EPEC), enterotoxigenic *E. coli* (ETEC) and enteroaggregative *E. coli* (EAggEC) strains (Basak Unver and Ahmet, 2017). The *E. coli* O157:H7 VTEC strain has become widely recognized as a very important cause of foodborne illness (Nileshkumar *et al*., 2015).

Water Quality: *E. coli* serves as an indicator of fecal contamination in water bodies, impacting both public health and aquaculture. Studies show significant *E. coli* presence in coastal lagoons and reservoirs, highlighting environmental risks (Najiah *et al*., 2023). These findings underscore the need for comprehensive monitoring and management strategies to ensure safe water sources and protect aquatic ecosystems. Regional Insights: In Arab countries, the prevalence of harmful *E. coli* in food supplies is under-researched, indicating a gap in food safety measures (Mohamed and Habib, 2023). This lack of data calls for targeted research initiatives to assess the extent of contamination and develop effective interventions tailored to local conditions.

Commensal and pathogenic *E. coli* strains display diverse phenotypic and genotypic variants. *E. coli* has been traditionally serotyped based on three types of somatic (O), capsular (K) and flagellar (H) antigens, and more than 700 *E. coli* serotypes have been identified based on the combination of O and H antigens (Nataro and Kaper 1998). *Escherichia coli* strains can be also classified into several phylogenetic groups: A, B1, B2 and D (Clermont *et al*. 2000).

Escherichia coli infections can indeed lead to chronic health conditions, as evidenced by various studies highlighting their long-term impacts. The following sections outline key findings from recent research.

Chronic Urinary Tract Infections (UTIs): *E. coli* is a primary cause of chronic urinary tract infections (cUTIs), which can be classified into persistent and recurrent types. Persistent infections are often linked to specific virulent strains that exhibit multidrug resistance, complicating treatment and leading to chronic health issues (Hernández-Chiñas *et al*., 2023).

Colibactin and Inflammatory Bowel Disease: Certain *E. coli* strains produce colibactin, a genotoxin that can disrupt colonic homeostasis. Following mucosal injury, these strains can cause chronic colitis, resembling human ulcerative colitis, by perpetuating inflammation and impairing tissue integrity (Harnack *et al*., 2023).

Chronic Sequelae of *E. coli* O157: A systematic review revealed that infections with *E. coli* O157 can lead to chronic conditions such as hemolytic uremic syndrome and inflammatory bowel disease, with significant proportions of affected individuals developing these sequelae (Keithlin *et al*., 2014).

The presence of mobile genetic elements such as plasmids, insertion sequences and transposons contributes to the plasticity of *E. coli*'s genome. Horizontal gene transfer has promoted the diffusion of antibiotic resistance genes among this species and other commensals (Raimondi *et al*., 2019) particularly in environments such as the intestinal tract, where the species diversity and bacterial population density are large. Therefore, *E. coli* has been used as a sentinel microorganism for antimicrobial resistance surveillance, especially in the case of the β-lactams (Nyirabahizi *et al*., 2020). The trends among food-producing animals are also evidenced by several other reports. Resistance to third-generation cephalosporins and quinolones was found among clinical *E. coli*, already resistant to most antimicrobials available for poultry, in a study conducted in 200 industrial poultry farms in Italy (Niero *et al*., 2018).

The long-term effects of *E. coli* infection can vary significantly depending on the context of the infection, including the host species and the specific strain involved. Research indicates that *E. coli* infections can lead to chronic health issues, particularly in the urinary and gastrointestinal systems.

Urinary Tract and Prostatic Health: In male mice, long-term *E. coli* infections resulted in increased prostatic inflammation and fibrosis, which are linked to urinary dysfunction. Mice with a history of repeated infections exhibited more severe bladder weight increases, indicating persistent urinary issues. In humans, similar patterns have been observed, with recurrent urinary tract infections often leading to complications such as interstitial cystitis and increased susceptibility to further infections (Erjavec and Zgur-Bertok, 2011). These complications can significantly quality of life, necessitating a deeper understanding of the underlying mechanisms and potential therapeutic interventions.

Gastrointestinal Impact: Colibactin-producing *E. coli* strains can cause long-term disruptions in colonic homeostasis, leading to chronic colitis. This condition is characterized by epithelial injury and inflammation, resembling human ulcerative colitis (Harnack *et al*., 2023). These findings underscore the importance of understanding the mechanisms behind *E. coli* pathogenesis, as they may inform potential therapeutic strategies for managing related chronic conditions in humans.

Bovine Health: In cattle, *E. coli* infections leading to mastitis have shown long-term effects on milk yield and quality. Cows with prolonged inflammation experienced significant reductions in daily milk production, with losses averaging 1,500 liters per cow (Blum *et al*., 2014). Additionally, the economic impact on dairy farms can be substantial, as decreased milk quality often results in lower market prices and increased veterinary costs. While these studies highlight severe long-term consequences of *E. coli* infections, it is essential to consider that not all infections lead to chronic conditions, and some individuals may recover fully without lasting effects (Blum *et al*., 2014).

