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Original Article

Risk Analysis of Escherichia coli Bacteria in Food at Cidu Market, Makassar City

Haerani*, Syamsuddin, Inayah
Department of Environmental Health, Poltekkes Kemenkes Makassar, South Sulawesi, Indonesia
Corresponding author: haerani@poltekkes-mks.ac.id

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ABSTRACT
Background: Foodborne diseases remain a major public health concern, particularly in settings where food hygiene and sanitation practices are inadequate. This study aimed to assess the quantitative risk of Escherichia coli contamination in street food sold at Cidu Market, Makassar City, using the Quantitative Microbial Risk Assessment (QMRA) approach.
Methods: A cross-sectional study was conducted involving 10 food samples, 10 food handlers, and 100 consumers. Data were collected through direct observation, structured interviews, and laboratory examination of food samples using the Membrane Filter method to determine *E. coli* contamination levels. Risk characterization was performed following the QMRA framework.
Results: All food samples (100%) were contaminated with *E. coli*, with bacterial counts ranging from 2 to 25 CFU/g. Among consumers, 19% reported health complaints after consuming food from Cidu Market, with abdominal pain as the most frequently reported symptom. QMRA results indicated that the probability of infection per day (Pinf/day), annual probability of infection (Pinf.annual), and probability of illness (Pill) were predominantly classified as high risk. Poor hygiene practices were observed among food handlers, including failure to wash hands with soap (100%), use gloves (100%), wear aprons (90%), wear face masks (80%), and wear head coverings (70%).
Conclusion: The findings indicate a high risk of *E. coli* exposure from street food at Cidu Market. Improving food handler hygiene practices and strengthening routine food safety monitoring are essential to reduce microbial contamination and prevent foodborne diseases.

INTRODUCTION

Foodborne diseases remain a major global public health problem, particularly in developing countries where food safety and sanitation practices are often inadequate. According to the World Health Organization, foodborne diseases affect hundreds of millions of people annually and contribute substantially to morbidity and mortality worldwide (WHO, 2016). Among foodborne pathogens, Escherichia coli (E. coli) is recognized as one of the leading bacterial causes of foodborne illness. WHO data show that approximately 20,098 confirmed food poisoning outbreaks resulted in 4,598 illnesses and 77 deaths, with E. coli accounting for nearly 41% of reported cases. Africa records the highest mortality burden, contributing approximately 175,000 deaths annually or 44.53%, while Southeast Asia experiences around 150 million foodborne disease cases each year, representing 34.22% of the global burden (Jumakil et al., 2021). Foodborne illnesses caused by pathogenic microorganisms, including gastroenteritis,

salmonellosis, shigellosis, typhoid fever, paratyphoid fever, cholera, amoebiasis, and poliomyelitis, continue to pose significant threats to public health(Aripin et al., 2024).

Food is one of the most fundamental human needs because it provides essential nutrients and energy required for growth, development, and daily activities (Zhang et al., 2022). However, food can also become a vehicle for disease transmission when contaminated by pathogenic microorganisms during processing, storage, distribution, or serving. Inadequate food hygiene and sanitation practices increase the risk of microbial contamination and contribute to the spread of foodborne diseases (Popkin et al., 2020). In Indonesia, foodborne diseases remain a significant public health concern, as food poisoning outbreaks ranked second among non-natural disasters in 2018. Moreover, the case fatality rate for diarrheal outbreaks reached 4.76%, substantially exceeding the national target of less than 1% set by the Ministry of Health (Saputri & Inayah, 2020). In South Sulawesi Province, the Food and Drug Monitoring Agency reported hundreds of food poisoning incidents in 2021, indicating that food safety remains an unresolved issue in the region (Kasim et al., 2022).

The rising incidence of diarrheal diseases in Makassar City underscores the need for food safety interventions. Data from the Makassar City Health Office showed that reported diarrhea cases increased from 7,410 in 2021 to 11,578 in 2022 (Nuralia, 2025). One of the primary causes of foodborne diarrhea is E. coli contamination, which serves as an indicator of fecal contamination and poor sanitary conditions (Joshi et al., 2022). The presence of E. coli in food is commonly associated with inadequate personal hygiene among food handlers, environmental contamination, improper food handling practices, and the use of contaminated water during food preparation and serving (Chen et al., 2025). Several studies in Indonesia have also reported substantial E. coli contamination in food products. Wardhana et al., (2021) found that approximately 40% of chicken meat samples collected in Surabaya were contaminated with E. coli, while Budiarso et al., (2021) identified enteropathogenic bacteria, including E. coli, in skewered meatball products. In addition, Sari et al., (2020) reported that food handlers may act as carriers of antibiotic-resistant E. coli strains, increasing the potential for pathogen transmission and complicating infection control efforts.

