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The Microbiological Hazards of *Enterobacter* spp. Contamination in Street Food in Developing Countries: A Literature Review

Jefyne Mali' Pareakan[1], Charis Amarantini[1], Tri Yahya Budiarso[1]*

[1] Biology Study Program, Faculty of Biotechnology, Universitas Kristen Duta Wacana, Yogyakarta, Indonesia

*Corresponding Author Email: yahya@staff.ukdw.ac.id

LITERATURE REVIEW

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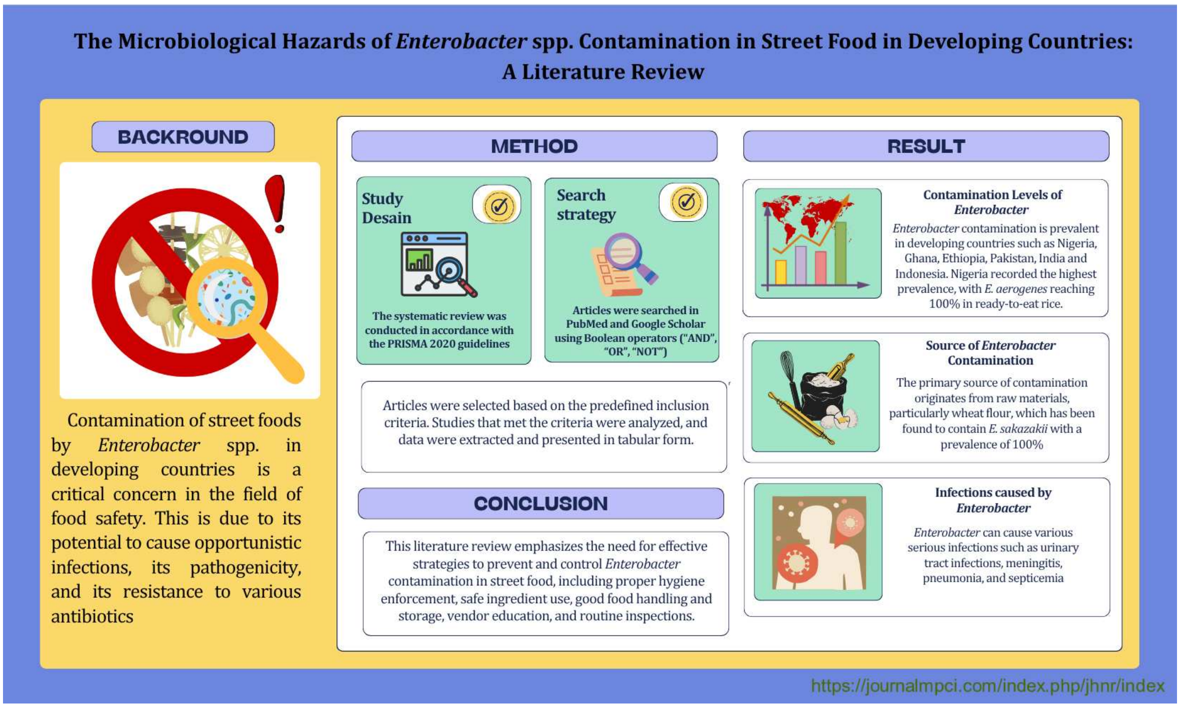
ABSTRACT

Street food is widely consumed by people in developing countries and often poses health risks due to bacterial contamination. The consumption of contaminated food has been linked to more than 200 types of diseases, resulting in 600 million cases and 420,000 deaths each year. One commonly found bacterium is *Enterobacter*, which can be pathogenic and exhibit resistance to various antibiotics. This review aims to assess the dangers of *Enterobacter* contamination in street food, including the level and source of contamination, pathogenicity, and management strategies. The review followed PRISMA 2020 guidelines, with literature searches performed in scientific databases such as PubMed and Google Scholar using Boolean operators and relevant keywords. Articles were selected based on specific inclusion criteria, analyzed, and grouped for ease of interpretation. The results showed that *Enterobacter* contamination is prevalent in developing countries such as Nigeria, Ghana, Ethiopia, Pakistan, India, and Indonesia. Nigeria recorded the highest prevalence, with *E. aerogenes* reaching 100% in ready-to-eat rice. The primary source of contamination is raw materials, particularly wheat flour, which contains *E. sakazakii* with a prevalence of 100%. *Enterobacter* can cause various serious infections, including urinary tract infections, meningitis, pneumonia, and septicemia. Efforts to reduce *Enterobacter* contamination in street food should include the implementation of hygiene and sanitation practices, the use of safe raw materials, proper processing and storage methods, education for vendors, and routine food safety supervision. These findings are crucial for supporting public health interventions and developing effective food safety policies.

