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Original Article

The contribution of banknotes to microbial contamination and transmission on grilled meat in Dodoma City, Tanzania

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Abstract

This study examines the transmission of germs from banknotes to grilled meat sold by street vendors. 100 banknotes and 100 grilled meat samples from 40 street vendors were analyzed and compared with the Tanzania Food Drugs Authority (TFDA) and the East African food standards (EAS) standards. Microbial contamination was higher on banknotes than on meat. Contamination of banknotes and grilled meat by *Escherichia coli* (28.2%, 9.5%), *Salmonella* spp. (11.9%, 5.7%), and *Staphylococcus aureus* (21.3%, 6.8%) was observed. The mean microbial load on banknotes and grilled meat ranged from 5.2 ± 1.31 x 10^3 CFU to 5.9 ± 1.23 x 10^3 CFU and from 5.1 ± 1.44 x 10^3 CFU to 5.4 ± 1.13 x 10^3 CFU, respectively. These levels were higher than the EAS 128:2011 and EAS 44:2011 standards. Fungal genera identified in banknotes by ITS PCR and 18S rDNA RT-PCR, were *Aspergillus* spp. (5%), and *Penicillium* spp. (3%), with no fungi found on grilled meat. Vendors with informal education and poor hygiene practices had higher contamination levels. Hygiene practices involved regular handwashing (40%), using clean water for meat preparation (55%), covering meat with clean covers (50%), disinfecting cooking equipment (35%), and avoiding raw meat and ready-to-eat meat contact (45%) aimed to reduce contamination. These results call for the need for improved hygiene education and interventions in street food vending.

Keywords: germ transmission, banknotes, grilled meat, street vendors, microbial contamination.
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Introduction

The potential for foodborne diseases arising from poor hygiene practices in the informal food sector is a growing global concern (Grace, 2023; Kuboka et al., 2024). In developing countries, street food vendors play a vital role in urban food systems, offering various foods, including grilled meat, as a primary source of nutrition for locals and tourists (Bouafou et al., 2021; Salamandane et al., 2023). One health risk in this sector is the transfer of microorganisms from sources such as banknotes to food products (Rane, 2011; Christiana Cudjoe et al., 2022). Banknotes, due to their widespread circulation and frequent handling, are known to harbor a variety of microorganisms (Cozorici et al., 2022). Studies show that paper money acts as a vector for pathogens like bacteria, viruses, and fungi (Angelakis et al., 2014; Bouafou et al., 2021). As money changes hands, pathogens accumulate from both clean and contaminated surfaces (Cozorici et al., 2022). In informal settings with limited sanitation, these pathogens are transferred to food products, especially when food hygiene is not strictly followed (Kussaga and Nziku, 2023; Okesanya et al., 2024).

Microorganisms such as *Enterobacteriaceae* and *coliforms* are present in considerable numbers on both money and food items due to the handling of currency during food transactions that contribute to the spread of pathogens. Ofoedu et al. (2021) in Nigeria found that banknotes were commonly contaminated with *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus*. Similarly, Allan et al. (2018) in Uganda highlighted the contamination of both banknotes and street food with a range of bacteria. Birgen et al. (2020) in Kenya found high levels of *Salmonella* and *Staphylococcus aureus* on food sold by street vendors, which are common culprits in foodborne diseases. Negassa et al. (2023) concluded that a significant proportion of street vendors lack formal training in hygiene and food safety, leading to an increased risk of microbial contamination. Although these studies provide valuable information on the microbial risks associated with street food vending, there is a gap in research specific to the study area.

