

MICROBIAL CONTAMINATION OF MEAT CONTACT SURFACES AND WATER IN ZANGO ABATTOIR, ZARIA KADUNA STATE, NIGERIA: IMPLICATIONS FOR FOOD SAFETY AND PUBLIC HEALTH

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ABSTRACT

Foodborne diseases remain a major public health concern in low- and middle-income countries, where unhygienic slaughter practices compromise meat safety. This study assessed the practices and microbial contamination in the Zango abattoir, Zaria, Nigeria. The activities in the abattoir were observed and a total of 57 samples – including slaughter floor swabs, table surfaces, knives, drainage water, and borehole water – were analyzed using standard microbiological protocols. Observational data revealed open-air slaughtering, unhygienic meat processing, indiscriminate waste disposal, and the use of untreated borehole water for meat processing, all of which deviate from Codex hygienic standards. The mean total aerobic plate count across all samples was 35.6 ± 11.9 CFU/cm², while coliform counts averaged 10.7 ± 6.2 CFU/cm². Borehole water recorded the highest aerobic and coliform counts, whereas knife surfaces had the lowest. The overall mean *Staphylococcus* count was 76.6 ± 48.4 CFU/cm², with borehole water and drainage water showing the highest levels. There were no statistically significant differences across sample sources ($p > 0.05$). Six bacterial genera were isolated: *Escherichia coli* (47.4%), *Proteus spp.* (15.8%), *Citrobacter spp.* (10.5%), *Enterobacter spp.* (10.5%), *Shigella spp.* (10.5%), and *Salmonella spp.* (5.3%). There was a significant association between bacterial occurrence and sample sources ($\chi^2 = 50.278$, $p < 0.05$), with *E. coli* being the most prevalent on knives and tables, and *Shigella* confined to drainage water. There's urgent need for improved infrastructure, strict hygiene enforcement, and One-Health surveillance to reduce microbial risks in the abattoir.

Keywords: Abattoir Hygiene, Microbial Contamination, One Health

INTRODUCTION

Meat is a vital source of protein and micronutrients, but it also represents a significant vehicle for foodborne illnesses when produced under unhygienic conditions (Odetokun *et al.*, 2025). Globally, unsafe food causes illness in one out of every ten people each year, with the burden disproportionately affecting low- and middle-income countries (LMICs) (WHO, 2022). Abattoirs are critical nodes in the meat supply chain where animal, human, and environmental health intersect, making them priority targets for food safety interventions. International frameworks, including the Codex Code of Hygienic Practice for Meat (CXC 58-2005, revised 2021) and the WHO/FAO Global Food Safety Strategy (2022–2030),

emphasize hygienic slaughter, potable water use, separation of clean and dirty operations, and effective waste management as central safeguards (FAO/WHO, 2021).

Despite these guidelines, compliance remains a major challenge in LMICs where infrastructural deficiencies, weak enforcement, and poor worker hygiene create persistent food safety risks. Studies in Africa have shown that many abattoirs continue to operate with open-air slaughtering, inadequate waste disposal, and contaminated water use, all of which increase microbial contamination and zoonotic threats (Ovuru, 2023; Nigussie *et al.*, 2025). Beyond acute infections, abattoirs have also been identified as hotspots for antimicrobial resistance (AMR), with multidrug-resistant

Escherichia coli, *Salmonella*, and *Staphylococcus aureus* frequently recovered from slaughter environments (Obanda *et al.*, 2022; Egbule *et al.*, 2023). This emphasises the need for a “One Health” approach that integrates veterinary, human, and environmental health measures.

In Nigeria, where red meat remains a key dietary component, abattoir practices often fall short of Codex-aligned benchmarks. Studies have reported unsafe handling practices, indiscriminate waste disposal, and high microbial loads across slaughter facilities (Adebowale *et al.*, 2022; Aworh *et al.*, 2022). Following recognition of these challenges, Nigeria recently introduced the National Policy on Food Safety and Its Implementation Strategy (2023–2024) (Codex, 2023). However, empirical field data remain essential to guide policy implementation and risk-based interventions. Based on these concerns, the present study investigates hygienic practices and microbial contamination in the Zango abattoir, Zaria. By documenting prevailing operational practices, quantifying bacterial loads, and identifying key pathogens, this study provides evidence to inform abattoir modernization and align Nigeria’s meat safety systems with international standards.

MATERIALS AND METHOD

STUDY DESIGN

A cross-sectional observational and microbiological study was conducted at the Zango abattoir, Sabon-Gari, Zaria, Kaduna State, Nigeria (11°08'13.7"N, 07°40'03"E). The abattoir is managed by the Kaduna State Government and slaughters approximately 30–40 cattle daily, with occasional slaughter of camels. During the study period, slaughtering was performed on an outdoor slab due to ongoing renovations in the main hall.

ETHICAL CONSIDERATIONS

Permission to access the abattoir was obtained from the management, and informed consent was sought from workers for observation of their activities and sample collection. The study followed the ethical principles for public health research outlined in the WHO Global Strategy for Food Safety 2022–2030.

