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Food safety practices of street vendors and microbial contamination of the night market foods in Morogoro Municipality, Tanzania

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ABSTRACT

Street food vendors nourish billions every day and boost the informal economy. Nevertheless, street-vended foods present considerable public health hazards owing to substandard cleanliness and insufficient food safety protocols. This study aimed to investigate the food safety practices of night market vendors in Morogoro Municipality and to evaluate the levels of microbiological contamination in selected street foods offered at night markets. A cross-sectional study conducted from April to August 2024 in Morogoro Municipality assessed 256 night-market street vendors using structured questionnaires and observational checklists. An experimental approach was employed to examine 200 food samples (barbecue, fried chicken, rice dishes, french fries, and salads) collected in eight different locations in five replications for microbial contamination. The results indicated inadequate adherence to food safety protocols, with 82% of vendors without valid medical certificates, 84.7% neglecting hand hygiene, and 76.1% not storing perishables at acceptable and safe temperatures. Salads samples exhibited the highest contamination, with a mean total coliform count (TCC) of 4.05×10^4 cfu/g and total viable count (TVC) of 7.22×10^4 cfu/g, both exceeding safety limits. *Escherichia coli* (20%) and *Staphylococcus* spp. (22.5%) were the most frequent isolates, particularly in salads, chips and fried chicken, while *S. warneri*, *S. succinus*, and *Aerococcus viridans* occurred rarely. *Salmonella* spp. was absent in all analyzed food samples. Principal Component Analysis (PCA) established that vendor compliance is driven by four independent factors (Core Hygiene, Barrier Use, Environmental Management, and Infrastructure Support), with the Core Hygiene cluster being the most significant. These findings highlight critical gaps in food safety practices and underscore the need for targeted interventions to mitigate contamination risks.

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1. Introduction

Street food vendors (SFVs) are very common in low and middle income countries (LMICs) such as Tanzania, supporting billions daily and underpinning the informal economy (1,2). The rapid urbanization and economic growth in urban regions of Tanzania have increased demand for street vended foods, which include meat, sugary drinks and processed and refined

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items (3) favor these foods due to their convenience, low cost, quick preparation time and palatability (4).

Despite its economic role, the informal food industry is significant source of food safety concern (5). Globally, roughly 600 million people (about one in ten) fall ill due to foodborne diseases annually WHO (2020) resulting in approximately 420,000 deaths (6). The annual cost of food hazards and foodborne diseases in LMICs is substantial, reaching USD 115 billion (5). Street foods face numerous risks during handling and preparation, including bacterial contamination, pesticide exposure, heavy metal presence, and contamination from dust or smoke (6).

Microbial contamination is the most significant threat associated with street food vending (7,8). Outbreaks are primarily driven by improper handling, cross-contamination, inadequate cooking, and poor temperature control during storage and display (9,10). Common contaminants include pathogenic bacteria such as *Staphylococcus aureus* and *Escherichia coli* (11). When these microorganisms exceed safety thresholds, they pose an immediate risk of foodborne illness, ranging from minor distress to severe or fatal conditions (12,13).

Food-borne illnesses result from vendors' limited awareness of food safety (12). Inadequate incentives for adopting basic hygiene (14) and pervasive infrastructural deficiencies, such as poor access to potable water and effective waste management (7). Street food vendors form a crucial supply network in Tanzania's urban environment. In rapidly urbanizing towns like Morogoro Municipality, a significant population relies heavily on street food for daily meals (15,16). Night markets present a unique environment introducing specific safety concerns due to extended operating hours and variable oversight. While the general risks of street food are established, there is significant dearth of integrated data specifically linking vendor food safety practices to quantifiable microbiological contamination levels within the unique, high risk environment of Morogoro night markets. Crucially, the specific behavioral and structural factors that drive contamination in this setting have not been determined, leaving regulatory bodies without the targeted evidence required to design and enforce effective, risk based interventions.

This study aimed to assess vendor's food safety practices of the night market vendors in Morogoro Municipal and determine the level and profile of microbial contamination in selected street foods and identify the key behavioral and structure factors (PCA) that contributes to contamination risks. The findings will provide local evidence based data that will be essential in designing targeted, effective regulatory and educational interventions to safeguard public health among the population heavily reliant on street vended foods.

2. Materials and Methods

2.1. Research design and sampling

A cross-sectional study was conducted from April to August 2024 to evaluate street vendors' food safety practices and the microbiological quality of food sold in various night markets in Morogoro Municipality. The study enrolled 256 food vendors for assessment of food safety practices. For microbiological analysis a total of 200 food samples were collected across eight-night market location (Dodoma Stand, Boma Road, Juwata Area, Kingalu Market, Iringa Road, Regional HSP Area, SUA Road, and Kaumba Areas). Sampling was

structured to include five primary food categories (barbeque, fried chicken, rice dishes, French fries, and salads), with five samples collected per food category at each of the eight locations. The sample size was statistically determined based on population estimates and reliability criteria from analogous studies (17).