Grilled meat, a popular street food in cities, can become a vehicle for disease transmission if contaminated during handling and preparation (Waldman et al., 2020). Ingesting contaminated grilled meat results in diarrhea, fever, and abdominal cramps (Ehuwa et al., 2021). Various pathogens, both bacterial and viral, are associated with foodborne illnesses transmitted from banknotes to grilled meat, posing health risks to consumers (Lianou et al., 2017). A pathogenic strain of *Escherichia coli*, particularly E. coli O157:H7, is linked to foodborne infections (Doyle, 1991; Lim et al., 2010). *E. coli* infections cause severe gastrointestinal illness, diarrhea, and, in extreme cases, kidney failure. E. coli are easily transferred from contaminated surfaces, such as banknotes, to food (Stein and Chirilă, 2017). *Salmonella* spp. is a major cause of foodborne illness worldwide and is frequently found on contaminated meat, especially in undercooked and improperly handled grilled meat transferred through improper handling and contamination by pathogens on banknotes (Ehuwa et al., 2021; Popa and Papa, 2021). *Staphylococcus aureus*, found in the nasal passages of humans and transferred to food via hand contact with contaminated

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banknotes (Ho et al., 2015; Sakr et al., 2018), produces heat-resistant toxins causing food poisoning, resulting in nausea, vomiting, abdominal pain, and diarrhea (Argudín et al., 2010; Hennekinne et al., 2012; Kadariya et al., 2014).

Enterobacteriaceae, *Klebsiella*, and *Enterobacter*, commonly found on food and banknotes (Guentzel, 1996; Janda and Abbott, 2021), are opportunistic pathogens, especially for individuals with weakened immune systems (Guentzel, 1996), causing various infections in vulnerable populations (Janda and Abbott, 2021). Molds and fungi, such as *Aspergillus*, *Penicillium*, and *Cladosporium*, can be transferred from contaminated banknotes to grilled meat (Baxi et al., 2016; Mastanjević et al., 2023). While some species cause immediate health issues in small quantities, others, particularly those producing mycotoxins, pose greater risks (Pitt and Hocking, 2022; Dembele et al., 2024). Informal food handling practices and inadequate sanitation raise concerns that food sold by vendors may be contaminated with harmful microorganisms. To investigate the pathogens on banknotes and their potential transmission to grilled meat, the following questions were addressed: What microorganisms are present on banknotes? Which pathogens transfer from banknotes to grilled meat during transactions? What health risks do consumers and vendors face from germ transmission? How can hygiene practices be improved to reduce microbial contamination? The objective of the study is to investigate the role of banknotes in microbial contamination and the potential transmission of harmful microorganisms to grilled meat and identify the types of pathogens present on banknotes and grilled meat.

Methods

Study area

The study was conducted in Dodoma City (6° 10' 43" South and 35° 45' 2" East), the capital of Tanzania, during the dry season from June to October 2024. In this dry season, the stability of outdoor temperatures was expected to favor the survival of pathogens. Twenty wards out of the 41 sampling sites were selected as sampling sites due to their high prevalence of selling grilled meat. Chamwino, Chang'ombe, Makulu, Hazina, Ipagala, Kilimani, Madukani, Kizota, Makole, and Majengo represented Dodoma central, while Miyuji, Mkonze, Mnadani, Msalato, Ng'ong'ona, Nkuhungu, Nzuguni, Ntyuka, Ihumwa, and Iyumbu represented Dodoma peripheral, both from high-traffic and residential areas.

Sampling procedure

Germ transmission from banknotes to grilled meat occurs through direct contact or indirect routes, such as contaminated surfaces or handling practices. Factors like temperature, humidity, cooking, and transaction handling influence contamination. To trace microbes, samples from both banknotes and meat were analyzed. The potential for contamination of raw meat prior to cooking was also considered, along with the risk of cross-contamination from improper sanitation practices. These factors helped establish a link between banknotes and microbial contamination on grilled meat. To ensure that only microbes originating from the banknotes and grilled meat were implicated in the contamination, data were gathered to specifically rule out these other potential sources. This included sampling the surrounding environment, transport conditions, and vendor equipment. The raw meat was analyzed for microbial contamination to assess whether it was a significant contributor to the pathogens found on the grilled meat. The cleanliness of surfaces and utensils used during the preparation process was verified, and the vendor's hand hygiene practices were monitored. After eliminating these potential sources of contamination, we confidently determined that the observed microbial contamination on the grilled meat originated solely from the banknotes. Socioeconomic factors such as access to clean water, income, and infrastructure, i.e., refrigeration, independently influence hygiene practices. The premises where samples were collected had adequate water access and refrigerators for meat storage.

