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Public Health Risk of *Escherichia coli* as A Foodborne Pathogen in Meat

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ABSTRACT

Foodborne pathogens, widely distributed in nature, especially in animal products, are recognized as significant public health risks in both developed and developing countries. *Escherichia coli* (*E. coli*) and other coliform bacteria are major foodborne pathogens. The primary sources of contamination for these microorganisms include poor hygiene, contaminated wastewater, and food products such as meat, cereals, and vegetables. The total number of coliform bacteria and *E. coli* indicates inadequate hygiene and fecal contamination of food. Despite this, foodborne diseases remain a significant global problem. A coordinated approach among all countries and relevant international organizations is essential for detecting and controlling foodborne issues that threaten human health and international trade. Although the biology, epidemiology, and analysis are complex, most foodborne diseases are preventable. It is crucial for public health that consumers and food producers adhere to internationally accepted safety principles. This review synthesizes recent evidence on the prevalence of *E. coli* contamination in meat and meat products, its pathogenic characteristics, antimicrobial resistance, and public health implications.

Keywords: *Escherichia coli*; food safety; foodborne disease; meat; public health

INTRODUCTION

Escherichia coli can be found in food and drink, although it is most often found in feces. It is a Gram-negative bacterium in the Enterobacteriaceae group. This bacterium is part of the normal digestive tract flora of humans and animals and plays a crucial role in human digestion. This bacterium is found in feces and can cause health problems, including diarrhea, vomiting, and other digestive issues [1]. Most *E. coli* strains are harmless commensals that form part of the normal intestinal microbiota [2], and phylogenetic groups differ in their association with pathogenicity [3], whereas pathogenic strains have acquired virulence factors and are classified into diarrheagenic pathotypes and extraintestinal pathogenic *E. coli* (ExPEC) [4] [5] [6]. Pathogenic strains can reach consumers through contaminated food, especially raw or undercooked meat [1] [7].

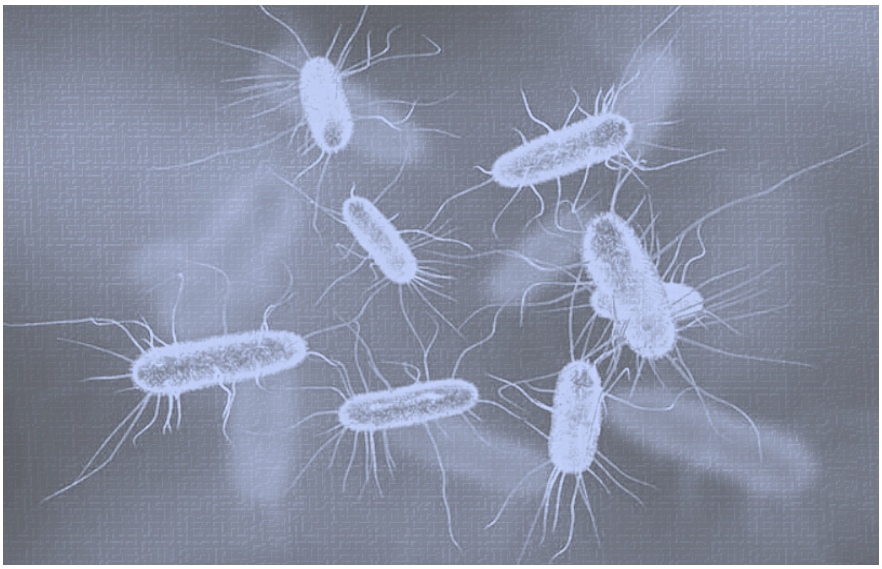


Figure 1. *Escherichia coli* with flagella [8]

Foodborne diseases are caused by living microorganisms that enter the body through food. Food that fails to meet quality requirements, poses safety concerns, or is contaminated with pathogenic bacteria can cause foodborne diseases. The incidence of foodborne diseases worldwide continues to rise, with frequent outbreaks. The national basic health survey (Riskesdas) indicates a national prevalence rate of 3.5% for diarrhea in Indonesia in 2018 [9].