2.2. Data collection

Data were collected using a multi-faceted approach combining quantitative and qualitative techniques: structured questionnaires, direct observational checklists, and laboratory-based microbial analysis of food samples.

2.2.1. Questionnaire administration

The data were gathered through the use of a structured questionnaire that was prepared in both Swahili and English and used to assess vendor's food safety practices. The initial section collected data regarding the vendors' demographics, including age, gender, and educational attainment. The second section comprehensively evaluated the vendors' adherence to food safety regulations, their food handling practices, and their awareness of microorganisms that can cause foodborne illnesses. While 256 food handlers chose to fill out the questionnaires, some vendors refused to answer certain questions, especially those questions about food safety. As a result, certain questions got different number of responds. All participants' privacy and anonymity were protected, and those who chose not to participate were not included.

2.2.2. Observational checklist

Direct observation was employed to systematically gather data on actual hygienic practices and environmental conditions at vendor night market stalls. A structured observational checklist was developed based on good manufacturing practices (GMP) and good hygienic practices (GHP) requirements to guide this process. Specific areas of focus included food handling techniques, personal hygiene of food service workers, and the cleanliness and condition of food-contact surfaces.

2.2.3. Microbial analysis of food samples

For microbial analysis, approximately 100 g of each 5 food samples was collected in five replications from the 8 different vendors' stalls and transported to the laboratory in sterile, sealed containers (zip bags) under refrigeration (4°C). The samples were subsequently examined within 24 h of collection.

2.2.3.1. Sample preparation

In the laboratory, a 10 g test portion of the food sample was aseptically weighed and transferred to 90 mL of sterile buffered peptone water, the mixture was homogenized for 2 min to obtain the initial 1:10 dilution. All analyses followed standard ISO microbiological techniques such as ISO 4833 for TVC, ISO 4832 for Coliforms, ISO 6888 for *Staphylococcus* spp, ISO 6579 for *Salmonella* and ISO 16649 for *E. coli*. All procedures were performed under aseptic conditions using sterile equipment and reagents.

2.2.3.2. Total viable count (TVC) and total coliform count (TCC)

From the serial dilutions, 1 mL aliquots were plated in triplicate onto plate count agar for TVC and MacConkey Agar for TCC using the pour plate method. Plates were incubated at 30^{o}C for 48-72 h for TVC enumeration. MacConkey Agar plates were incubated at 37^{o}C for 24 h for TCC enumeration. Visible colonies on countable plates (30-300 colonies) were enumerated

using a colony counter. Results were expressed as colony forming units per milligrams (cfu/g) of food sample, calculated using the formula:

$$\text{No. of bacteria in } \frac{\text{cfu}}{\text{g}} = \frac{\text{number of colonies x reciprocal of dilution factor}}{\text{inocilum size (mL)}}$$

2.2.3.3. Isolation and presumptive identification of specific pathogens

Staphylococcus spp.: The isolation and enumeration of Staphylococci were performed following the procedure outlined in ISO 6888-1:2018. The appropriate serial dilutions were spread-plated onto Mannitol Salt Phenol Red Agar (MSA, Merck 1.05404). Plates were incubated at 37^0C for 24 to 48 h. Presumptive *Staphylococcus* colonies were identified based on their ability to ferment mannitol: Yellow colonies surrounded by a yellow zone were considered presumptive mannitol-fermenting *Staphylococci* (e.g., *S. aureus*). Selected isolates from MSA were subsequently subjected to further confirmation. Colony testing included microscopic examination using gram stain, followed by the oxidase and catalase tests. Confirmation of pathogenicity was performed using the coagulase test (Tube Method) as specified in the ISO 6888 series.

Escherichia coli: For presumptive *E. coli* isolation, a loopful from the initial food sample homogenate/BPW enrichment was streaked onto MacConkey Agar plates. These plates were incubated at 37^0C for 24 h. Presumptive *E. coli* colonies, typically appearing as pinkish-red colonies with or without a surrounding halo (due to lactose fermentation), were selected. Additionally, for thermotolerant coliforms, parallel MacConkey Agar plates were incubated at 44.5°C for 24 h.