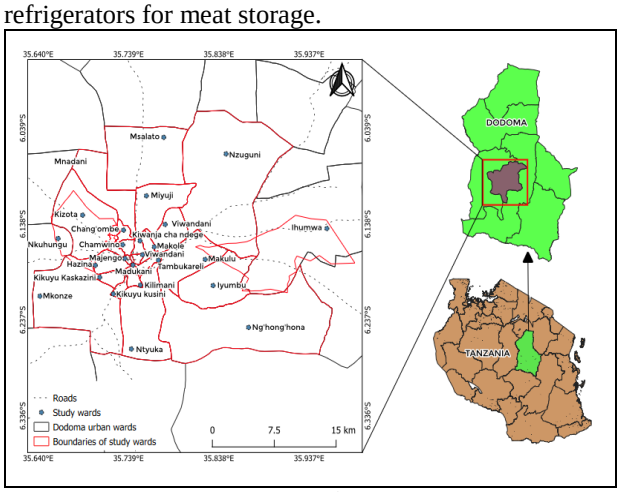

Figure 1: Map showing study wards of Dodoma City in Tanzania.

Sample collection

A total of forty street vendors selling grilled meat (nyama choma), 2 from each ward, were randomly selected based on their willingness to cooperate. One hundred banknotes (5 from each ward) comprising Tshs. 1000, 2000, 5000, and 10,000 were collected during vendor-customer transactions. Using sterile gloves, each banknote was placed in sterile plastic bags. A sterile cotton swab moistened with saline was used to sample specific areas of the banknotes. Additionally, 100 grilled meat samples, 20 g each (5 samples from each ward), were collected from the surface and interior of the meat in sterile conditions. Banknote and grilled meat samples were immediately placed in sterile containers and sent to the laboratory for microbiological analysis.

Preparation and isolation of samples

Grilled meat tissue was homogenized in a sterile blender to evenly distribute microbial cells before

dilution. Each banknote was swabbed with a sterilized cotton swab moistened with saline and then streaked onto MacConkey agar for bacterial isolation. To decrease microbial load and obtain isolated colonies, the collected samples (banknote swabs and meat tissues) were serially diluted in sterile saline and plated on agar by 10 µL. Bacteria identification followed International Organization for Standardization (ISO) protocols: *Escherichia coli* (ISO 16649-1:2001, ISO 16649-2:2001), *Salmonella* spp. (ISO 6579:2017), and *Staphylococcus aureus* (ISO 6888-1:1999).

Pathogen enumeration and incubation

MacConkey agar isolated bacteria, Sabouraud dextrose agar (SDA) was used in fungal isolation, followed by incubation for 48 to 72 hours at 30°C. Incubated bacterial plates at 37°C for 24 - 48 hours in aerobic conditions, while fungal plates were incubated for 3-7 days at 25 - 30°C to allow colony growth.

Colony counting and identification

Microbial colonies were assessed by counting distinct types (based on size, shape, color, and texture), and colony-forming units (CFU) per gram of meat or banknote were recorded. Presumptive colonies were counted with a colony counter (Galenkamp, England) and reported as CFU per 25 grams of the sample. Polymerase Chain Reaction (PCR) was used for strain identification of *E. coli* O157:H7, *Salmonella* spp., and fungi; primers targeting unique genetic markers were used to confirm them on banknotes and grilled meat samples. The DNA is broken down, annealed with primers, and extended by DNA polymerase. This makes millions of copies that can be used for precise identification by gel electrophoresis or sequencing. To detect fungi, selective fungal media, direct microscopic examination to observe fungal morphology, and swab techniques were used. Sterile techniques and disinfection protocols were followed to avoid cross-contamination for accurate results.

Third-party hygiene verification

In this study, third-party verification was employed through independent observers who monitored vendor hygiene practices, such as hand washing and sanitization of banknotes. These observers carefully documented vendor compliance with hygiene protocols, effectively reducing the risk of self-reporting bias. This approach ensured the collection of more reliable, accurate, and objective data for the study's findings.