Key Messages:

- The presence of *Enterobacter* in street food represents a potential public health concern, as it may contribute to foodborne illnesses and nosocomial infections due to its marked pathogenicity, virulence factors, and substantial antibiotic resistance.
- Contamination of street food with *Enterobacter* is commonly caused by poor hygiene and sanitation practices, underscoring the need to implement effective food safety management systems to prevent the risk of contamination.

GRAPHICAL ABSTRACT



INTRODUCTION

The global consumption of food contaminated with pathogenic bacteria is increasing, leading to more than 200 types of potentially fatal infections, particularly affecting infants, the elderly, and pregnant women (1,2). his issue impacts approximately 600 million people about 1 in 10 of the global population and results in an estimated 420,000 deaths annually (3). Foodborne infections are primarily associated with the consumption of street food, ready-to-eat (RTE) food, and fast food (4,5). Street food refers to food sold outdoors, in public places, or on the roadside, prepared and served directly for consumption without the need for further processing (6,7). The development of street food sector, which operates without adequate regulations regarding hygiene and safety standards increases the risk of microbiological contamination. Street food vendors face several challenges in maintaining food hygiene and safety, including limited access to clean water, the use of low-quality raw materials, improper packaging methods, inappropriate storage temperatures, and unsupportive environmental conditions (6).These factors contribute to rapid bacterial growth, thereby elevating the risk of foodborne infections. For instance, a listeriosis outbreak in South Africa in 2018 infected 674 people and caused 183 deaths (8). Similarly, in Bangladesh, approximately 30 million people contract foodborne infections annually, with an estimated 2.2 million dying from diarrhea (5).

Escherichia coli and *Enterobacter* are the most common pathogenic bacteria found in street food (9,10). A study conducted in Nigeria revealed that 50% of street food samples were contaminated with *Enterobacter* spp. (11), while in India, 36.7% of 44 samples were infected (12), and in Ethiopia, 15.87% of 44 samples also showed similar contamination (13). *Enterobacter* can produce various cellular toxins, including enterotoxins, hemolysins, and pore-forming toxins, which significantly contribute to foodborne diseases (14). Studies indicate that the types of *Enterobacter* commonly found in street food include *E. cloacae*, *E. aerogenes*, *E. agglomerans*, and *E. Hafniae* (15,16). Although numerous studies have examined microbial contamination in street food, there has been limited focus on the hazards posed by *Enterobacter* contamination in developing countries. Previous research has emphasized pathogens such as *Escherichia coli*, *Salmonella*, and *Staphylococcus aureus*. It has been demonstrated that Enterobacter contamination can lead to nosocomial infections and gastrointestinal diseases through the fecal-oral route, presenting symptoms such as fever, diarrhea, and abdominal pain (15,17). Therefore, there is a pressing need for more in-depth studies on the microbiological hazards associated with *Enterobacter* contamination in street

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food within developing countries. This literature review aims to highlight the dangers related to *Enterobacter* contamination in street food, focusing on prevalence, sources, risk factors, and its impact on public health. It is expected that this review will significantly contribute to the development of evidence-based food safety policies, the improvement of hygiene practices in food handling, and the formulation of public health risk mitigation strategies concerning *Enterobacter* spp. contamination in street food in developing countries.

METHODS

This review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA) guidelines.

Search strategy

Data collections were performed by searching scientific articles across multiple databases, including Google Scholar and ScienceDirect. The search employed Boolean operators ("AND," "OR," "NOT") combined with keywords relevant to the study topic, such as *Enterobacter*, street food or ready-to-eat food, microbial contamination, foodborne infection, and developing countries. Various keyword combinations were used to maximize the retrieval of pertinent articles. The search and article selection process were systematically documented using a PRISMA flow diagram (Figure 1), illustrating the number of articles identified, screened, assessed for eligibility, and included in the analysis.

Inclusion and Exclusion Criteria

This review included studies conducted in various countries and comprised original research articles, review articles, peer-reviewed papers, and systematic reviews. Inclusion criteria were: articles published in English, available in full text, and published between 2010 and 2025. Selected articles had to be relevant to the topic, particularly those reporting data on the prevalence of contamination and microbiological hazards posed by bacteria, especially *Enterobacter* species, in street food within developing countries. Articles providing information on the pathogenic characteristics, virulence mechanisms, and types of infections or diseases caused by *Enterobacter* at the individual and population levels were also included. Exclusion criteria encompassed editorials, opinion pieces, articles unavailable in full text, and studies not focused on human health.

Study selection

The article selection process was conducted in multiple stages. Initially, all retrieved articles were de-duplicated using reference management software (Zotero). Subsequently, titles and abstracts were screened to assess their preliminary eligibility based on the inclusion criteria.