One of the largest street-food centers in Makassar City is the Cidu Market Culinary Area, located on Jalan Tinumbu, Tabaringan Village, Ujung Tanah District. This area is a popular culinary destination and hosts approximately 171 food vendors selling a variety of ready-to-eat foods, including meat products, seafood, fruit-based products, vegetables, traditional snacks, and beverages (Zaenab et al., 2024). The high density of vendors and consumers, along with prolonged exposure of food to the surrounding environment, creates favorable conditions for microbial contamination. Preliminary observations and laboratory examinations conducted in the study area revealed E. coli contamination in food products sold at Cidu Market. Several hygiene and sanitation deficiencies were also identified, including the absence of handwashing before food preparation, inadequate use of personal protective equipment, direct exposure of food to environmental contaminants, open food preparation and serving areas, heavy human activity and motor vehicle traffic, and the proximity of the culinary area to fish market activities. These conditions may increase the risk of foodborne disease transmission among consumers.

Although previous studies have reported E. coli contamination in various food products, limited research has quantitatively assessed the potential health risks of microbial exposure among street-food consumers using the Quantitative Microbial Risk Assessment approach (Yang & Yoon, 2022). Quantifying the probability of infection and illness is important for understanding the magnitude of public health risk and supporting evidence-based food safety interventions. Therefore, this study aimed to assess the quantitative risk of E. coli contamination in foods sold at Cidu Market, Makassar City, using the QMRA framework. Specifically, this study sought to determine the presence of E. coli in food products, assess food handlers' personal hygiene practices, estimate the daily probability of infection, calculate the annual probability of infection, and evaluate the probability of illness associated with the consumption of contaminated foods. The findings are expected to provide scientific evidence for developing effective food safety policies and interventions to reduce consumer foodborne disease risks.

METHODS

This cross-sectional study was conducted in the Cidu Market Culinary Area, Makassar City. A purposive sampling technique was used to select 10 food vendors based on the sale of ready-to-eat foods, processed meat products, high-moisture foods, and products with high consumer demand. The study included 10 food handlers, 100 consumers, and 10 food samples.

Data were collected through direct observation, structured interviews, and laboratory examination. Food handler hygiene practices were assessed using a standardized observation checklist, and consumer information on food consumption patterns and health complaints was collected through structured questionnaires. Food samples were collected aseptically and analyzed at the Environmental Health Laboratory of Poltekkes Kemenkes Makassar using the Membrane Filter method to determine *Escherichia coli* concentrations, expressed as colony-forming units per gram (CFU/g).

Quantitative Microbial Risk Assessment (QMRA) was conducted through four stages: hazard identification, exposure assessment, dose-response assessment, and risk characterization. The exposure dose (d) was calculated as:

$$d = C \times V$$

where C is the concentration of *E. coli* in food (CFU/g), V is the serving size (g), and d is the ingested microbial dose (CFU).

The probability of infection was estimated using the exponential dose-response model:

$$Pinf = 1 - \exp(-r \times d)$$

where r is the infectivity constant and d is the ingested dose. The exponential model was selected because it is widely used in QMRA and assumes that a single viable microorganism may initiate infection. Risk characterization was performed by estimating the probability of infection per day (Pinf/day), annual probability of infection (Pinf.annual), and probability of illness (Pill). Descriptive statistics were used to summarize respondent characteristics, hygiene practices, microbiological findings, and QMRA outcomes. All participants provided informed consent before data collection. Ethical approval was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Makassar, Ethical Clearance No. 0229/M/KEPK-PTKMS/II/2025.

RESULTS

This study was conducted in March 2025 at the Cidu Market Culinary Area, Makassar City. A total of 100 consumers and 10 food handlers participated in the study. In addition, 10 ready-to-eat food samples were collected from selected vendors and analyzed for Escherichia coli contamination. The findings are presented according to respondent characteristics, food handler hygiene practices, microbiological analysis, exposure assessment, and Quantitative Microbial Risk Assessment (QMRA).