Salmonella spp.: The detection of *Salmonella* species was performed following the horizontal method for the detection, enumeration, and serotyping of *Salmonella* (EN ISO 6579-1:2017). The initial 10 g food sample aliquot (used for general homogenization) was pre-enriched in Buffered Peptone Water (BPW). The BPW culture was incubated for 18−24 h at 37^0C. Following pre-enrichment, 0.1 mL of the BPW culture was transferred into 10 mL of Rappaport-Vassiliadis Soya (RVS) broth. The RVS broth was incubated under aerobic conditions for 24±3 h at 41.5^0C±1^0C to ensure optimal selective inhibition of competing non-Salmonella bacteria. A loopful of the RVS broth was then streaked onto Xylose Lysine Deoxycholate (XLD) Agar plates. XLD plates were incubated at 37^0C for 24−48 h. Presumptive *Salmonella* colonies, typically appearing as red colonies with or without black centers (due to H_2S production), were selected and confirmed using appropriate biochemical and serological tests.

Confirmatory identification and final species confirmation: Presumptive colonies obtained from selective media for each target organism (e.g., suspected *Salmonella* colonies from XLD) were purified through sub-culturing onto Nutrient Agar. Purified isolates underwent initial screening using traditional staining and biochemical tests:

Gram staining was employed to assess cell morphology and the gram reaction. For presumptive *Staphylococcus*: The catalase test distinguished *Staphylococcus* (positive) from other cocci, and the coagulase test confirmed the pathogenicity of *S. aureus* (positive). For Presumptive Enterobacteriaceae (including *Salmonella* and *E. coli*): A

reduced panel of biochemical tests, including the Triple Sugar Iron (TSI) Agar (for sugar fermentation, H_2S, and gas production) and the urease test (to distinguish *Salmonella* from urease-positive enterics), was used for primary differentiation. Final, definitive identification of all purified bacterial species was performed using the VITEK MS system (matrix-assisted laser desorption/ionization-time of flight mass spectrometry, or MALDI-TOF MS technology). The MALDI-TOF MS system provided rapid and highly accurate species confirmation, with all reported results yielding a confidence level of 99.9%. This final identification method superseded the full panel of traditional biochemical results (IMViC, LIA, etc.) as the official method of species confirmation in this study.

2.3. Statistical analysis

Descriptive statistics were employed to summarize vendor food safety practices and microbial contamination findings. Frequencies, percentages, and means were calculated using SPSS Version 27 software. This software was utilized primarily for data cleaning, management, and the generation of all fundamental descriptive statistics, as it offers a user-friendly interface for initial data exploration. For inferential and multivariate analyses, R programming version 4.4.2 was employed. This was chosen for its robustness in advanced statistical analyses, particularly in public health and environmental research. specifically, Analysis of variance (ANOVA) was conducted using R to assess significant differences in microbial contamination levels across different food categories. Principal component analysis (PCA) was performed using R to identify and cluster the most significant variables contributing to vendor food safety practices and microbial contamination risks. PCA facilitated dimensionality reduction and the extraction of underlying patterns from the raw data, providing insights into how specific compliance factors influenced overall practices

2.4. Ethical considerations

A permit for research was requested from the Vice Chancellor of Sokoine University of Agriculture (SUA), and the conduct of the research was approved by the Directorate of Postgraduate Studies, Research, Technology Transfer and Consultancy (DPRTC) of SUA. A research permit was also sought from the Executive Directors of Morogoro District Councils. Before the interview, verbal consent was obtained from each participant after explaining the purpose and importance of the study. Participation in the study was voluntary. All data collected during this study were treated with the strictest confidence and compliance with research ethics. To ensure the anonymity of participants and vendors, all identifying information, including vendor names and specific location details, was immediately removed and replaced with unique numerical codes upon transcription. This coding process was explicitly stated in the questionnaire preamble provided to all participants. Furthermore, the data collected were strictly used for academic research purposes as outlined in the study objectives.

3. Results

3.1. Demographic characteristics of food vendors

The demographic details of the 256 food vendors surveyed in Morogoro Municipality are shown in Table 1. Females comprised the majority of vendors at 77.0%, whereas males represented only 23.0%. A majority of vendors were married (78.9%), while smaller

percentages were single (16.4%) or divorced (4.7%). The age distribution indicated that 50.0% of the vendors were aged 20 to 30 years, while 46.1% fell within the 31 to 40-year range. A minimal proportion were younger than 20 years (1.2%) or older than 40 years (2.7%). In terms of education, the majority of vendors achieved a secondary school level (71.5%), followed by primary school (22.3%), with a minority attaining a tertiary level of education (6.3%). A notable percentage of the vendors (65.6%) lacked prior experience in food vending. Regarding vending experience, the majority of vendors (62.9%) had been engaged in food vending for 4–5 years, while 27.0% had been vending for less than 12 months, and 10.2% had been vending for over 5 years. A substantial percentage of married sellers suggests that food vending functions as a source of family support for many individuals. The age distribution indicates that most sellers fall within their economically productive years, consistent with the role of food vending as a source of income. The educational attainment data reveal that most merchants have basic educational qualifications. The considerable number of suppliers without prior experience in the food sector indicates a potential necessity for the implementation of food safety training and educational programs.