Data extraction and analysis

Data were systematically extracted from articles that met the inclusion criteria using a pre-designed data extraction form. The form covered three main aspects: (1) levels of *Enterobacter* contamination in various developing countries, (2) sources of *Enterobacter* contamination in street food, and (3) types of infections caused by *Enterobacter* species. Extracted information from each article included the author's name, year of publication, study location, type of food tested, identified *Enterobacter* species, prevalence rates, contamination sources, and reported health effects or infections.

Descriptive and thematic analyses were conducted. Data were categorized and presented in three separate tables to facilitate visualization and interpretation. Thematic analysis was employed to identify common patterns, regional differences, and potential public health risks associated with the presence of *Enterobacter* in street food. The synthesized findings formed the basis for drawing conclusions and making recommendations aimed at controlling microbiological risks in street food within developing countries.

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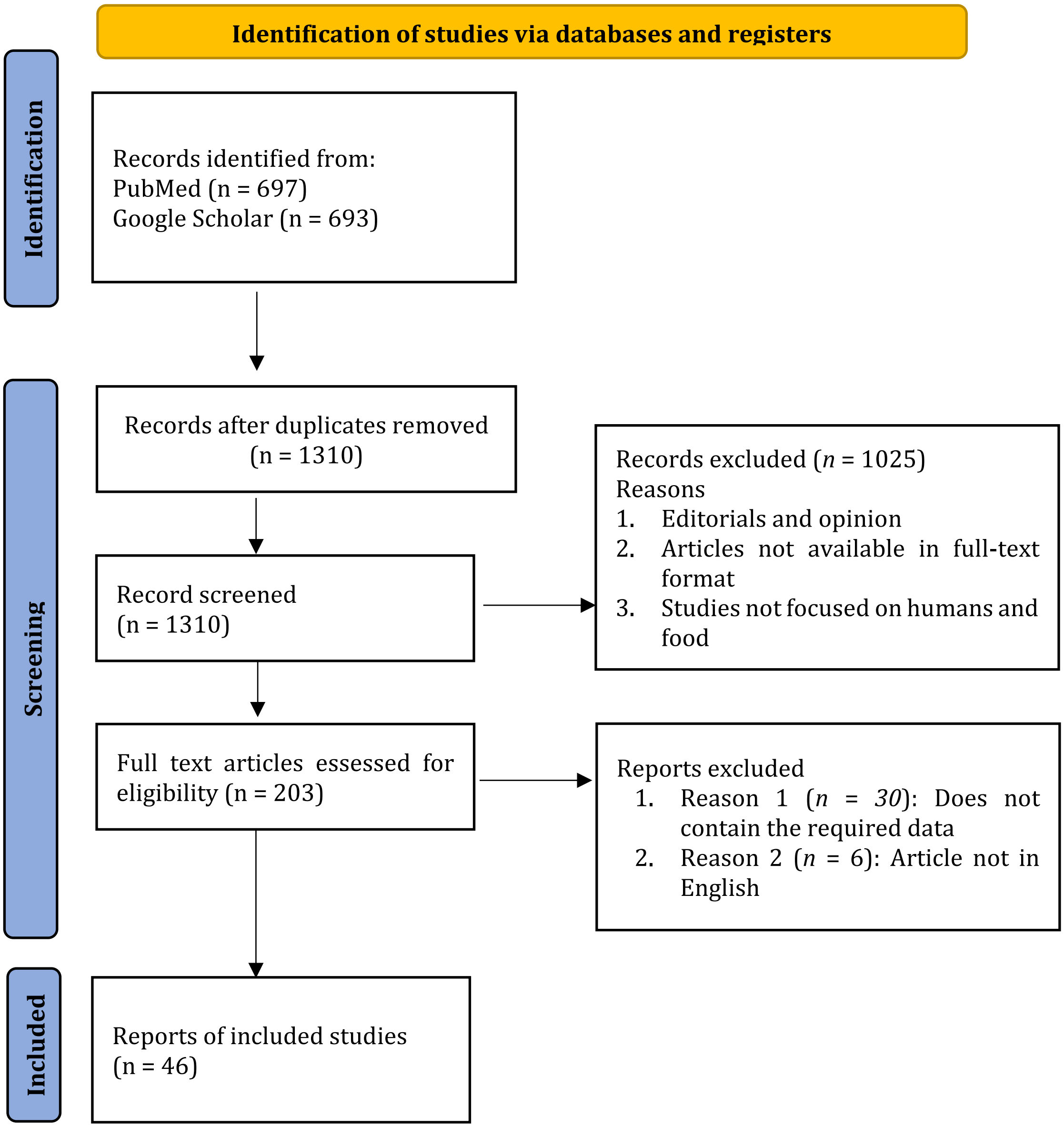

Figure 1. Prisma Flow Diagram

RESULTS

Contamination Profiles of Pathogenic Bacteria in Street Food across Different Countries

The levels of pathogenic bacterial contamination in street food vary significantly across countries, reflecting differences in sanitation practices, food processing, and handling methods. Table 1 summarizes the findings by geographical region and type of food sample analyzed, providing a comprehensive overview of the prevalence of pathogenic bacterial contamination in street foods worldwide.