To compile the data summarized in Table 1, a narrative literature search was conducted using Google Scholar, ScienceDirect, PubMed, and Scopus. The search used the following keywords: "*Escherichia coli*," "*E. coli* O157," "prevalence," "meat," "beef," "chicken," "pork," "foodborne," and "antimicrobial resistance," combined using the Boolean operators AND and OR. The search was restricted to articles published between January 2021 and December 2025. Studies were included if they (i) reported the prevalence of *E. coli* or the number of *E. coli*-positive samples in raw or processed meat, including beef, chicken, pork, lamb, and fish, or in meat-based products; (ii) were peer-reviewed original research articles or systematic reviews; and (iii) were available in full text in English. Studies were excluded if they focused exclusively on clinical, fecal, or environmental isolates; investigated non-meat food products, such as milk or vegetables; or

did not provide prevalence data. Duplicate records were removed before data compilation. The prevalence values presented in Table 1 were extracted from the original studies. When a study reported prevalence separately for multiple sample types, the values were recorded according to the respective sample types. When an average prevalence was calculated, it was based on the reported data and should be interpreted in the context of the sample types and denominators used in the original study.

Table 1. Prevalence of *E. coli* incidence in food and meat

No	Cases	Prevalence (%)	References
1	Central Java, Indonesia	9	Study report [10]
2	Pork (average from references study)	25	Brito-Junior, *et al.,*[11]
3	Meat (average from references study)	18.75	Brito-Junior, *et al.,* [11]
4	Lamb (average from references study)	12.5	Brito-Junior, et al., [11]
5	Fish meat	6.25	Brito-Junior, et al., [11]
6	Chicken meat, Chine (142/162)	87.65	Wang *et al.* [12]
7	Pork, Chine (142/164)	62.25	Wang *et al.* [12]
8	Beef (frozen beef liver, minced fresh beef and fresh beef sausage) 6/200,100% resistant to antibiotics, resistance to ampicillin, penicillin, amoxicillin/ cyclavulinic acid, ceftriaxone, ceftazidime, cefotaxime, erythromycin, and clindamycin, Egypt	3	Abdel-Atty *et al*. [13]
9	*E.coli* was found in 45% of the beef, Hyderabad, Pakistan.	45%	Ansari *et al*. [14]
10	15 pork, resistant to colistin, Vietnamese markets	40	Nguyen *et al.* [15]
11	15 chicken, resistant to colistin, Vietnamase markets	66.7	Nguyen *et al.* [15]
12	Hamburger Meat, resistant to penicillin (100%), cephalexin (86.27%) and amoxicillin (80.00%), fast-food outlets and restaurants in northwestern Iran	48	Rajaei *et al*. [16]
13	Chicken meat, Surabaya, Indonesia	40	Wardhana *et.al*. [17]
14	chicken meat, 54/122 from loca, were resistant to ≥3 antimicrobials (Multi-drug resistant), from government poultry slaughterhouses in East Java, Indonesia	44.2	Wibawati *et al*.[18]
15	chicken meat from poultry slaughterhouses in the Prayagraj district, India	80	Jaiswal *et al*. [19]

Central Java Province has a clinical diarrhea prevalence of more than 9% and ranks third in estimated diarrhea cases. Bacteria are closely related to hygiene conditions, including sanitation

indicator bacteria. Coliform is one bacterium often used as an indicator of food contamination. Sanitation indicator bacteria are generally those that live in the human intestine. *Salmonella* is a food safety indicator bacterium because all known *Salmonella* species worldwide are pathogenic. Elementary school children are among the age groups most susceptible to disease, so it is essential to pay attention to what they eat. Poor-quality snacks can affect the teaching and learning process and undermine children's academic achievement.