Escherichia coli can cause a range of illnesses, from mild gastrointestinal disturbances to severe infections, contributing to substantial morbidity and mortality globally (Pokharel *et al*., 2023). These health risks are particularly pronounced in vulnerable populations, such as young children, the elderly, and those with compromised immune systems, highlighting the urgent need for targeted prevention strategies and effective response protocols. Inadequate cooking and poor hygiene practices further exacerbate the risk of transmission, highlighting the importance of public awareness and education in preventing outbreaks. Efforts to monitor and control *E. coli* outbreaks must involve collaboration between public health officials, farmers, and food industry stakeholders to implement effective safety measures and promote sustainable practices. These efforts, combined with policy changes that support sustainable farming and food safety regulations, can significantly reduce the incidence of infections and improve overall public health outcomes. Pathogenic *E. coli* strains are often present in food products, especially meat, which can become contaminated through exposure to animal feces. This contamination poses significant health risks, as farm animals serve as a natural reservoir for these bacteria (Corcionivoschi *et al*., 2024).

3.5. **Transmission**

Contaminated food, especially meat and dairy, is a primary transmission route, exacerbated by poor hygiene practices (Mulyati *et al*., 2024; Mohamed and Habib, 2023). Improving sanitation measures in food processing and handling, along with public awareness campaigns, can significantly reduce the risk of outbreaks. Contamination Sources: Cattle are primary reservoirs for Verocytotoxigenic E. coli (VTEC), and their fecal shedding can contaminate food, water, and the environment. Contaminated meat and dairy products are common transmission routes (Doyle and Erickson, 2012). Additionally, the role of environmental factors, such as agricultural practices and climate change, must be considered, as they can influence the prevalence and spread of these pathogens in both rural and urban settings. *Escherichia coli* can be transmitted to humans primarily through consumption of contaminated food or water, such as raw or undercooked ground meat products, raw milk, and contaminated raw vegetables and sprouts (Mesele and, Abunna, 2019). *Escherichia coli* can also be spread through direct contact with infected animals or their feces, or through person-to-person contact with infected individuals or their feces (Ferens and Hovde, 2011).

Reservoirs: *E. coli* strains can affect both humans and animals, with cattle, sheep, and poultry serving as reservoirs. Asymptomatic carriers in cattle contribute to food and water contamination. Understanding the dynamics of these reservoirs is vital for developing effective control strategies, including vaccination programs and improved farm management practices. Inadequate cooking and cross-contamination during food preparation further exacerbate the risk of transmission, highlighting the need for stringent hygiene protocols in both domestic and commercial kitchens (Besser *et al*., 2011).
One of the most common causes of *E. coli* O157:H7 outbreak is the consumption of undercooked beef or foods contaminated with beef. Such outbreaks are typically identified by a sudden increase in illness within a community, indicating a common-source outbreak. These outbreaks are usually short-lived, limited by the quantity and shelf life of the contaminated products (Review of *Escherichia coli* Infection of Veterinary Importance, 2022).

3.6. **Symptoms**

Escherichia coli infections present a range of symptoms that can vary in severity depending on the strain involved. Commonly, these infections lead to gastrointestinal disturbances, with diarrhea being a predominant symptom. The following sections outline the key symptoms associated with E. coli infections based on recent research. Diarrhea: Often loose and watery, diarrhea can be mild to severe, with some cases reporting up to 40 bowel movements per day (Kralicek *et al*., 2022). Abdominal Pain and Cramping: Patients frequently experience significant abdominal discomfort, which can accompany diarrhea (Beauchamp and Sofos, 2014). Vomiting and Fever: These symptoms are particularly prevalent in children, with vomiting occurring alongside fever in many cases (Kralicek *et al*., 2022). Bloody Stools: In severe cases, especially with enterohemorrhagic strains, patients may present with bloody diarrhea (Matano *et al*., 2012).

Complications: Severe infections can lead to conditions such as hemolytic-uremic syndrome, characterized by kidney failure and other systemic complications (Matano *et al*., 2012). While *E. coli* infections are often self-limiting, the potential for severe outcomes necessitates awareness of these symptoms for timely medical intervention. However, it is important to note that not all *E. coli* strains cause disease, and some individuals may remain asymptomatic carriers (Kralicek *et al*., 2022). *E. coli* infections can have long-term consequences for individuals who have experienced them, especially those who have developed hemolytic uremic syndrome (HUS) or other complications (Rosales *et al*., 2012). Some of the possible long-term effects include chronic kidney disease, hypertension, proteinuria, neurological impairment, cognitive impairment, behavioral problems, and reduced quality of life (*Escherichia coli*, 2018). These effects can require lifelong medical care and monitoring, and can affect the physical, mental, and social well-being of the individuals and their families.