Table 1. Contamination levels of *Enterobacter* and other pathogenic bacteria in street food in developing countries

Country	Types of food	Prevalence of *Enterobacter*	Prevalence of other bacteria	References
Nigeria	RTE-cooked rice	*E. aerogenes* (100%)	*S. aureus* (91.7%) *Brahamella sp.* (80.6%) *Salmonella spp.* (69%)	(18)
Nigeria	Rice, soup, and beans	*Enterobacter spp.*	*E. coli* (%)	(11)

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Country	Types of food	Prevalence of *Enterobacter*	Prevalence of other bacteria	References
		(50%)	*Streptococcus spp.* (50%) *S. aureus* (60%) *P. aeroginosa* (90%) *Salmonella spp.* (30%) *B. cereus* (40%) *Micrococcus spp.* (30%) *A. faecalis* (10%)	
Africa	Vegetables, potatoes, rice, pies, beef, and chicken stew	*Enterobacter spp.* (18%)	*Listeria spp.* (22%) *A. hydrophila* (12%) *K. oxytoca* (8%) *P. mirabilis* (6.3%) *S. aureus* (3.2%) *P. luteola* (2.4%)	(19)
Ghana	Ampesi, banku, beans, bofloat, bread, fried egg, fried fish/ meat, fried, pepper, fried rice, gari, ground pepper, hausa kooko, indomie/ spaghetti, jollof, kenkey, rice, salad, soup, stew, waakye	*Enterobacter spp.* (16.8%)	*Citrobacter spp.* (10.1%) *E. faecalis* (7.8%) *Pseudomonas spp.* (6.7%) *K. pneumoniae* (4.0%)	(10)
Ethiopia	Sanbusa, Donat, Bombolino, and bread	*Enterobacter spp. (15.87%)*	*S. aureus* (53.96%) *E.coli* (23.8%) *Citrobacter spp.* (6.3%)	(13)
Pakistan	Nehari, wonton, wonton, chicken shashlik, grilled chicken, stuffed chicken, pani puri, haleem, chicken manchurian, chicken mayo garlic roll, sandwich, french fries, bbq items, zinger, samosa, coleslaw salad, finger fish	*E. aerogenes* (10%)	*Pseudomonas spp.* (20%) *Bacillus spp.* (18%), *S. aureus* (6%) *S. epidermidis* (6%) *S. fecalis* (2%) *E. coli (*14%)	
India	Panipuri, chaats, and eggrolls	*Enterobacter spp*. (8,93%)	*E. coli* (37.5%) *P. aeruginosa* (3.57%) *S. aureus* (14.20%) *Salmonella spp.* (5.36%) *Klebsiella spp.* (10.71%) *Shigella spp*. (19.64%)	(20)
Indonesia	Cilok, dumplings, and skewer meatballs	*E. cloacae* (6.6%)	*E. coli* (16.6%) *K. pneumoniae* (13.3%) *Y. enterocolitica* (13.3%) *Pantoea spp.* (6.6%) *A. hydrophila* (6.6%) *S. marcescens* (6.6%) *Moraxella spp.* (6.6%) *S. liquefaciens* (3.3%) *P. mirabilis* (3.3%) *Shigella spp.* (3.3%) *E. Americana* (3.3%)	(21)
India	Fried rice, jollof rice, moi-moi, salad, oil beans, non-oil beans, and African salad	*E. cloacae* (5.36%)	*E. coli* (41.07%) *C. freundii* (5.36%)	(16)

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The prevalence of *Enterobacter* genus bacteria in street food from developing countries showed considerable variation, influenced by the type of food as well as local environmental and sanitation conditions. Notably, the highest prevalence of *Enterobacter aerogenes* was observed in ready-to-eat (RTE) cooked rice in Nigeria, reaching 100%. In contrast, countries such as Ghana, Ethiopia, Pakistan, India, and Indonesia reported *Enterobacter* spp. prevalence rates ranging from 5.36% to 50%. In addition to *Enterobacter*, other predominant pathogenic bacterial isolates identified included *Staphylococcus aureus*, *Escherichia coli*, *Salmonella* spp., and *Pseudomonas* spp. These findings suggest potential cross-contamination and multispectral infection risks for consumers. Overall, these results underscore the urgent need to strengthen microbiological surveillance systems and enhance hygienic practices in street food preparation and handling to minimize pathogen exposure and mitigate associated public health risks.