Livestock foods are essential for humans as a source of animal protein, providing amino acids that are easier to digest and more efficiently utilized [20]. One vital livestock food source humans depend on is meat. Meat is essential to food security due to its fairly complete nutritional content. Commonly consumed meats include beef, chicken, and goat meat. Beef contains iron that is more bioavailable than the iron found in plant foods [20]. As an animal product, meat presents several significant considerations, including contamination, harmful bacteria, drug residues, pharmaceuticals, and chemicals that can pose risks to consumers. *E. coli* can be transmitted in meat both ante-mortem and post-mortem, with sources of contamination including soil, skin, digestive tract contents, water, equipment, containers, and workers, as well as pen, carcass handling, distribution, and processing [21] [22]. Food should be safe from the pen to the table (Figure 2). Common bacteria that contaminate meat include coliforms, *E. coli*, *Staphylococcus aureus*, and *Salmonella* spp., which can cause illness if ingested [23]. Therefore, special hygienic handling and good sanitation are necessary to avoid meat contamination during processing. The presence of *E. coli* in meat indicates fecal contamination and poor sanitation during food processing [24]. Hygiene in meat processing is crucial because *E. coli* can originate from the hide and gut contents, equipment, workers, and process water [21], [22]. Therefore, people need to prioritize cleanliness and sanitation in their surroundings. Meat-processing equipment must be kept clean. Similarly, food consumed, especially meat, must be thoroughly cooked before being eaten. Consuming meat contaminated with *E. coli* can lead to gastrointestinal illness; one disease caused by *E. coli* is diarrhea, which spreads easily both directly and indirectly [4]. Diarrhea is characterized by watery bowel movements occurring more than three times a day, with liquid stool that may be accompanied by blood or mucus. In Indonesia, diarrhea is an endemic disease and a potential Extraordinary Event of Public Health Concern, often associated with severe complications and death. Diarrhea remains a major cause of morbidity and mortality, particularly in developing countries, and *E. coli* is one of its principal bacterial causes [4].

E. coli can cause acute diarrhea, which may occur if a strain or variant of the bacteria produces verotoxigenic and enterohemorrhagic toxins. This may damage endothelial cells, resulting in bloody diarrhea and potentially causing death [25]. Strains that produce Shiga toxin (Stx) cause this pattern: after intestinal colonization, the toxin enters the bloodstream and damages vascular endothelial cells by inhibiting protein synthesis, which underlies hemorrhagic colitis and hemolytic uremic syndrome [26].

Previous reviews have addressed the biology and genomic evolution of *E. coli* O157:H7 [1], risk factors and control measures along the bovine meat chain [22], and the prevalence of generic and pathogenic *E. coli* in pork [20]. However, each covers a single aspect or a single type of meat, and evidence on prevalence, pathogenicity, antimicrobial resistance, and transmission along the meat production chain has rarely been synthesized. This review's novelty lies in integrating these aspects and linking them to public health implications. Therefore, this review aims to synthesize

recent evidence on the prevalence, pathogenic characteristics, antimicrobial resistance, transmission pathways, and public health implications of *E. coli* contamination in meat and meat products, with particular emphasis on contamination along the meat production chain and strategies for risk reduction