Table 1. Characteristics of Consumers and Food Handlers at Cidu Market, Makassar City

Characteristics	Consumers (n=100) n (%)	Food Handlers (n=10) n (%)
Gender		
Male	25 (25.0)	4 (40.0)
Female	75 (75.0)	6 (60.0)
Age (years)		
15–20	44 (44.0)	–
16–22	–	3 (30.0)
21–26	47 (47.0)	–
23–29	–	4 (40.0)
27–32	6 (6.0)	–
30–36	–	2 (20.0)
33–38	1 (1.0)	–
37–43	–	1 (10.0)
39–44	2 (2.0)	–

Characteristics	Consumers (n=100) n (%)	Food Handlers (n=10) n (%)
Education		
Primary School	1 (1.0)	0 (0.0)
Junior High School/Equivalent	5 (5.0)	3 (30.0)
Senior High School/Equivalent	65 (65.0)	7 (70.0)
Bachelor's Degree	29 (29.0)	0 (0.0)

Source: Primary Data, 2025

Table 1 summarizes the characteristics of consumers and food handlers included in this study. Among consumers, females predominated (75.0%), most were aged 21–26 years (47.0%), and the majority had completed senior high school education (65.0%). Similarly, most food handlers were female (60.0%), aged 23–29 years (40.0%), and had a senior high school education (70.0%).

Table 2. Distribution of Personal Hygiene Respondents: Food Handler at Cidu Market, Makassar City

No	Personal Hygiene Practices	Meets Requirements (MR)		Does Not Meet Requirements (DNMR)	
		Quantity	%	Quantity	%
1.	Washing hands with soap	0	0	10	100
2.	Handwashing handles in running water	4	40	6	60
3.	Drying hands with a clean cloth after washing hands	0	0	10	100
4.	Covering visible wounds	10	100	0	0
5.	Wearing clean/work clothes	10	100	0	0
6.	Wearing an apron	1	10	9	90
7.	Wearing a mouthguard	2	20	8	80
8.	Wearing a head covering	3	30	7	70
9.	Wearing tools/gloves	0	0	10	100
10.	Not while smoking, scratching limbs	8	80	2	20
11.	Not talking while touching	3	30	7	70
12.	Short-hoofed	10	100	0	0
13.	Removing jewelry	7	70	3	30
14.	Not receiving/holding the source of contamination from the buyer	0	0	10	100

Source: Primary Data, 2025

Based on Table 2, the personal hygiene practices of food handlers were generally inadequate. All respondents (100%) did not wash their hands with soap, and 60% did not use running water for handwashing. In addition, none of the food handlers (100%) dried their hands with a clean towel after washing. Although all respondents (100%) covered visible wounds and wore clean work clothes, the majority did not use appropriate personal protective equipment: 90% did not wear aprons, 80% did not wear face masks, 70% did not wear head coverings, and 100% did not wear gloves or use food-handling utensils. Risky behaviors were also observed, including smoking or scratching body parts while handling food (20%), talking while handling food (70%), and wearing jewelry during food preparation (30%). Furthermore, all food handlers (100%) had direct contact with potential contamination sources from buyers.

Table 3. Frequency of Food Consumption by Respondents in Cidu Market Makassar City

Consumption Frequency	Amount(s)	Percentage (%)
Every day	4	4
2-3 times a week	8	8
Once a week	11	11
2-3 times a month	23	23
Once a month	54	54
Total	100	100

Source: Primary Data, 2025

Based on Table 3, the most frequent respondent visit is once a month, with 54 respondents (54%). Meanwhile, the frequency of respondent visits was the least frequent of the 4 respondents (4%).

Table 4. Distribution of Respondents Based on Health Disorders After Food Consumption at Cidu Market, Makassar City

Experiencing Health Problems	Amount(s)	Percentage (%)
Yes	19	19
No	81	81
Total	100	100

Source: Primary Data, 2025

Based on Table 4, it can be seen that 19% of respondents experienced disturbances after consuming food at the Cidu market, while 81% did not.

Table 5. Quantitative Microbial Risk Assessment (QMRA) Results of Escherichia coli Contamination in Foods Sold at Cidu Market, Makassar City

Sample	E. coli Count (CFU/g)	Serving Size (g)	Exposure Dose (CFU)	Pinf/day	Pinf. annual	Pill	Risk Category
Meatballs1	10	75	750	2.42×10^{-1}	1	3.5×10^{-1}	High risk
Meatballs2	23	75	1725	5.13×10^{-1}	1	3.5×10^{-1}	High risk
Meatballs3	12	75	900	2.90×10^{-1}	1	3.5×10^{-1}	High risk
Meatballs4	25	75	1875	5.46×10^{-1}	1	3.5×10^{-1}	High risk
Sausage1	11	51	561	2.53×10^{-1}	1	3.5×10^{-1}	High risk
Sausage2	2	51	102	3.81×10^{-2}	0.3726	1.30×10^{-1}	High risk
Sausage3	24	51	1224	5.11×10^{-1}	1	3.5×10^{-1}	High risk
Suki	2	30	60	3.38×10^{-2}	0.3381	1.18×10^{-1}	High risk
Odeng	20	100	2000	4.71×10^{-1}	1	3.5×10^{-1}	High risk
Dimsum	14	50	700	3.19×10^{-1}	1	3.5×10^{-1}	High risk