Source of *Enterobacter* Contamination in Street Food

The presence of bacterial contamination in street food is influenced by various factors, including the quality of raw materials, environmental cleanliness, hygienic practices of food handlers, and food processing and storage methods. These factors interact synergistically, increasing the risk of bacterial contamination and proliferation on food, which may lead to adverse health effects for consumers. Table 2 presents the identified sources of bacterial contamination in street food.

Table 2. Sources of *Enterobacter* contamination and other pathogenic bacteria in street food

Source	Prevalence of *Enterobacter*	Prevalence of Other Bacteria	References
Wheat flour	*E. sakazakii* (100%)	-	(22)
Raw vegetable	*Enterobacter spp.* (64%)	*S. aureus* (48%) *P. aeruginosa* (60%) *E. coli* (48%) *Salmonella spp.* 8%	(23)
Fresh Vegetables	*E. cloacae (61,46%)* *E. aerogenes (2,08%)* *E. cancerogenus (2,08%)* *E. gergoviae (1,04%)* *E. Sakazakii (4,17%)*	*K. oxytoca* (19,79%.) *K. pneumoniae* (9,38%)	(24)
RTE/slice fruit	*Enterobacter* (40%)	*Bacillus spp.* (*100%)* *S. aureus* (80%) *Penicillium spp.* (80%) *A. niger* (60%) *E. coli* (40%) *Salmonella* (40%) *Klebsiella* (40%) *Mucor spp.* (40%) *P. aeruginosa* (20%) *Proteus* (20%) *Micrococcus* (20%) *Lactobacillus spp.* (20%)	(25)
Dishwashing water	*Enterobacter spp.* (36.67%)	*E. coli* (50%) *P. aeruginosa* (26.67%)	(12)
RTE meat beef, pork, and chicken	*E. cloacae* (29%)	*Escherichia* (27%) *P. mirabilis* (25%)	(26)
RTE meat chicken and beef	*E. cloacae (27%)* *E. sakazakii (13%)* *E. kobei (5%)* *E. ludwigii (8%)* *E. hormaechei (4%)*	*P. luteola* (5%) *P. aeruginosa* (4%) *P. stutzeri* (4%) *K. pneumonia* (15%) *K. oxytoca* (14%) *C. koseri* (2%)	(27)
Raw fruits and vegetables	*Enterobacter spp.* (25,3%)	*E. coli* (17,4%) *Klebsiella spp.* (43%) *Proteus spp.* (4%) *Citrobacter spp.* (2%)	(28)

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Source	Prevalence of *Enterobacter*	Prevalence of Other Bacteria	References
		Providencia spp. (0,7%)	
Cooking water, storage water, and washing water	*E. cloacae* (11.1 %).	*K. pneumoniae* (20.8 %) *Aeromonas spp.* (16.7 %)	(10)
Kitchen instruments	*Enterobacter* (9,40%)	*S. aureus* (15.05%) *S. epidermidis* (16.50%) *E. coli* (18.27%) *Shigella spp.* (0.91%) *Bacillus spp.* (13.02%) *Pseudomonas* (2.11%)	(29)
Hand rinse	*Enterobacter spp.* (9.1%)	*S. aureus* (23.5%) *Klebsiella spp.* (16.1%) *E. coli* (10.9%) *Citrobacter spp.* (4.3%) *S. marcescens* (2.6%) *P. aeruginosa* (3.5%) *Proteus spp.* (2.2%) *P. rettegri* (1.3%) *Salmonella spp.* (0.9%)	(30)
Pupuru and plantain flour	*Enterobacter spp.* (0.99%)	*Klebsiella spp.* (91.12%) *Acinetobacter sp.* (1.97%) *Campylobacter sp.* (4.61%) *Corynebacterium sp.* (0.33%) *B. subtilis* (0,99%)	(31)

Data in Table 2 indicate that *Enterobacter* species are widespread across various food items and environments associated with street food. High prevalence rates were observed in wheat flour (*E. sakazakii*, 100%), fresh vegetables (*E. cloacae*, 61.46%), and ready-to-eat cut fruits (40%). Significant contamination was also detected in ready-to-eat processed meats such as chicken and beef (*E. cloacae*, 27–29%), as well as in environmental sources, including equipment wash water (36.67%) and kitchen utensils (9.4%). These contaminations frequently co-occur with other pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella* spp., and *Salmonella* spp., cumulatively heightening the risk of transmission of gastrointestinal infections and other opportunistic diseases.