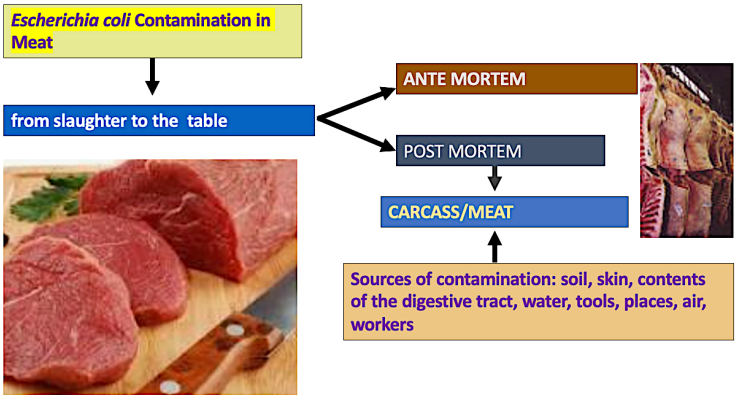


Figure 2. *Escherichia coli* contamination in meat

Classification and Pathogenicity of *Escherichia Coli*

The classification of *E. coli* serotypes is based on the presence of lipopolysaccharides (LPS)—referred to as O antigens, flagellar proteins (H antigens), and polysaccharides (K antigens) [4]. A serotype is defined by a combination of O and H antigens and is commonly used to detect potential pathogenic genes. Polysaccharides or lipopolysaccharides form the outer layer of the cell wall in Gram-negative bacteria, such as *E. coli, and are classified as antigens*. However, *E. coli* can also carry F (fimbriae) and C (capsule) antigens [4]. *Escherichia coli* has optimal conditions for becoming a pathogen, including ideal intestinal conditions, receptors, temperature, and genetic factors (the ability to change or maintain pathogenic genes and to uphold resistance genes) [1]. There are several significant pathotypes of *E. coli* that cause diarrhea, including Shiga toxin-producing *E. coli* (STEC), enterohemorrhagic *E. coli* (EHEC), enteropathogenic *E. coli* (EPEC), enteroaggregative *E. coli* (EAEC), disseminated adherent *E. coli* (DAEC), *Shigella*/enteroinvasive *E. coli* (EIEC), enterotoxigenic *E. coli* (ETEC), and adherent-invasive *E. coli* (AIEC) [27] [28]. Diarrhea caused by *E. coli* is a significant cause of death and, in developing countries, is associated with bacterial infections alongside other pathogens. Infectious diarrhea is linked to moderate mortality and is generally less severe in industrialized countries, but it affects many people and represents a significant burden of disease.

Epidemiology

E. coli O157:H7 infection is a worldwide public health concern. It causes hemorrhagic colitis (HC) and can progress to hemolytic uremic syndrome (HUS) or thrombotic thrombocytopenic purpura (TTP); about 5–10% of patients with HC are estimated to develop these complications, and children and the elderly are more likely to develop severe disease [26]. In the United States, O157:H7 was estimated to cause about 63,000 domestically acquired foodborne illnesses, 2,100 hospitalizations, and 20 deaths per year during 2000–2008, fewer illnesses than *Campylobacter* spp. or non-typhoidal *Salmonella*, but with more severe outcomes [29]. Older estimates from 1999 (73,000 illnesses, 2,200 hospitalizations, and 60 deaths) are historical figures [30].

Treatment is mainly supportive, and the use of antimicrobials in Shiga toxin-producing *E. coli* infection remains controversial; therefore, prevention and control are essential.

E. coli O157:H7 expresses the O157 somatic and H7 flagellar antigens. Unlike most commensal *E. coli*, it does not ferment sorbitol within 24 h and lacks β-glucuronidase activity, which enables isolation on sorbitol-MacConkey (SMAC) agar [24]; the serotype is then confirmed by O157 and H7 agglutination or molecular assays.

E. coli O157:H7 is transmitted mainly through contaminated food. Beef, particularly ground beef, other meat products, raw vegetables, and unpasteurized dairy products have been the main vehicles in outbreaks [7]. The association of *E. coli* O157 with an outbreak of hemorrhagic colitis was first recognized in the United States in 1982 [31]. Cattle are the main reservoir of O157:H7, and the bacterium has also been found in the feces of sheep, goats, swine, dogs, birds, and other animals [1] [25]. People can be infected through contaminated food or water, or through direct contact with animals and their environment, including soil and water contaminated with animal feces [1] [25].

Bacterial Infections in Food

Raw meat is likely to be contaminated with *E. coli* O157 and VTEC. Carcasses are contaminated during slaughter and processing at the slaughterhouse, and cross-contamination can occur at the meat seller's premises. Contamination levels relate to the level of intestinal infection, the amount of feces excreted, and overall hygiene. Chase-Topping et al. [32] noted that EHEC and VTEC can survive in the environment for a relatively long time. Secondary contamination can occur in some food processing facilities. Contamination mainly occurs when enteric bacteria from the hide and gastrointestinal contents of carrier animals are transferred to the carcass surface during hide removal and evisceration, for example through spillage of gut contents or contact with contaminated knives, hands, and equipment [21] [22]. The bacteria can then spread to other carcasses and meat cuts (cross-contamination) through shared surfaces, water, and workers' hands [21] [22].