Source: Primary Data, 2025

Table 5 summarizes the QMRA results for *Escherichia coli* contamination in foods sold at Cidu Market, Makassar City. The *E. coli* counts ranged from 2 to 25 CFU/g, with exposure doses varying from 60 to 2,000 CFU per serving. The daily probability of infection (Pinf/day) ranged from 3.38×10^{-2} to 5.46×10^{-1}, with the highest value observed in Meatballs4 and the lowest in Suki. Most samples had a Pinf.annual value of 1, indicating a very high probability of infection following repeated consumption over the course of 1 year. Only Sausage2 and Suki showed lower annual infection probabilities of 0.3726 and 0.3381, respectively. The probability of illness (Pill)

ranged from 1.18×10^{-1} to 3.5×10^{-1}. Based on the QMRA assessment, all food samples were classified as high risk, indicating a substantial risk of foodborne illness to consumers.

DISCUSSION

Interpretation of Key Findings

Based on the QMRA results, several risk management strategies can be implemented to reduce consumer exposure to Escherichia coli contamination. The first priority is reducing microbial contamination at the source by improving food-handling and environmental sanitation practices. Food handlers should be encouraged to wash their hands with soap before and after handling food, wear appropriate personal protective equipment, and avoid behaviors that may increase contamination risk, such as smoking, talking directly over exposed food, wearing jewelry during food preparation, or frequently touching non-food surfaces. These behaviors can facilitate cross-contamination by transferring microorganisms from hands, respiratory droplets, personal items, and environmental surfaces to ready-to-eat foods.

The presence of E. coli in all food samples is a critical food safety concern because this bacterium is widely recognized as an indicator of fecal contamination and poor sanitation practices. Although not all strains of E. coli are pathogenic, their presence in ready-to-eat foods reflects the possibility that pathogenic microorganisms may also be present (Damayanti et al., 2021). This situation is particularly concerning because consumers directly consume these foods without additional cooking processes that could eliminate microbial contaminants. Consequently, consumers may be exposed to foodborne pathogens capable of causing gastrointestinal disorders and other infectious diseases (Fusaro et al., 2025).

The findings of this study also demonstrated poor personal hygiene practices among food handlers. None of the food handlers washed their hands with soap before handling food, and all respondents failed to use gloves during food preparation and serving. Furthermore, most food handlers did not wear aprons, face masks, or head coverings. Risky behaviors were also observed, including smoking while handling food, talking while preparing food, and wearing jewelry. These practices may substantially increase the risk of cross-contamination. Smoking and touching cigarettes can transfer microorganisms from contaminated hands and surfaces to food products. Talking over exposed food may release saliva droplets containing bacteria, which can directly contaminate ready-to-eat foods. In addition, rings, bracelets, and other jewelry can harbor microorganisms and organic debris that are difficult to remove during handwashing, creating reservoirs for bacterial growth and facilitating the transfer of pathogens to food. Together, these behaviors may contribute to the widespread contamination of food products observed in this study and highlight the critical role of food handler hygiene in preventing foodborne diseases.

Another important finding of this study was that 19% of consumers reported experiencing health complaints after consuming food from Cidu Market. The most frequently reported symptoms were abdominal pain and diarrhea, followed by vomiting. These symptoms are commonly associated with foodborne illnesses caused by bacterial contamination. Although the study design does not allow direct confirmation that the reported symptoms were exclusively caused by E. coli, the findings suggest a potential association between food contamination and adverse health outcomes among consumers.

The QMRA analysis further strengthened the evidence regarding the potential health risks associated with food consumption at Cidu Market. The probability of infection per day (Pinf/day) ranged from 3.38×10^{-2} to 5.46×10^{-1}. The highest infection probability was observed in the fourth meatball sample, reflecting the combined effects of a high bacterial concentration and a large serving size. Similarly, the annual probability of infection (Pinf.annual) reached 1.0 for most food samples, indicating that repeated exposure over 1 year could result in a very high likelihood of infection. The probability of illness (Pill) ranged from 1.18×10^{-1} to 3.50×10^{-1}, and all food samples were categorized as high-risk foods according to WHO microbial risk criteria. These findings demonstrate that regular consumption of contaminated foods from Cidu Market may pose a substantial health risk to consumers.