Infections Caused by *Enterobacter*

Contamination of street food by *Enterobacter* species poses a potential risk of infection to consumers, as these bacteria are opportunistic pathogens capable of causing a variety of nosocomial and community-acquired infections. Table 3 summarizes the types of infections caused by different *Enterobacter* species, highlighting their clinical significance and public health impact.

Table 3. Various types of Infections caused by various *Enterobacter* species

Enterobacter	Infection	Source
E. cloacae	Endocarditis, septic arthritis, osteomyelitis, urinary tract infections (UTIs), intra-abdominal infections, wound infections, eye infections, musculoskeletal infections, bloodstream infections (bacteremia), skin infections, soft tissue infections, respiratory tract infections, post-surgical peritonitis, blood and brain infections	(32–35)
E. sakazakii	Neonatal meningitis, hydrocephalus, sepsis, and necrotizing enterocolitis.	(36–38)
E. aerogenes	Pneumonia, UTIs, bacteremia, wound infections, respiratory tract infections, skin infections, soft tissue infections, gastrointestinal infections, and septic infections, as well as fulminant forms of necrotizing meningitis in infants.	(39)

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Enterobacter	Infection	Source
E. hormaechei	Bacteremia, lung infections, pneumonia, biliary tract infections, and UTIs	(40,41)
E. amnigenus	Endophthalmitis, bacteremia, UTIs	(42,43)
E. asburiae	Pneumonia, UTIs, intra-abdominal infections, and septicemia	
E. carcinogenus	Bacteremia and pneumonia	(44,45)
E. cowanii	Rhabdomyolysis, bacteremia, and acute cholecystitis	(46)
E. dissolvans	Septicemia and respiratory tract infections	(47)
E. gergoviae	Pneumonia, bacteremia, UTIs, respiratory tract infections, and peritonitis.	(48,49)
E. kobei	UTIs and sepsis	(50,51)
E. ludwigii	UTIs, bacteremia	(52,53)
E. nimipressuralis	Pseudobacteremia	(54)
E. radicincitans	Cholangiocarcinoma	(55)
E. taylorae	Bacteremia, UTIs, and meningitis.	(56)

The identified *Enterobacter* species exhibit extensive pathogenic potential, particularly as agents of opportunistic infections. *E. cloacae* is the predominant species, associated with a broad spectrum of infections including urinary tract infections, respiratory tract infections, bloodstream infections, and soft tissue infections. *E. sakazakii* (now classified as *Cronobacter sakazakii*) is notably linked to severe neonatal infections such as meningitis and sepsis. Other species, including *E. aerogenes*, *E. hormaechei*, and *E. gergoviae*, are frequently implicated in nosocomial infections such as pneumonia, bacteremia, and gastrointestinal infections. Less common species like *E. cowanii*, *E. dissolvens*, and *E. ludwigii* have been reported to cause serious conditions, including rhabdomyolysis, septicemia, and urinary tract infections. The detection of these species in ready-to-eat and street food environments underscores a tangible risk of infection transmission, especially in regions with inadequate sanitation.

DISCUSSION

Enterobacter Contamination Levels in Street Food in Various Countries

Foodborne infections are a serious health problem worldwide, affecting millions yearly (57). Globally, foodborne infections cause approximately 600 million cases and 420,000 deaths each year with the highest incidence in children under 5 years of age (3,58). This corresponds with the results in the United States, where foodborne pathogen contamination is expected to cause 9.4 million infections, 56,000 hospitalizations, and 1,350 deaths in 2022 (59). The United Kingdom reports approximately 2.4 million cases of foodborne infections each year with 180 deaths (60). The number of people suffering from foodborne diarrhea and other cases in developing countries exceeds 1.5 billion with 5 million deaths yearly (61). Therefore, the incidence suggests that the causative factor of infections refers to the microbiological quality of food. Various countries have provided alarming reports related to high pathogen contamination levels in food, specifically *Enterobacter*.

Sources of *Enterobacter* Contamination in Street Food

The human body is an ecological habitat for various microbial communities. *Enterobacter* is among the bacteria that can live on the skin and digestive tract of human, thereby playing a complex role in health and infections (62). Food poisoning, known as foodborne infections, is a condition caused by consuming food contaminated with microbes or toxins (63). The lack of effective implementation of regulations regarding safety and hygiene standards by sellers is a problem endangering consumer health (5). The main sources of bacterial contamination in food are generally caused by several factors, including unclean equipment, unhygienic sales locations, and inadequate sanitation facilities (64,65). Additionally, limited access to clean water, poor waste management, and storage of raw materials and food at inappropriate temperatures play a role in increasing contamination risk. These factors produce an environment supporting the growth and spread of bacteria, which can endanger consumer health. The method of preparing, processing, and serving food affects the microbiological quality (19).