3.2. Food safety practices of night market street food vendors

Food safety practices of street food vendors at night markets in Morogoro Municipality are presented in Table 2. The findings indicate significant shortcomings in basic food safety requirements among food vendors at night markets evaluated in this study. The data generally demonstrates substantial non-compliance with fundamental hygienic standards. A substantial percentage of vendors failed to maintain proper refrigeration unit functionality (87.9%), implement cross-contamination prevention measures (79.6%), or ensure adequate waste disposal (87.8%). Personal hygiene is overlooked, as evidenced by a substantial proportion of food handlers exhibiting insufficient hand hygiene practices (84.7%) and lacking medical certifications (82.0%).

Moreover, essential practices such as adequate temperature regulation for perishable items (76.1% non-compliance) and secure food transportation (88.1% non-compliance) are frequently overlooked, highlighting systemic risks to food safety.

3.3. Assessment of the level of microbial contamination of street food vended at different night markets in Morogoro.

Microbiological investigation indicated the widespread occurrence of TVC (cfu/g) and TCC (cfu/g) in night market street foods in Morogoro, with contamination levels exhibiting considerable variation among different food categories, as detailed in Table 3. Salad demonstrated the highest mean level of TVC contamination at 7.22 x 10^6 cfu/g, which was significantly greater than all other food types ($p<0.05$). Chips exhibited a mean contamination level of 4.33 x 10^4 cfu/g, categorizing them as potentially hazardous. Barbeque (7.10 x 10^3 cfu/g), Fried Chicken (7.20 x 10^3 cfu/g), and Rice Dish (5.43 x 10^3 cfu/g) exhibited lower TVC counts relative to other food items. All analyzed fruit salad samples were found to be contaminated with coliforms, with levels exceeding 1.4×10^4 MPN/g, suggesting inadequate hygiene and fecal contamination. In terms of TCC contamination, Salad exhibited the highest mean count at 4.05 x 10^4 cfu/g,

significantly surpassing Barbeque, Chips and Fried Chicken ($p<0.05$).

3.4. Prevalence of bacterial species across different food types

The findings of the prevalence analysis are displayed in Table 4. *Escherichia coli* was found to be the most frequently detected pathogen in an analysis of forty street food samples for each food category, with the highest incidence occurring in salads (20%), followed by chips and rice (12.5% each), barbecue (10%), and fried chicken (7.5%). *Staphylococcus* spp. was also prominent, particularly in salads (22.5%), chips (12.5%), rice (7.7%), and barbeque (5%), but absent in fried chicken. The recurrent detection of *E. coli* highlights fecal contamination and general hygiene failures, while the presence of *Staphylococcus* spp. points to contamination from food handlers. Importantly, *Salmonella* spp. was not detected in any of the analyzed samples.

3.5. Bacteria isolation in selected food types in different locations

Bacterial isolations from food samples collected at various street night market vending locations in Morogoro Municipality are presented in Table 5. Results revealed consistent pattern of microbial contamination based on frequencies. *Escherichia coli* and *staphylococcus epidermidis* were the most frequently isolated bacteria across the diverse range of food types (Chips, fried chicken, meat, rice, and salads), as well as vending locations. *E. coli* was primarily identified in salads (6 isolates) and fried chicken (4 isolates), with significant findings in Kingalu (3 isolates in salads, 2 in chips) and Juwata/SUA (2 isolates each in fried chicken). *Staphylococcus epidermidis* was isolated from salads (5 isolates) and chips (2 isolates), demonstrating its prevalent occurrence. Infrequent isolates comprised solitary instances of *Staphylococcus warneri*, *Staphylococcus succinus*, and *Aerococcus viridans*. *Staphylococcus aureus* was absent among the identified isolates. The recurrent detection of *E. coli*, a significant faecal indicator organism, across diverse food items and locations indicates widespread deficiencies in basic hygiene practices, including insufficient handwashing by vendors, possible use of contaminated water, or cross-contamination during food preparation. This indicates a notable public health risk. The recurrent isolation of *Staphylococcus epidermidis*, a coagulase-negative *Staphylococcus*, underscores the contamination resulting from human handling, insufficient personal hygiene among food handlers, and inadequate sanitation of the vending environment. While typically less pathogenic than *S. aureus*, its prevalence, in conjunction with *E. coli,* highlights a significant pattern of microbial contamination that requires immediate and focused food safety measures to safeguard public health.