Comparison with Previous Studies

The results of this study are consistent with numerous previous investigations that have reported microbiological contamination in street-vended foods and traditional market environments. Several studies conducted in Indonesia have demonstrated that poor sanitation and inadequate personal hygiene among food handlers are major contributors to bacterial contamination in ready-to-eat foods.

Noviana & Ruhban (2020) reported that improper handwashing practices and failure to use personal protective equipment were significantly associated with contamination by Escherichia coli and Salmonella in food products. Similarly, Zaenab et al., (2024) found that poor compliance with hygiene standards among food vendors significantly affected the bacteriological quality of foods sold in traditional market settings. The current study supports these findings: all food handlers failed to wash their hands with soap, and none used gloves during food-handling activities.

The contamination levels identified in this study are also comparable to findings reported by Okito et al. (2025), who detected E. coli contamination in street-vended meat products and highlighted inadequate sanitation as a major determinant of microbial contamination. Likewise, Saputri & Inayah (2020) emphasized that contaminated cooking equipment and repeated use of improperly cleaned utensils facilitate cross-contamination and microbial growth in processed meat products. Observations conducted in the present study similarly revealed inadequate cleaning of food preparation equipment and repeated use of cooking utensils without proper sanitation procedures.

The QMRA findings are consistent with previous microbial risk assessments conducted in Indonesia. Ayu (2020) In a QMRA study of Salmonella and Escherichia coli contamination in chicken-based foods around Hasanuddin University, a probability of illness value of approximately 3.5×10^{-1} was reported, indicating a high risk of foodborne illness. Similar findings were reported by Sari et al. (2020), who observed high-risk QMRA values for foods contaminated with enteric bacteria. The consistency of findings across studies strengthens the evidence that microbiological contamination remains a major public health concern in street food environments across Indonesia.

However, differences in contamination levels across studies may be explained by variations in environmental sanitation conditions, food types, climatic factors, food-handling practices, and sampling procedures. These differences highlight the importance of conducting local risk assessments to identify context-specific factors contributing to food contamination and disease transmission.

Implications for Public Health

The findings of this study have important implications for food safety management and public health policy (Utami, 2021). Street food is a major source of affordable meals for urban populations, particularly students, workers, and low-income communities. However, the widespread contamination identified in this study suggests that consumers may unknowingly be exposed to harmful microorganisms on a regular basis (Nasution, 2020).

If food contamination is not adequately controlled, repeated exposure may contribute to increased incidence of foodborne diseases, including diarrhea, gastroenteritis, abdominal pain, vomiting, and other gastrointestinal infections (Popkin et al., 2020). These illnesses not only affect individual health but also contribute to economic losses through healthcare expenditures, reduced productivity, and decreased quality of life (Romadhon et al., 2023).

The findings emphasize the urgent need for strengthening food hygiene and sanitation programs targeting food handlers. Educational interventions should focus on proper handwashing techniques, use of personal protective equipment, prevention of cross-contamination, safe food storage, and environmental sanitation. Regular training programs can improve food handlers' knowledge, attitudes, and practices regarding food safety.

In addition, local health authorities should increase routine monitoring and inspection of street food vendors. Food safety regulations should be consistently enforced to ensure compliance with hygiene standards (Alhadlaq et al., 2024). Provision of adequate sanitation facilities,

including access to clean water, handwashing stations, waste disposal systems, and pest control measures, is essential for reducing contamination risks (Mohamed & Habib, 2023). Furthermore, public awareness campaigns should encourage consumers to make informed food choices and recognize the importance of food hygiene. Community participation in food safety initiatives may contribute to sustainable improvements in food quality and consumer protection.

Risk Management Considerations

The QMRA findings indicate the need for integrated risk management measures to reduce foodborne disease risks associated with street-vended foods at Cidu Market. In addition to improving food handler hygiene practices, attention should be directed toward strengthening environmental sanitation and food safety infrastructure. Food preparation areas should be protected from environmental contaminants such as dust, insects, and rodents, while cooking utensils and serving equipment should be regularly cleaned and sanitized. Appropriate food storage and temperature control are also essential to limit bacterial growth, particularly in ready-to-eat and meat-based products (Magfirah, 2024). Effective risk communication is equally important. Local health authorities should provide regular food safety education and communicate contamination risks to both vendors and consumers. Routine monitoring, inspection, and enforcement of food safety regulations are necessary to ensure compliance with hygiene standards. Collaboration among health authorities, market managers, food vendors, and consumers is essential to establish a sustainable food safety culture and reduce microbial contamination risks in traditional market environments (Mulyati et al., 2024).