Data analysis and reporting

The data were analyzed using the Social Sciences Statistical Package (IBM SPSS) version 26 and one-way ANOVA, with statistical significance ($p < .05$). Results were compared with the Tanzania Food and Drugs Authority (TFDA, 2019) and the East African food standards (EAS 128:2011, EAS 44:2011) guidelines.

Ethical considerations

Ethical approval, with reference number MA.84/261/02, was acquired from the University of Dodoma. Permission to collect samples from street vendors was obtained from the vendors themselves, and customer consent was obtained during the banknote collection process. To ensure vendor anonymity, no personal identifiers were collected, and all data were coded. Participation was voluntary, and vendors' identities remained confidential throughout the study. Vendors were assured that their participation was voluntary and that the collected samples would not be linked to any personal or business information.

Results and Discussion

Table 1 presents demographic data on grilled meat vendors, categorized by sex, age, education, hygiene practices, location, and customer volume, indicating the percentage of those adhering to proper hygiene standards. Males are the predominant, largely youthful workforce, mostly aged 21–30. Most vendors have primary education and practicepractices, operate in central locations, and serve a moderate number of customers daily. The table illustrates how regional socioeconomic, cultural, and infrastructural conditions influence microbial contamination levels. Limited access to proper sanitation facilities among lower-income groups heightens the risk of food contamination and related health issues. Cultural food handling habits, poor waste disposal, and inconsistent healthcare services further exacerbate the problem. These necessitate the need for region-specific interventions to improve hygiene in street food vending environments and designing effective public health strategies in informal food sectors.

Table 1 presents of vendors distribution based on sex, education level, age, hygiene practices, vendor location, and the number of customers served per day. It shows the percentage of vendors who follow proper hygiene practices and their characteristics across

Table 1. Vendor demographics (n=40) and hygiene practices in Dodoma City

Factor	Category	Number of vendors (%)	Factor	Category	Number of vendors (%)
Sex	Male	29 (72)	Hygiene	Practiced	24 (60)
	Female	11 (28)	practices	Not Practiced	16 (40)
Education level	Informal	13 (32)	Vendor	Central	24 (60)
	Primary	16 (40)	location	Peripheral	16 (40)
	Secondary	8 (20)	Customers	Low (1–20)	8 (20)
	Tertiary	3 (8)	served/ day	Moderate (21–50)	19 (47.5)
Age	< 21 years	13(32)		High (50+)	13 (32.5)
	21- 30 years	19 (48)			
	> 30 years	8 (20)			

different categories**.**

Several microorganisms, *Escherichia coli* (E. coli), *Salmonella* species, and *Staphylococcus aureus* (S. aureus), were identified on banknotes, indicating a high level of contamination. In grilled meat sample *E. Coli* and *Salmonella* were the most commonly detected bacteria, posing significant food safety concerns. Fungal species such as *Penicillium* and *Aspergillus* were
exclusively found on banknotes, suggesting different contamination sources between the two sample types (Table 2).

Table 3 displays the microbial load for *E. coli*, *S. aureus*, and *Salmonella* across different factors such as sex, education level, and hand hygiene practice. It also includes the contamination percentages for each microorganism. The microbial load from banknotes to grilled meat varies by vendor demographics. Vendors with informal education showed the highest microbial load. Higher education may correlate with better knowledge of hygiene practices and increased access to clean environments, thus reducing pathogen exposure. Most vendors were males, with a notable proportion having low levels of formal education, aligning with findings from studies in Africa, India, and Indonesia that link lower education levels to poorer food safety practices (Bouafou et al., 2021). Vendors practicing hand hygiene had significantly lower contamination than those who didn't. Males show higher microbial loads than females for *E. coli*, *S. aureus*, and Salmonella, with the largest difference in E. coli. Hand hygiene practice significantly reduces microbial loads. Poor hand hygiene increases pathogen transfer risk, especially in food settings, highlighting the importance of hygiene in preventing contamination. The majority of vendors are young adults, a group often engaged in street vending due to economic factors in the developing world (Rane, 2011). Hygiene practices were followed by majority (60%) of vendors, highlighting a gap in food safety adherence, which is consistent with research indicating that insufficient hygiene training is a common issue among vendors in urban areas of the Gedeo Zone, Southern Ethiopia (Negassa et al., 2023). The central location of many vendors, with higher foot traffic, increases exposure to microbial contamination, as noted in Indian urban street food (Salamandane et al., 2023).