3.6. Principal component analysis of street food vendor practices

Principal component analysis (PCA) was conducted to reduce the dimensionality of the vendor practice data and uncover the basic framework of adherence as presented in Fig 1. The initial four components were maintained for analysis, together accounting for 57.5% of the total variance observed in vendor practices. The analysis indicated that food safety performance comprises distinct, independent dimensions rather than being a singular factor.

The initial two dimensions accounted for 37.3% of the variance, identifying the primary compliance factors. Dimension 1, accounting for 22.4% of the variance, represented the core hygienic practices factor. Variables associated with the fundamental and direct management of food exhibited a strong positive loading on this dimension, particularly B9 (Proper food storage), C14 (Cleaning frequency), and B27 (Handwashing setup). The observed clustering suggests significant internal consistency; vendors adhering to one core measure are likely to comply with others, reflecting a comprehensive level of operational diligence. Dimension 2, accounting for 14.9% of the variance, represented a Barrier Protection Factor, primarily characterized by B20, which pertains to the use of serving utensils and gloves. The weak correlation between Dim1 and Dim2 indicates that adherence to barrier practices operates independently of core hygienic routines.

The following dimensions emphasized distinct environmental and infrastructural challenges. Dimension 3, accounting for 10.7% of the variance, was primarily influenced by the independent practice of B24 (Waste Management), indicating a weak correlation between waste disposal routines and both core food handling and barrier practices. Dimension 4, accounting for 9.5% of the variance, was primarily characterized by B10, which pertains to the availability of running water. The identified inverse correlation between the waste management (B24) factor and the infrastructure (B10) factor indicates that resource constraints, including the absence of running water, may independently influence suboptimal environmental practices. The PCA illustrates that food safety is a multidimensional construct, emphasizing the necessity for targeted interventions in four specific areas: operational diligence, physical barrier implementation, waste management, and infrastructure support.

Training and regulatory activities should target each dimension separately. The core hygienic practices factor (Dim1) requires the most attention. Operational diligence interventions (ODI) should teach B9 (appropriate food storage), C14 (cleaning frequency), and B27 (hand washing facilities) together to strengthen the behavioral link between these fundamental practices. Distinct monitoring and enforcement measures are needed for B20 (use of gloves/utensils) because the Barrier practice factor (Dim2) acts independently and is unlikely to increase by focusing on core hygiene. Finally, targeted public health investment is needed for environmental impact (Dim3) and infrastructure support (Dim4). Most effective structural intervention is improving B10 (access to flowing water) since improved infrastructure will improve B24 (waste management). This multi-faceted PCA-guided strategy implements efficient and strategic food safety measures.

Table 1. Demographic characteristics of night street food vendors in Morogoro Municipality

Variable	Frequency	Percent
Gender		
Male	59	23.0
Female	197	77.0
Marital status		
Single	42	16.4
Married	202	78.9
Divorce	12	4.7
Age group		
< 20 years	3	1.2
20 – 30 years	128	50.0
31 – 40 years	118	46.1
> 40 years	7	2.7
Education level		
Primary school	57	22.3
Secondary School	183	71.5
Tertiary level	16	6.3
Do you have any previous experience working in the food industry		
No	168	65.6
Yes	88	34.4
For how long have you been vending food		
less than 12 months	69	27.0
4-5 years	161	62.9
over 5 years	26	10.2

Table 2. Food safety practices among night market street food vendors in Morogoro Municipality

Variable		Freq.	Percent
Are refrigeration units in good working condition	No	152	87.90%
	Yes	21	12.10%
Is there a system in place to prevent cross-contamination between raw and cooked foods	No	160	79.60%
	Yes	41	20.40%
Is the vending stall maintained in a clean condition	No	122	59.20%
	Yes	84	40.80%
Are there adequate waste water or food disposal facilities available	No	201	87.80%
	Yes	28	12.20%
The vendors possess medical examination certificate	No	164	82.00%
	Yes	36	18.00%
Are perishable foods stored at the appropriate temperatures	No	172	76.10%
	Yes	54	23.90%
Food from outside the outlet are properly transported	No	177	88.10%
	Yes	24	11.90%
Are food handlers using proper hand hygiene practices, such as washing hands before handling food	No	182	84.70%
	Yes	33	15.30%

Table 3. Mean levels of TVC and TCC contamination levels from night street-vended foods in Morogoro Municipality

Food	TVC (cfu/g)	TCC (cfu/g)
Barbeque	7.10×10^{3ab}	6.46×10^{3a}
French fries (chips)	4.33×10^{4a}	8.97×10^{3a}
Fried chicken	7.20×10^{3b}	8.96×10^{3a}
Rice dish	5.43×10^{3b}	2.90×10^{4ab}
Salad	7.22×10^{6c}	4.05×10^{4b}