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Enterobacter contamination in street food primarily originates from raw materials used during food preparation, with *Enterobacter* species detected in water, wheat flour, meat, fruits, and vegetables (24,66–69). The equipment employed in street food processing is also a critical factor to consider. The hygiene practices of food handlers significantly influence the transmission of infections caused by *Enterobacter* bacteria. Moreover, *Enterobacter* can be transmitted directly or indirectly from the human body to food (70). Studies have demonstrated that food handlers may carry pathogenic *Enterobacteriaceae* on their hands and nails, which can lead to contamination during food preparation or handling (71–73).

Pathogenicity and *Enterobacter* Infection

Enterobacter is a genus of gram-negative, facultative anaerobic, rod-shaped, non-spore-forming, and motile bacteria belonging to *Enterobacter*iaceae family (74) known as opportunistic pathogens, which cause infections mainly in people with weakened immune systems and produce endotoxins and exotoxins contributing to virulence (33). This can be found in various habitats such as soil, plants, and the intestinal tract of humans and animals as well as in food (75). Furthermore, contamination of the bacteria in street food is transmitted through food handlers, cooking utensils, raw materials, water, and the environment (76,77). The presence of enterotoxigenic *Enterobacter* species in street food poses a significant public health risk, specifically due to the association with foodborne poisoning commonly referred to as foodborne infections. Currently, there are around 22 species belonging to the genus *Enterobacter,* namely *E. aerogenes, E. amnigenus, E. arachidis, E. asburiae, E. carcinogenus, E. cloacae, E. cowanii, E. dissolvans, E. gergoviae, E. helveticus, E. hormaechei, E. kobei, E. ludwigii, E. mori, E. nimipressuralis, E. oryzae, E. pulveris, E. pyrinus, E. radicincitans, E. soli, E. taylorae,* and *E. sakazakii* (33,78).

The pathogenicity and virulence factors of *Enterobacter spp.* are still not specifically known due to the lack of relevant studies. This group of bacteria has flagella playing a role in the pathogenicity which is used for motility/movement, biofilm formation, protein export, and adhesion (79). *Enterobacter* genus can excrete enterotoxins, alpha-hemolysin, and cytotoxins similar to Shiga-like toxins II and thiol-activated pore-forming cytotoxins (80,81). SLT-II inhibits protein synthesis and vascular damage, while thiol-activated pore-forming cytotoxins play a role in pore formation and cell lysis. In gram-negative bacteria, there is a type of secretion system (T3SS) that functions to inject effector proteins into eukaryotic host cells, where this system plays a role in the virulence of pathogenic bacteria (82). *E. cloacae* has 2 types of type VI secretion systems (T6SS), namely T6SS-1 and T6SS-2, which enhances the ability of bacteria to survive in a competitive environment (83). *E. cloacae* is capable of attaching to and penetrating epithelial cells as well as inducing apoptosis in Hep2 cells, which could be a crucial mechanism contributing to the development of infections (84). *E. cloacae complex* has Pqc plasmids containing virulence-encoding genes (ter and sea) and resistance-encoding genes (blaCTX-M-9, qnrA1, aadB, aadA2, sukK, and sat), contributing to the virulence and adaptation of *E. cloacae* [1]. This *complex* comprises *E. cloacae, E. asburiae, E. hormaechei, E. kobei, E. ludwigii, E. mori,* and *E. nimipressuralis*, grouped based on the similarity of approximately 60% of the genomes (85). Additionally, *E. hormaechei* bacteria are more dangerous due to being an EHOS (*E. hormaechei* Outbreak Strain) containing a High Pathogenicity Island (HPI) (86). A key genetic element in pathogenicity known as HPI encodes virulence factors essential for the acquisition, regulation, and transport of iron, promoting pathogenicity and the ability of bacteria to cause infections (87,88). The ability to assimilate iron through chelators is crucial for bacterial metabolism and the establishment of infection. Siderophore encoding genes are commonly observed in HPI, particularly in *Yersinia spp*. Among these genes, the irp2 gene has been identified in *Enterobacter spp*. (89). Moreover, *E. cloacae* can express Curli fimbriae, which are extracellular protein fibers included in the amyloid category, functioning to increase bacterial adhesion to surfaces, cell aggregation, and biofilm formation (90). The genes encoding Curli are grouped into two operons, namely csgBA(C) and csgDEFG, with studies showing that 11 (78.6%) of 14 isolates has the csgBA operon. The ability of *E. cloacae* isolates to form biofilms was significantly correlated with the mRNA expression levels of the csgA encoding Curli subunit and csgD activating the csgBA operon promoter as well as csgE, csgF, and csgG. Differences in pathogenicity between *E. aerogenes* and *E. cloacae* have been reported in various investigations (91). *E. aerogenes* has virulence-encoding genes fimH and mrkD such as those encoding fimbrial adhesins types 1 and 3, with a key role in adhesion and biofilm