The PCR confirmation results in Table 4 show *E. coli* O157:H7 and *Salmonella* spp. the presence in both banknotes and grilled meat samples, indicated by positive results for specific target genes (stx1, stx2, eae, hlyA, invA, fimA). Fungal contamination was more pronounced in banknotes, with positive results for *Aspergillus* spp. and *Penicillium* spp., while grilled meat samples showed negative results for fungal genes, suggesting less fungal contamination in meat, consistent with Ofoedu et al. (2021), showig currency as a vector for Nigerian currency bacterial contamination. Fungi, such as *Aspergillus* and *Penicillium* spp., were found on banknotes, though not on grilled meat.

Previous research has similarly indicated that improper handling of food and money increases the risk of foodborne illnesses (Allan et al., 2018; Ehuwa et al., 2021). Higher microbial loads were observed among vendors with informal education and those who did not practice hand hygiene. *E. coli*, *S. aureus*, and *Salmonella* spp. were the most common contaminants, with male vendors showing slightly higher contamination levels than female vendors. This finding aligns with Kussaga and Nziku (2023), indicating improper hygiene and low education levels contribute to higher microbial contamination in street food in Morogoro Municipality, Tanzania. According to Renaud et al. (2011), the transfer of microbes from banknotes to meat further exacerbates the health risks associated with street food vending.

Figure 2 presents the hygiene practices followed by vendors, their effectiveness in reducing germ transmission, and the associated health risk severity

Table 2. Pathogen contamination on banknotes and grilled meat (Mean ± SD, n = 100).

Pathogen	Banknotes (%), n =100	Grilled meat (%), n =100	Mean ± SD CFU/Banknote (x10³)	Mean ± SD CFU/Grilled meat (x10³)	EAS128:2011& EAS 44: 2011
S. aureus	21.3	6. 8	3.9± 1.32	1.7± 1.03	<1 log CFU/g
E. coli	28.2	9.5	4.5± 1.12	1.3± 1.20	<1 log CFU/g
Salmonella spp.	11.9	5.7	1.8± 1.43	1.1± 1.11	<1 log CFU/g
TVC *S. aureus*	-	-	5.9 ± 1.23	5.4± 1.13	5 log CFU/g
TVC *E. coli*	-	-	5.7± 1.01	5.3± 1.23	5 log CFU/g
TVC *Salmonella*	-	-	5.2 ± 1.31	5.1 ± 1.44	5 log CFU/g
Aspergillus spp.	5.0	-	-	-	-
Penicillium spp.	3.0	-	-	-	-

Table 3. Microbial load and contamination on banknotes and grilled meat sold by vendorsbased on various factors **(**Mean ± SD, n = 100).

Factor	Category	Microbial Load (CFU) ± SD x 10³			Contamination (%)		
		E. coli	*S. aureus*	*Salmonella*	*E. coli*	*Salmonella*	*S. aureus*
Sex	Male	4.0 ± 1.81	3.0 ± 1.25	3.0 ± 1.91	33	25	20
	Female	3.5 ± 1.57	2.8 ± 1.41	2.8 ± 1.42	30	20	25
Education level	Informal	5.5 ± 1.33	4.2 ± 1.52	4.2 ± 1.73	45	35	30
	Primary	4.3 ± 1.41	3.0 ± 1.80	3.0 ± 1.81	35	25	20
	Secondary	3.2 ± 1.21	2.5 ± 1.01	2.5 ± 1.31	25	20	15
	Tertiary	2.0 ± 1.70	1.5 ± 1.23	1.5 ± 1.91	15	10	5
Hand hygiene	Practiced	2.1 ± 1.31	1.8 ± 1.71	1.8 ± 1.11	n/m	n/m	n/m
	No Practice	4.5 ± 1.26	3.2 ± 1.61	3.2 ± 1.71	n/m	n/m	n/m
Transfer (banknotes-meat)		3.8 ± 1.01 (combined)					