Table 4. Prevalence of bacterial species across different food types (N = 40 samples)

	Prevalence (%)				
Bacteria	Chips	Fried chicken	Barbeque	Rice	Salad
E. Coli	12.5%	7.5%	10%	12.5%	20%
Staphylococcus spp	12.5%	0	5%	7.7%	22.5%
Salmonella spp	0	0	0	0	0

Table 5. Bacteria isolation in selected food types in different locations

Location	Bacteria	Chips Freq.	Fried chicken Freq.	Meat Freq.	Rice Freq.	Salad Freq.
Boma road	*E. Coli*	0	0	0	0	1
	S. Epidermidis	0	0	0	0	1
Dodoma stand	*S. Epidermidis*	0	0	1	0	0
	S. Warne	0	0	0	0	1
Iringa road	*E. Coli*	0	0	1	1	1
	A. Viridae	0	0	0	1	0
	S. Epidermidis	1	0	0	0	2
Juwata	*E. Coli*	0	2	1	0	0
Kingalu	*E. Coli*	2	1	0	1	3
	S. Epidermidis	1	0	0	0	1
Regional Hospital	*E. Coli*	1	0	0	0	1
	S. Epidermidis	0	0	0	1	1
	S. succinus	0	0	0	0	1
SUA	*E. Coli*	0	2	1	0	0
	S. Epidermidis	1	0	0	0	1

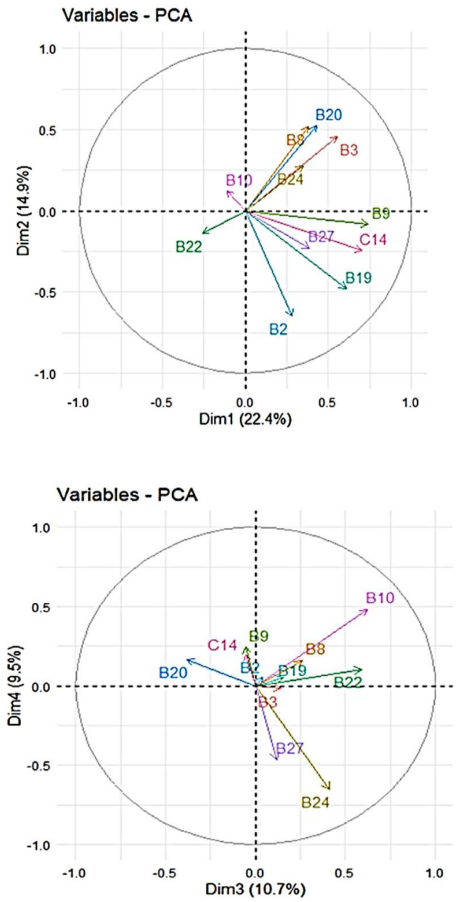

Figure 1. PCA of street food vendor practices

4. Discussion

The findings of this study illuminate critical intersections between vendor profiles, food safety practices, and microbiological contamination within Morogoro's night market street food sector. These results provide a multifaceted understanding of the public health risks present in this informal economy and point toward necessary interventions. The demographic profile of the vendor's population presents both opportunities and imperatives for intervention

The predominance of female vendors suggests potential gender-specific economic opportunities, while the high secondary education level indicates a basic educational foundation that could support food safety training interventions (18). The limited prior food industry experience coupled with a substantial 4–5-year operational period suggests a need for targeted professional development and food safety education program. Furthermore, the age distribution, predominantly between 20-40 years, represents a workforce at a critical stage of professional skill acquisition and potential behavioral change (19), which

could be strategically leveraged for improving food safety compliance and public health outcomes.

The findings regarding observed food safety practices offer empirical evidence supporting the low self-reported practice levels noted in a prior study on the knowledge, attitudes, and practices (KAP) of night market street food vendors in Morogoro Municipality (20). The non-compliance rates presented in the current study, particularly the significant failures in hand hygiene, temperature control, and cross-contamination prevention, demonstrate the knowledge-practice gap identified by (20). This phenomenon is prevalent in informal food sectors within low- and middle-income countries (LMICs), where, despite some awareness, the practical application of safe food handling practices is hindered by various constraints (21,22). The widespread non-compliance at these essential control points, ranging from cold chain management and cross-contamination prevention to personal and environmental hygiene, fosters conditions that are highly favorable for microbial growth and transmission. This is consistent with various studies that consistently associate deficiencies in hygienic practices with increased microbial contamination in street foods (7,23). Specific deficiencies, such as inadequate temperature control, are recognized as significant contributors to foodborne illness (24) alongside poor hand hygiene (25). The significant proportion of vendors without medical certificates indicates a wider issue of systemic non-compliance with regulatory frameworks prevalent in these informal settings (26). The observed widespread poor practices could be related to increased microbial contamination (TVC and TCC in cfu/g) as shown in Table 3, highlights a significant and preventable public health risk in Morogoro's night street food sector. The systematic failures identified are significant risk factors that directly lead to elevated microbial loads in food samples, especially in high-risk items such as salads. This underscores the necessity for comprehensive interventions that extend beyond awareness to implement regulations and offer practical, ongoing training and infrastructure support (27).