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formation, which are crucial aspects of bacterial virulence (33,91,92). Furthermore, iron transport genes kfu, entB, and ybtS participating in the production of siderophores were identified in *E. aerogenes*, which facilitate iron absorption through the production of siderophores such as enterobactin and yersiniabactin. These genes enhance the ability of bacteria to survive and reproduce in competitive host environments (91). *Enterobacter aerogenes* can produce beta-lactamases, specifically Extended-Spectrum Beta-Lactamases (ESBLs) and AmpC cephalosporinase playing a role in virulence and adaptability of resistance genes (93,94).

Strategy and Recommendations for Addressing *Enterobacter* Contamination of Street Food in Developing Countries

Contamination of *Enterobacter* spp. in street food poses a serious public health challenge in developing countries, contributing substantially to the burden of microbiological infectious diseases, particularly among vulnerable populations. Therefore, the development of effective management strategies should adopt a multidisciplinary approach integrating education, regulation, technology, and enhanced infrastructure.

First, empowering street food vendors through education and training programs focused on food hygiene and sanitation principles is essential. Studies indicate that vendors' lack of knowledge regarding sanitation practices, safe food processing, and raw material handling are major contributors to the risk of *Enterobacter* spp. contamination (95). Continuous training should be implemented promptly to enhance vendors' competencies in controlling microbial contamination, emphasizing effective handwashing, guaranteed use of clean water, and standardized food processing and storage methods.

Furthermore, the implementation of strict and well-documented hygiene and sanitation standard operating procedures (SOPs) is necessary to reduce variability in hygiene practices in the field (96). SOPs should cover cleaning of cooking utensils, work surfaces, waste management, and handling of raw and cooked foods, tailored specifically to the characteristics of local street food. The enforcement of these SOPs requires regular internal and external audits to ensure compliance and effectiveness.

Government regulation plays a crucial role in supporting these interventions. Local authorities need to strengthen supervision, certification, and law enforcement related to street food safety (97). Systematic, risk-based periodic inspections should be conducted to identify and mitigate critical contamination points. Additionally, awarding hygiene certificates to vendors who meet safety standards can serve as an incentive, motivating businesses to adopt safe and hygienic practices. The availability and quality of clean water is another critical factor demanding serious attention. Since water is extensively used for washing materials and equipment, improving access to microbiologically safe water sources and implementing water treatment systems at street food vending sites are essential to eliminate potential contaminants.

Moreover, consumer empowerment through education about the health risks associated with consuming unhygienic food is vital. Increased consumer awareness of food safety encourages the selection of safer food products, thereby motivating vendors to improve their food handling practices. Continuous monitoring to track the presence of *Enterobacter* spp. in street food, contamination pathways, and antibiotic resistance patterns is imperative. This monitoring supports the formulation of adaptive and effective control policies and provides a basis for evaluating the success of intervention programs.

In summary, addressing *Enterobacter* spp. contamination in street food in developing countries requires multisectoral collaboration and an evidence-based approach to achieve optimal food safety and reduce the risk of microbiological infectious diseases in the community.

CONCLUSION

Street food in various developing countries has been found to be contaminated with *Enterobacter* at levels that pose significant public health risks. The prevalence of *Enterobacter* contamination in street food varies widely, ranging from 5.36% up to 100%. *Enterobacter aerogenes* was identified as the most dominant species, with the highest prevalence detected in ready-to-eat (RTE) cooked rice samples from Nigeria. Sources of *Enterobacter* contamination in street food include raw materials, cooking utensils,

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water, and food handlers, with prevalence rates ranging from 0.99% to 100%. Wheat flour was recorded as the raw material with the highest contamination level, where *E. sakazakii* prevalence reached 100%. The high pathogenicity, virulence, and antibiotic resistance capabilities of *Enterobacter* make it a significant causative agent in various infections. The predominant bacterial species, *E. sakazakii* and *E. cloacae*, are frequently associated with urinary tract infections, meningitis, gastrointestinal infections, pneumonia, septicemia, and bacteremia.

This literature review underscores the critical need for multidisciplinary prevention and control strategies to mitigate *Enterobacter* contamination in street food and reduce the associated public health risks. Recommended strategies include the implementation of good hygiene and sanitation practices, the use of safe raw materials, education and training for food vendors, and regular food safety monitoring. Furthermore, additional research is warranted to elucidate contamination mechanisms, characterize virulence factors, and understand antibiotic resistance patterns to support the development of more effective policies and interventions.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest

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