Table 4. PCR confirmation results for bacterial and fungal species in banknotes and grilled meat

Species	PCR Target Gene	PCR Result (Banknotes)	PCR Result (Grilled Meat)	Primers Used	References
*E. coli*O157:H7	*stx1*, *stx2* (Shiga toxins)	+ve for *stx1* and *stx2* genes	+ve for *stx1* and/or *stx2* genes	F: 5'-AGTCCGTGGGATTACGTT-3', R: 5'-CTCTGGATGCATCTCTGG-3'	Paton & Paton (1998)
	eae (Pathogenic *E. coli*)	+ve for *eae* gene	+ve for *eae* gene	F: 5'-GACCCGGCACAAGCATAAGC-3', R: 5'-CCACCTGCAGCAACAAGAGG-3'	Paton & Paton (1998)
	hlyA (*Hemolysin* gene)	+ve for *hlyA* gene	+ve for *hlyA* gene	F: 5'-GCATCATCAAGCGTACGTTCC-3', R: 5'-AATGAGCCAAGCTGGTTAAGCT-3'	Paton & Paton (1998)
Salmonella spp.	*invA* (*Invasin* gene)	+ve for *invA* gene	+ve for *invA* gene	F: 5'-GTGAAATTATCGCCACGTTCGGGCAA-3', R: 5'-TCATCGCACCGTCAAAGGAACC-3'	Ali et al. (2017)
	fimA (*Fimbrial* gene)	+ve for *fimA* gene	+ve for *fimA* gene	F: 5'-TTGAGCGCAGACTTTAATGG-3', R: 5'-GCTGCGGTAGAAATGTTGTT-3'	Ali et al. (2017)
Fungi spp. (*Aspergillus* spp,*Penicillium* spp.)	*ITS* (Internal Transcribed Spacer region)	+ve for *ITS* region (common for fungi)	+ve for *ITS* region (for fungi)	ITS1: 5'-TCCGTAGGTGAACCTGCGG-3', ITS4: 5'-TCCTCCGCTTATTGATATGC-3'	White et al. (1990)
	LSU (Subunit rRNA gene)	+ve for *LSU* gene	-ve for *LSU* gene	LR0R: 5'-ACCCGCTGAACTTAAGC-3', LR5: 5'-TCCTGAGGGAAACTTCG-3'	White et al. (1990)
	18S rRNA (Ribosomal RNA gene)	+ve for *18S rRNA* gene	-ve for *18S rRNA* gene	NS1: 5'-GTAGTCATATGCTTGTCTC-3', NS8: 5'-TCCGCAGGTTCACCTACGGA-3'	Medlin et al. (1988)

based on the Ricket scale (1-5). The act of using clean water for meat preparation and covering meat with clean covers, reported, was found to significantly reduce bacterial contamination and airborne microbes (Salamandane et al., 2023). Regular handwashing with soap, though practiced by only 40% of vendors, showed moderate effectiveness in reducing foodborne infections, a finding consistent with literature on the role of personal hygiene in preventing disease (Christiana et al., 2022). The sanitization of banknotes, though rarely practiced, was identified as the most effective practice for reducing germ transmission, highlighting the need for interventions targeting money handling (Cozorici et al., 2022) and improving hygiene practices to reduce foodborne illnesses (Kuboka et al., 2024).

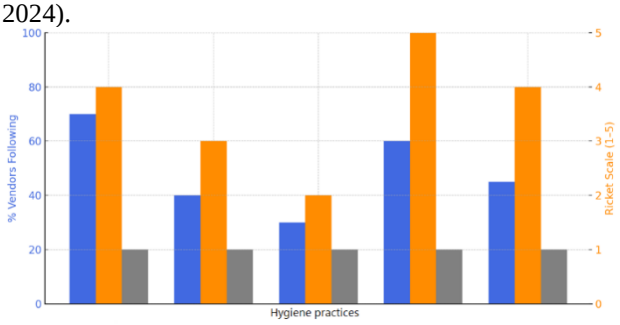

Figure 2. Hygiene practices, vendor compliance, and effectiveness in reducing germ transmission. Ricket scale (1-5), Key 1- negligible, 2-low, 3-moderate, 4-high, and 5-very high.