Salad demonstrated the highest mean level of TVC contamination which was significantly greater than all other food types ($p<0.05$). This level significantly surpasses the commonly accepted safe limit of 106 cfu/g and falls within the range deemed unsatisfactory or potentially hazardous to public health as reported by Odo et al. (28) while Issa-Zacharia et al. (29) reported comparable findings, indicating that the total aerobic count (TAC) varied from 5.05 x 103 to 1.92 x 104 cfu/g. All analyzed fruit salad samples were found to be contaminated with coliforms, with levels exceeding 1.4×104 MPN/g, suggesting inadequate hygiene and fecal contamination (29). Higher bacterial contamination levels in street-vended foods at night markets in Morogoro that was observed in the current study have been linked to inadequate vendor hygiene, unsafe food handling practices, and use of contaminated water in food preparations as similarly reported by Kussaga et al. and Ndunguru et al. (30,31). The presence of specific coliforms, notably *E. coli*, is often associated with high levels in feces from humans and animals, indicating a potential link to fecal contamination (29).

In terms of TCC contamination, salad exhibited the highest mean count surpassed the permissible safety

limit of 10^6 cfu/g in salads and rice signifying faecal contamination and a heightened risk of enteric pathogens (28,32). The primary risk associated with salads is attributed to the lack of heat treatment and substandard hygiene practices, including the use of contaminated water, unclean utensils, and insufficient handwashing (33,34). Previous study reported reduced yet still unacceptable levels of TCC in barbecues, chips, and fried chicken, indicating potential post-cooking contamination or insufficient storage (35). The detection of TCC in thermally processed foods highlights significant deficiencies in hygiene practices during and subsequent to food preparation. The findings correspond with research connecting *E. coli* presence in ready-to-eat (RTE) foods to inadequate handling and water quality in resource-limited environments (25).

The recurrent isolation of *E. coli* from salads, chips, and fried chicken indicates ongoing contamination risks, likely attributable to inadequate vendor hygiene (20,37). The prevalence of *E. coli* in street foods reached 20% in salads, while *Staphylococcus* spp. showed prevalence of 22.5% in salads, the current study showed lower prevalence rates of *E. coli* and *Staphylococcus* spp. than those reported by Schlegelová et al. (38), who found pooled prevalence of *E. coli* (33.8%), *Salmonella* (26.0%), and *S. aureus* (46.3%) in ready-to-eat foods. Nonetheless, the consistent detection of *E. coli* and *Staphylococcus* spp. in this study reinforces the conclusion that microbial contamination of street-vended foods remains a significant public health concern, underscoring the urgent need for strengthened food hygiene and safety practices.

A study conducted by Ndunguru et al. (31) on ready-to-eat foods in the Morogoro Municipal Market revealed that *E. coli* was the predominant isolate among all food types evaluated. Additional isolated bacteria were *Bacillus cereus*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Salmonella* spp.

Additionally, the identification of *Staphylococcus* spp., especially in salads and chips, indicates inadequate food handling practices. Coagulase-Negative Staphylococci (CoNS), including *S. epidermidis* and *S. warneri*, were the most prevalent, suggesting contamination from human skin or mucosal surfaces (38, 39). Raw foods, such as salads, are particularly susceptible to contamination due to direct handling and the absence of thermal processing (40). Even processed foods like chips showed contamination, suggesting post-cooking exposure to unsanitary environments (41). While CoNS exhibit lower virulence compared to *S. aureus*, elevated counts pose food safety risks, especially for immunocompromised individuals (42). *S. warneri*, a component of normal skin flora, may function as an opportunistic pathogen and has been linked to raw animal products and serious infections in at-risk populations (43,44). The occurrence of this substance in salads is likely due to direct contact during preparation or cross-contamination from areas where raw meat is handled. The isolation of *Staphylococcus succinus*, typically present in fermented products such as cheese and sausages, highlights deficiencies in hygiene practices. Although not commonly linked to foodborne illness, its occurrence in street salads indicates potential contamination during handling or from environmental sources (45,46). *S. succinus* and other CoNS, while not primary foodborne pathogens,

serve as indicators of sanitation deficiencies and increase microbiological risk.