Study Limitations

Several limitations should be acknowledged when interpreting the findings of this study. First, the sample size was relatively small, comprising only 10 food samples and 10 food handlers. Although the selected samples represented the most frequently consumed foods in the market, the findings may not fully represent all food vendors operating within Cidu Market or other traditional markets.

Second, the cross-sectional design captured contamination conditions at a single point in time and therefore could not evaluate seasonal variations or temporal changes in microbial contamination. Environmental conditions such as temperature, humidity, rainfall, and market crowding may influence contamination levels throughout the year.

Third, health complaints reported by consumers were based on self-reported information and may be affected by recall bias. The reported symptoms may also be influenced by factors unrelated to food consumed at Cidu Market. Therefore, causal relationships between food contamination and reported illnesses cannot be definitively established.

Finally, the QMRA model relied on assumptions regarding exposure frequency, serving size, and dose-response relationships. While these assumptions were based on established scientific methods, uncertainties remain regarding actual exposure conditions among consumers.

Recommendations for Future Research

Future studies should include larger sample sizes and multiple traditional market locations to improve the representativeness of findings. Longitudinal studies are recommended to evaluate seasonal fluctuations in contamination levels and microbial risks. Researchers should also investigate additional foodborne pathogens, including Salmonella spp., Shigella spp., Staphylococcus aureus, and Listeria monocytogenes, to provide a more comprehensive assessment of food safety hazards.

Further QMRA studies incorporating molecular identification techniques and antimicrobial resistance testing would provide deeper insights into the pathogenic potential of bacterial contaminants. Additionally, intervention studies evaluating the effectiveness of food safety training, sanitation improvements, and regulatory enforcement are needed to identify the most effective strategies for reducing consumer foodborne disease risks.

Overall, this study's findings highlight the urgent need for comprehensive food safety interventions at Cidu Market and similar street food environments. Improving hygiene practices,

strengthening sanitation infrastructure, and enhancing food safety surveillance are essential steps toward reducing microbial contamination and protecting public health.

CONCLUSION

In conclusion, this study highlights the significant public health risks posed by Escherichia coli contamination in ready-to-eat foods sold at Cidu Market in Makassar City. Laboratory analysis showed that all food samples were contaminated with E. coli, with bacterial counts ranging from 2 to 25 CFU/g, while food handlers demonstrated low compliance with hygiene practices. The Quantitative Microbial Risk Assessment (QMRA) demonstrated a high probability of infection per day (Pinf/day), reaching 5.46×10^{-1} in the highest-risk food sample, an annual probability of infection (Pinf.annual) of 1.0 for most food samples, and a probability of illness (Pill) ranging from 1.18×10^{-1} to 3.50×10^{-1}, indicating a high risk of foodborne disease among consumers. These findings suggest that inadequate hygiene and sanitation practices among food handlers contribute substantially to microbial contamination and the risk of gastrointestinal illness. Therefore, strengthening food hygiene and sanitation practices, improving food handling and storage procedures, enhancing routine monitoring and food safety education by health authorities, and increasing public awareness regarding safe food consumption are essential measures to reduce microbial contamination and protect public health. Future studies should include larger, more diverse samples, assess additional foodborne pathogens and environmental risk factors, and conduct repeated sampling over different periods to provide a more comprehensive understanding of microbial risks in street food environments.

Author's Contribution Statement: Haerani conceptualized and designed the study, conducted field data collection, performed data analysis, interpreted the findings, and drafted the manuscript. Andi Aulia Anugrah Nurdin contributed to the study design, supervised the research process, assisted in data interpretation, and critically reviewed the manuscript. Syamsuddin contributed to methodological development, laboratory data interpretation, and manuscript revision. Inayah contributed to data analysis, quality assurance of laboratory examinations, interpretation of results, and final manuscript editing. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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BIBLIOGRAPHY

Alhadlaq, M. A., Aljurayyad, O. I., Almansour, A., Akeel, S. I. Al, Alzahrani, K. O., Alsalman, S. A., Yahya, R., Hindi, R. R. Al, Hakami, M. A., Alshahrani, S. D., Alhumeed, N. A., Moneea, A. M. Al, Seghayer, M. S. Al, Alharbi, A. L., Reshoodi, F. M. A. L., & Alajel, S. (2024). Overview of Pathogenic Escherichia coli, With a Focus on Shiga Toxin - Producing Serotypes, Global