Figure 3 outlines the transmission likelihood percentages and associated health risk severity (on a scale of 1 to 5) for various risk factors related to banknote contamination and handling. The highest health risk is associated with the handling of contaminated banknotes, which is linked to a high likelihood of transmission of *E. coli*, Salmonella, and Staphylococcus, as shown.

Negassa et al. (2023) noted this risk is exacerbated when vendors handle meat with contaminated banknotes, increasing the likelihood of food borne illnesses, diarrhea, and infections. Inadequate handwashing contributes to skin and respiratory infections (Okesanya et al., 2024). Cross-contamination between cooked and raw meat also posed a significant health risk, consistent with findings from various food safety research as per Waldman et al. (2020). Cozorici et al. (2022) reinforce hygiene education

and interventions to reduce microbial transmission and its associated health risks in street food vending.

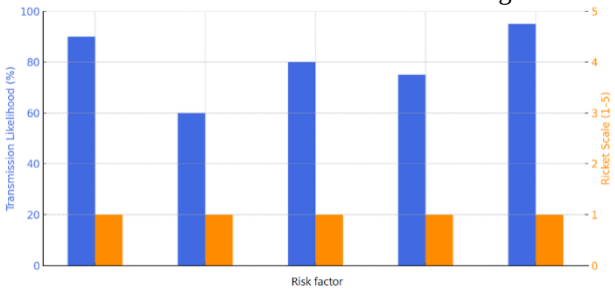

Figure 3.Risk Factors, Transmission Likelihood, and Health Risk Severity for Contaminated Banknotes**.** Ricket scale (1-5), Key 1-negligible, 2- low, 3-moderate, 4-high, and 5-very high.

Table 4 summarizes the PCR target genes and their confirmation results for various bacterial species (*E. coli* O157:H7, *Salmonella* spp.) and fungal species (Fungi spp.) detected in banknotes and grilled meat samples. The use of established primers indicated, such as those by Paton & Paton (1998) for *E. coli* virulence genes and Ali et al. (2017) for *Salmonella* genes, ensures specificity and reliability of the PCR assays. Similarly, fungal identification using universal primers from White et al. (1990) and Medlin et al. (1988) strengthens the taxonomic accuracy. Referencing these studies not only justifies the choice of primers but also aligns the current research with globally accepted molecular diagnostic standards, enabling comparison of results across different studies and settings. This

approach supports the reproducibility and scientific integrity of microbial contamination analysis.

The confirmatory test results presented in Table 4 suggest that both banknotes and grilled meat are contaminated with pathogenic *E. coli* and *Salmonella* strains, indicating a potential health risk. Fungal DNA was detected on banknotes but not in grilled meat, highlighting banknotes as possible reservoirs for fungal spores and cross-contamination sources in food handling environments.

Conclusion

Significant health risks associated with germ transmission from banknotes to grilled meat sold by street vendors were noted. Vendors, primarily young and male with low levels of education, are particularly vulnerable to microbial contamination. The presence of harmful bacteria like *E. coli*, *Salmonella*, and *S. aureus* on both banknotes and grilled meat emphasizes the importance of addressing hygiene practices, especially in handling money and food. Vendors with improper hygiene practices and limited education showed higher microbial contamination, contributing to increased risks of foodborne illnesses and infections. To mitigate these health risks, targeted hygiene education programs should be implemented for vendors, focusing on proper handwashing, sanitization of banknotes, and the use of clean water for meat preparation. Further studies should explore raw meat contamination, incorporate third-party verification, control for access to clean water, income, and infrastructure like refrigeration, which independently influence hygiene practices, and establish direct links between microbial presence and health outcomes using clinical data.

Limitation of the study

Although environmental factors, sanitation practices, meat transport conditions, grill cleanliness, vendor equipment, and hand hygiene were observed during data collection, these variables were not quantitatively assessed and systematically documented in the manuscript. Therefore, their potential influence on microbial contamination is acknowledged but not analyzed in detail (*data not shown*).

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Disclosure of interest

The author reports no conflict of interest.

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