The absence of *Salmonella* spp. is a positive aspect, yet the persistent detection of *E. coli* and *Staphylococcus* spp. in various food categories indicates significant deficiencies in street food safety protocols in Morogoro. The findings support previous research by Omari et al. (20) which identified deficiencies in hand hygiene, temperature regulation, and health certification among vendors. Addressing these deficiencies is crucial for protecting public health and mitigating the risks associated with foodborne diseases.

The PCA revealed that Dim.1 (22.4% variance) was primarily defined by key hygienic practices such as proper storage and temperature control, cleaning, handwashing, and possession of medical certificates, linking vendor compliance to microbial contamination risks. This is consistent with recent studies indicating that essential hygiene practices are critical for reducing microbial risks in street-vended foods (23). Vendors demonstrating excellence in any of these critical areas generally exhibit consistent performance across all domains, indicating that compliance with these practices signifies a broader commitment to food safety. Conversely, Dim.2, defined by the utilisation of gloves or utensils (B20) which emerged as a separate compliance dimension. Barrier protection behaviours, although significant, may not directly relate to other hygienic practices. Recent studies have noted similar separations, indicating that glove use among food vendors was inconsistently adopted and did not consistently align with other safe handling practices (47). The environmental factors, specifically the cleanliness of vending stalls (B22) and waste management (B24), were associated with Dim.3 and Dim.4, accounting for approximately 10–11% of the variance. These findings highlight that environmental hygiene functions independently while significantly influencing overall contamination risk. Research conducted in Nairobi (48) and Dodoma, Tanzania (49) has demonstrated that inadequate stall hygiene and waste disposal markedly increase microbial contamination in street foods.

5. Conclusion

This study on night market street food vending in Morogoro Municipality shows a strong link between vendor non-compliance with food safety regulations and high microbiological contamination, posing a serious public health risk. Key contributors include lack of medical certification (82.0%), improper perishable food storage (76.1%), poor cross-contamination prevention (79.6%), inadequate waste disposal (87.8%), and insufficient hand hygiene (84.7%), which correspond with high microbial levels in food samples. High TCC (4.05×10^4 cfu/g) and TVC (7.22×10^6 cfu/g) indicated fecal and human-skin contamination. Bacterial isolation revealed predominance of *Escherichia coli* (highest in salads, 20%) and *Staphylococcus* spp. (highest in salads, 22.5%), alongside occasional *Staphylococcus warneri*, *Staphylococcus succinus,* and *Aerococcus viridans,* while *Salmonella* spp. was absent. PCA identified two main dimensions of non-compliance: essential hygiene practices and lack of protective food handling equipment, showing that food safety issues stem from both behavioral and structural factors, which is concerning given reliance on street foods for daily nutrition.

Morogoro Municipality and other relevant authorities should implement and rigorously enforce comprehensive food safety training programs for street vendors, ensuring cultural sensitivity. To mitigate significant non-compliance issues, programs must emphasize the necessity of routine medical examinations, appropriate food storage temperatures, hand hygiene, and the avoidance of cross-contamination. Practical examples and ongoing feedback are essential components of an effective training program. Local governments ought to augment food safety inspections and implement clear penalties for noncompliance to improve regulatory enforcement and infrastructure support. Vendors should be assured access to economical and reliable refrigeration units, potable water, and sanitary waste disposal facilities through proactive measures. Relevant agencies in public health and food safety must organize training and teaching on food safety and hygiene for food vendors, especially compliance with hazard analysis and critical control points principles (HACCP) during preparation, packaging, and serving of these foods to consumers.

The study used a cross-sectional design, which offers only a time-based picture of vendor food safety practices and microbial contamination. This design inhibits the establishment of causality between low compliance and high contamination, indicating that we cannot conclusively assert that a particular non-compliant practice directly resulted in the observed contamination levels over time. Seasonal variations or long-term trends in hygiene practices or contamination could not be evaluated.

The extracted components of PCA only explain a portion of the total variance (57.5% in this study), meaning almost half of the variability in vendor practices remains uncaptured by the factors. Furthermore, the naming and interpretation of the derived components are subjective, representing the researchers' theoretical understanding of the underlying factor structure.

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Author contributions

A. N.O. Methodology, Analyses, and Writing-Original draft preparation, **Z.A.S** Methodology, Analyses, and Writing-Original draft preparation, **A.I.Z.** Writing, Editing, Reviewing, and Supervision, **D.N.C.** Writing, Editing, Reviewing, and Supervision.

Declaration of competing interest

The authors declare no competing financial or personal interests.

Data availability

The data generated and analyzed in this study are available from the corresponding author upon reasonable request.

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