Outbreaks (1982 – 2024) and Food Safety Criteria. *Gut Pathogens*, *16*(57), 1–18. https://doi.org/https://doi.org/10.1186/s13099-024-00641-9

Aripin, S., Gusmayanti, E., & Fathmawati, F. (2024). Kualitas Air Sungai Pampang di Sekitar TPA Pampang Harapan Kabupaten Kayong Utara Kalimantan Barat. *Sulolipu: Media Komunikasi Sivitas Akademika Dan Masyarakat*, *24*(1), 110–119. https://doi.org/10.32382/sulo.v24i1.298

Ayu, A. D. (2020). *Quantitative Microbial Risk Assessment (QMRA) Bakteri Salmonella dan Escherichia coli pada Ayam Lalapan di Warung Makan Sekitar Kampus Universitas Hasanuddin Kota Makassar* (Vol. 2507, Issue February). Universitas Hasanuddin.

Budiarso, T. Y., Prihatmo, G., Restiani, R., Pakpahan, S., & Sari, L. (2021). Detection Staphylococcus aureus Producing Enterotoxin A on the Skewers Meatballs Product in Yogyakarta City Indonesia. *Journal of Physics: Conference Series*, 1–7. https://doi.org/10.1088/1742-6596/1397/1/012044

Chen, Y., Lin, C. H., Huang, Y. C., & Tsai, Y. H. (2025). Quantitative Microbial Exposure Assessment of Uropathogenic Escherichia coli in Ready-to-Eat Chicken: Consumer Risk and Mitigation Strategies in Taiwan. *Food Research International*, *222*, 117642. https://doi.org/10.1016/j.foodres.2025.117642

Damayanti, A. Y., Syafii, N. K., & Fathimah, F. (2021). The Relationship Between Food Handlers' Knowledge and Behavior with the Presence of E. coli Bacteria in Food in Islamic Boarding Schools. *Tambusai Health Journal*, *2*(1), 47–60. https://doi.org/10.31004/jkt.v2i1.1545

Fusaro, C., Guerrero-vargas, N., Sarria-guzmán, Y., Serrano-silva, N., Bernal, J. E., Ríos-montes, K., Eliza, H., Luna, R., Antonio, J., Ángel, D., Peredo-lovillo, A., & González-jiménez, F. E. (2025). Molecular Identification of Escherichia coli Isolated from Street Foods : Global Evidence and Public Health Implications. *Microbiology Research*, *16*(1), 1–22.

Joshi, A., Bhardwaj, D., Kaushik, A., Juneja, V. K., Taneja, P., Thakur, S., & Taneja, N. K. (2022). Advances in Multi-Omics Based Quantitative Microbial Risk Assessment in the Dairy Sector: A Semi-Systematic Review. *Food Research International*, *156*, 111323. https://doi.org/10.1016/j.foodres.2022.111323

Jumakil, Yanti, V., Harleli, & Fithria. (2021). Taste, Price, Hygiene and Hygiene Related to the Selection of Places to Eat Marine Juice. *Jurnal Ilmiah Kesehatan Sandi Husada*, *10*(2), 431–439. https://doi.org/10.35816/jiskh.v10i2.609

Kasim, K. P., Juherah, Rahmadani, F. F., Rostina, & Saleh, M. (2022). Personal Hygiene Analysis on Food Serving at Panakkukang Fresh Market, Makassar City. *Hygiene: Jurnal Kesehatan Lingkungan*, *8*(3), 171–177. https://doi.org/https://doi.org/10.24252/higiene.v8i3.35825

Magfirah, I. (2024). Analysis of the Presence and Risk Factors of Bacteria Escherichia Coli In Orange JuiceIn Takengon 2023 JUK-Medifa. *Jurnal Kesehatan, Rekam Medis Dan Farmasi*, *3*(01), 151–155. https://doi.org/https://doi.org/10.58471/juk-medifa.v3i01.632

Mohamed, M.-Y. I., & Habib, I. (2023). Pathogenic E. coli in the Food Chain across the Arab Countries: A Descriptive Review. *Foods*, *12*, 1–18. https://doi.org/https://doi.org/10.3390/foods12203726