3.7. **Diagnosis**

The diagnosis of *Escherichia coli* is critical for public health due to its association with foodborne illnesses and antibiotic resistance. Effective detection methods are essential to mitigate outbreaks and ensure food safety. Molecular Methods: Techniques such as Polymerase Chain Reaction (PCR) and biosensors have improved the specificity and sensitivity of *E. coli* detection in food and water, surpassing traditional culturing methods (Molecular Diagnostic Platforms for Specific Detection of *Escherichia Coli*, 2023). These advancements allow for rapid identification of pathogenic strains, enabling quicker response times during outbreaks and enhancing overall food safety protocols. Point-of-Care Devices: Microfluidic systems enable rapid, portable diagnostics for pathogenic strains like *E. coli* O157:H7, facilitating timely treatment and reducing health risks (Abbas *et al.*, 2023).

3.8. **Treatment**

Treatment options vary by infection type. For urinary tract infection (UTI), antibiotics are commonly used, but resistance is increasing (Kot, 2017). Alternative therapies, such as phage therapy, are being investigated to address antibiotic resistance and effectively target pathogenic strains (Ayata, 2023). Research is also looking into the use of probiotics to restore healthy gut flora, potentially reducing the incidence of infections caused by pathogenic *E. coli*. While significant advancements have been made in understanding and managing *E. coli* infections, the ongoing challenge of antibiotic resistance necessitates continued research into innovative prevention and treatment strategies. Management of *E. coli* infections primarily focuses on hydration and supportive care, as antibiotics may worsen certain strains. In addition, patients are advised to avoid anti-diarrheal medications, as they can prolong the infection and increase the risk of complications

3.9. Control and prevention

Preventive measures focus on food safety and hygiene, targeting contamination sources in agriculture and food processing (Kim *et al*., 2017). Prevention is key; practicing good hygiene, such as thorough hand washing and proper food handling, can significantly reduce the risk of infection. Vaccination strategies are being explored to combat the rising antibiotic resistance among *E. coli* strains (Pokharel *et al*., 2023) Research into novel antimicrobial agents and alternative therapies is also gaining momentum, aiming to reduce reliance on traditional antibiotics while effectively managing infections. Additionally, public health initiatives emphasize the importance of education on proper sanitation practices to minimize transmission risks and promote awareness of Urinary Tract Infection (UTI) symptoms for early intervention. Furthermore, collaboration between healthcare providers and agricultural sectors is essential to implement comprehensive strategies that address both human and animal health, ensuring a holistic approach to combating *E. coli* infections.

Some of the public health interventions that can improve food safety include (McCabe-Sellers and Beattie, 2004): conducting surveillance and monitoring of disease outbreaks and trends; developing and implementing policies and regulations to reduce the risk of exposure and transmission; providing health education and promotion to raise awareness and encourage healthy behaviors; providing immunization and vaccination programs to prevent and eliminate diseases; providing diagnosis, treatment, and care services to infected individuals and their contacts; conducting research and evaluation to improve the knowledge and evidence base for effective interventions; and collaborating and coordinating with other sectors and stakeholders to address the determinants and consequences of infectious diseases (Nsubuga *et al*., 2021; Ellwanger *et al*., 2021).

4. CONCLUSION

The public health impact of *E. coli* is profound, necessitating enhanced food safety protocols and public education and ongoing surveillance are essential on hygiene practices to mitigate risks associated with this versatile pathogen. Addressing these challenges is vital for safeguarding public health against this versatile pathogen. Continued surveillance and research are essential to address the challenges posed by *E. coli* in food systems. By fostering collaboration between government agencies, food producers, and consumers, we can create a comprehensive approach that not only protects public health but also promotes a culture of safety and responsibility in food handling practices. This collaborative effort will not only enhance our response to *E. coli* outbreaks but also build resilience against future foodborne illnesses, ensuring a safer food supply for all. Food safety and hygiene practices, personal hygiene to emphasizing the importance of food handlers' hygiene can significantly reduce *E. coli* contamination, sanitation protocols to implementing rigorous sanitation practices in food preparation and storage is essential to prevent outbreaks, education and training to continuous education for food handlers about safe food practices is crucial. Surveillance and monitoring, regular testing to conducting regular microbiological testing of food products, especially meat, can help identify contamination early, data collection to gathering data on *E. coli* prevalence in food supplies is necessary for effective public health interventions. Public awareness campaigns, community engagement to raising awareness about the risks associated with *E. coli* and promoting safe food handling practices can empower consumers to make informed choices.

5. RECOMMENDATION

E. coli is a significant concern due to its potential to cause severe gastrointestinal illness, highlighting the need for effective monitoring and prevention strategies. Effective public health interventions, including education on food safety and improved sanitation practices, are essential to mitigate the risks associated with E. coli outbreaks. Furthermore, ongoing research into the pathogenic mechanisms of E. coli can aid in developing targeted therapies and vaccines, ultimately enhancing public health responses to this persistent threat. Additionally, collaboration between public health agencies, food industry stakeholders, and researchers is crucial to ensure a comprehensive approach to managing E. coli risks and safeguarding community health. By fostering partnerships and sharing data, these entities can identify potential sources of contamination more rapidly and implement timely interventions to protect consumers. Enhanced surveillance, public education on food handling, and stricter food safety regulations are crucial to mitigate *E. coli* risks and ensure that food producers adhere to best practices. Vaccination strategies against pathogenic *E. coli* are being explored as a preventive measure against rising antibiotic resistance.

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