Meat is also a vehicle for antimicrobial-resistant *E. coli*. Multidrug resistance was found in 59.26% of *E. coli* isolates from broiler meat in East Java [29], colistin-resistant *E. coli* carrying *mcr-1* in 40.0% of retail pork and 66.7% of chicken samples in Vietnam [24], and high resistance to penicillin, cephalexin, and amoxicillin in isolates from raw hamburger and kebab in Iran [23]. A meta-analysis of pork reported that pathotypes were detected in 4.7% of samples along the supply chain, much less often than generic *E. coli* (35.6%) [20]. Non-pathogenic strains still indicate fecal contamination and hygiene failures, and they can carry resistance genes, including plasmid-borne ESBL genes [33]. Resistance has also been documented in *E. coli* O157 isolated from humans, cattle, swine, and food [6].

Evolution of *Escherichia Coli*

Evolution in E. coli is primarily driven by factors that trigger change and by the presence of mobile genetic elements. These elements lead to heterogeneity in virulence and survival factors, as well as in genes associated with transfer elements. These elements can move horizontally, moving between bacterial strains or species [34]. However, the most important chromosomal elements in *E. coli* include pathogenicity islands and prophages. Elements assimilated into the bacterial chromosome within a given genus often become increasingly immobile as mutations accumulate, creating immobile portions of the host genome. *E. coli* virulence determinants can be found outside the chromosome, encoded by plasmids, and can be transmitted horizontally.

Most human pathogenic *E. coli* strains rely on at least this type of pathogenic plasmid to acquire an infectious phenotype. As *E. coli* strains age, they continue to acquire mobile elements; old elements deteriorate and are lost, no practical benefit is gained from them, and additional elements are incorporated [34]. Nevertheless, horizontal gene transfer is a powerful force in *E. coli evolution*. Insertion sequences (IS) are small transposable elements commonly found in bacterial genomes and drive *E. coli* evolution [35].

Genome comparison shows that *E. coli* O157:H7 (strain EDL933, about 5.5 Mb) and the non-pathogenic laboratory strain K-12 (about 4.6 Mb) share a conserved backbone of about 4.1 Mb; O157:H7 carries 1.34 Mb of strain-specific DNA, including O islands that encode virulence-related genes [36], much of it acquired horizontally through prophages and other foreign elements, whereas K-12 has 0.53 Mb of specific DNA [23]. O157:H7 is a highly clonal lineage with little diversity in housekeeping genes [37] and is thought to have evolved from an enteropathogenic O55:H7-like ancestor through stepwise acquisition of a Shiga toxin-encoding prophage and the virulence plasmid pO157, together with loss of sorbitol fermentation and β-glucuronidase activity [38], The plasmid pO157 (about 92 kb) encodes enterohemolysin, the serine protease EspP, the toxin ToxB, a type II secretion system, and catalase-peroxidase KatP [39].

Transmission Through Contact In Developing Countries

Pathogenic bacteria can be transmitted through blood products from live animals and slaughterhouses [21] [40] [41], but the exact transmission route is often unknown. In developing countries, many families keep livestock in backyards for egg, milk, or meat production [42]. China has a wide range of livestock farms, from poultry farms where humans are involved at all stages of the production cycle [41] to large industrial cattle farms [27]. Both have been reported to transmit zoonotic diseases from livestock to humans, including avian influenza and *T. verrucosum* [42, 43]. In summary, the literature to date has not addressed patterns of livestock-human contact in developing countries [44].

CONCLUSIONS

The factors related to the presence of *E. coli* in food in public places include: cleanliness of food handlers, how eating utensils are washed, food handlers not paying attention to poor food sanitation, food handlers paying less attention to controlling environmental conditions, starting from handling raw materials to the distribution process, and the storage of eating utensils and proper food presentation.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the research design, data collection, analysis, and manuscript writing.

COMPETING INTERESTS

We also declare that there is no conflict of interest in our review.

ETHICAL CLEARANCE

Ethics declaration not applicable.

GENERATIVE AI DECLARATION

The authors prepared and wrote this manuscript entirely without generative artificial intelligence (AI) or AI-assisted technologies at any stage of development.

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