Mulyati, S., Raharjo, M., & Nurjazuli, N. (2024). Factors Associated with the Presence of E.coli in Food: Literature Review. *Media Publikasi Promosi Kesehatan Indonesia*, *7*(7), 1804–1810. https://doi.org/https://doi.org/10.56338/mppki.v7i7.5325

Nasution, A. S. (2020). Hygiene of Food Handlers Causes Contamination of Escherichia coli in Traditional Market Snacks. *Promotor*, *3*(1), 1–6. https://doi.org/10.32832/pro.v3i1.3119

Noviana, N., & Ruhban, A. (2020). Identify the Content of Escherichia coli and Salmonella Bacteria in Burgers Sold by Street Vendors in Makassar City. *Sulolipu*, *19*(2), 259. https://doi.org/10.32382/sulolipu.v19i2.1348

Nuralia. (2025). *Risk Assessment of Bacterial Exposure from the Consumption of Student Snacks at Elementary School of Biringkanaya District, Makassar City* [Hasanuddin University]. http://repository.unhas.ac.id/id/eprint/43166

Okito, A. M., Wagacha, J. M., Lukhoba, C. W., Lina, A. A., & Mukabana, W. R. (2025). Food and Water Safety Risks From Salmonella enterica and Escherichia coli Contamination in Bukavu City, Democratic Republic of the Congo Study area. *Cureus*, *17*(3), 1–17.

https://doi.org/10.7759/cureus.79951
Popkin, B. M., Corvalan, C., & Strawn, L. M. G. (2020). Dynamics of the Double Burden of Malnutrition and the Changing Nutrition Reality. *The Lancet*, *395*, 65–74.
Romadhon, T., Rahayu, W. P., & Kusumaningrum, H. D. (2023). Dayak Onion Extract Inhibits the Growth of Escherichia coli and Staphylococcus aureus in Chicken Meat. *Jurnal Ilmu Pertanian Indonesia*, *28*(3), 504–512. https://doi.org/10.18343/jipi.28.3.504
Saputri, D. E., & Inayah, I. (2020). The Relationship Between Hygiene, Sanitation, Meatball Processing and Bacteriological Quality in Limbung, Gowa Regency. *Sulolipu: Media Komunikasi Sivitas Akademika Dan Masyarakat*, *20*(1), 42. https://doi.org/10.32382/sulolipu.v20i1.1472
Sari, D. Y., Pisestyani, H., & Lukman, D. W. (2020). Antibiotic Resistance in Escherichia coli Isolated from Döner Kebab Sold in Dramaga Bogor, Indonesia. *Advances in Animal and Veterinary Sciences*, *8*(3), 278–284. https://doi.org/10.17582/journal.aavs/2020/8.3.278.284
Utami, A. P. (2021). Literature Review: Relationship of Personal Hygiene of Food Handlers with Escherichia coli Contamination in Food. *Journal of Food and Culinary*, *4*(1), 25. https://doi.org/10.12928/jfc.v4i1.4032
Wardhana, D. K., Safitri, D. A., Annisa, S., Effendi, M. H., & Harijani, N. (2021). Detection of Escherichia coli Contamination Using Most Probable Number (MPN) Methods in Chicken Meats in Market of Surabaya. *Jurnal Medik Veteriner*, *4*(1), 118–124. https://doi.org/10.20473/jmv.vol4.iss1.2021.118-124
WHO. (2016). *Quantitative Microbial Risk Assessment: Application for Water Safety Management*. World Health Organization. https://www.who.int/publications/i/item/9789241565370
Yang, S. Y., & Yoon, K. S. (2022). Quantitative Microbial Risk Assessment of Listeria monocytogenes and Enterohemorrhagic Escherichia coli in Yogurt. *Foods*, *11*(7), 971. https://doi.org/https://doi.org/10.3390/foods11070971
Zaenab, Z., Nurhaidah, N., Chalizhah, I., & Azizah, N. (2024). Personal Hygiene Factors of Handlers and Sanitary Conditions of TPM on the Bacteriological Quality of Snack Food in Culinary Cidu Market, Makassar City. *Sulolipu*, *24*(2), 378–391. https://doi.org/https://doi.org/10.32382/sulo.v24i2.952
Zhang, Y., Schmidt, J. W., Arthur, T. M., Wheeler, T. L., Zhang, Q., & Wang, B. (2022). A Farm-to-Fork Quantitative Microbial Exposure Assessment of β-Lactam-Resistant Escherichia coli Among U.S. Beef Consumers. *Microorganisms*, *10*(3), 661. https://doi.org/10.3390/microorganisms10030661