OBSERVATIONAL ASSESSMENT

The abattoir environment and practices were observed for three weeks during peak slaughtering hours (6:00 am – 9:00 am). Key aspects included sanitation, waste disposal, meat handling, and personnel hygiene. Observations were benchmarked against the Codex Code of Hygienic Practice for Meat (CXC 58-2005, revised 2021) and WHO/FAO recommendations for abattoir hygiene. Photographs were taken to document critical observations.

Sample sources

Samples were collected from: water: borehole water (used for processing) and drainage water; and meat contact surfaces: slaughter floor, knives, and tables.

Sample collection procedures

Swab samples were collected aseptically following ISO 18593:2018 (surface sampling) guidelines. Sterile swabs moistened with buffered peptone water (ISO 6887-1:2017) were rubbed over 10 cm² of each surface. Also, water samples were collected into sterile containers. All samples were immediately stored in sterile tubes, transported in ice-packed coolers at 4°C, and delivered to the Bacterial Zoonosis Laboratory, Department of Veterinary Public Health and Preventive Medicine, Ahmadu Bello University, Zaria within 2 hours of collection.

LABORATORY METHODS

Aerobic plate and coliform counts

Plate Count Agar (PCA) was used for total aerobic mesophilic counts (ISO 4833-1:2013) and MacConkey Agar was used for total coliform counts (ISO 4832:2006). Plates were incubated at 37°C for 24–48 hours. Counts were expressed as colony-forming units (CFU/cm²).

STAPHYLOCOCCUS COUNT

Staphylococcus spp. were isolated using Mannitol Salt Agar (MSA), following ISO 6888-1:2021 protocols for coagulase-positive *Staphylococci*. Plates were incubated at 37°C for 24–48 hours.

BACTERIAL IDENTIFICATION

Representative colonies were purified and characterized by colony morphology and biochemical tests (indole, citrate utilization, triple sugar iron [TSI], urease, oxidase). The identification followed CLSI M100 (2023) performance standards. All media were quality-checked using reference strains.

DATA ANALYSIS

Microbial counts were log-transformed before statistical processing. Descriptive statistics (mean, standard deviation, and frequency distribution) were computed. Results were presented in tables, figures, and photographic plates. Data interpretation followed the FAO/WHO guidelines for food safety risk assessment (FAO/WHO, 2021).

RESULTS

OBSERVATION OF ABATTOIR PRACTICES

The Zango abattoir was found to be in a generally unhygienic condition. Key practices included open-space slaughter and meat processing directly on the floor with workers not wearing any form of personal protective equipment (PPE) (Figure IA), indiscriminate waste disposal (Figure IB),

washing of tripe at the borehole (Figure IC), and food vending close to slaughter areas (Figure ID). These practices deviated from recommended hygienic standards for safe meat production.

TOTAL AEROBIC PLATE AND COLIFORM COUNTS

The microbial loads of the different sample types are summarized in Figure II. The mean total aerobic plate count across all samples was 35.6 ± 11.9 CFU/cm², while the mean coliform count was 10.7 ± 6.2 CFU/cm². Borehole water samples had the highest aerobic plate count (55.0 ± 0.0) and coliform count (20.0 ± 0.0), whereas knife surfaces showed the lowest aerobic (29.6 ± 6.9) and coliform (7.1 ± 1.3) counts. Statistical analysis revealed no significant differences in total aerobic counts across sample types ($F = 1.532, p > 0.05$), although aerobic counts in borehole water was higher than knives and table surfaces. Coliform counts also did not differ significantly among samples ($F = 1.562, p > 0.05$), however, borehole water and slaughter floor had higher counts than knives.

STAPHYLOCOCCUS COUNT ON MANNITOL SALT AGAR

Following inoculation on Mannitol Salt Agar, colonies were observed with characteristic growth of *Staphylococci*. Microscopy after gram staining revealed gram-positive cocci in cluster formation. The overall mean microbial count on Mannitol Salt Agar was 76.6 ± 48.4 CFU/cm² (Figure III). Borehole water recorded the highest counts (106.7 ± 11.5), followed by drainage water (89.3 ± 57.5), knife surfaces (63.0 ± 55.7), and table surfaces (55.5 ± 62.9). The slaughter floor yielded the lowest count (32.0 ± 0.0).

Statistical analysis indicated no significant differences in *Staphylococcus* counts among the sample types ($H = 2.463, p > 0.05$). Pairwise comparisons showed borehole water and drainage water to be non-significantly higher than slaughter floor samples.

OCCURRENCE OF BACTERIAL ISOLATES

The distribution of bacterial isolates based on the biochemical tests conducted is summarized in Table I. Six bacterial genera were identified. *Escherichia coli* was the most prevalent (47.4%), followed by *Proteus spp.* (15.8%), *Citrobacter spp.* (10.5%), *Enterobacter spp.* (10.5%), *Shigella spp.* (10.5%), and *Salmonella spp.* (5.3%).

Chi-square analysis of bacterial occurrence across sample sources revealed a significant association ($\chi^2 = 50.278, p < 0.05$), with *E. coli* significantly more likely to be isolated from knives and table surfaces, while *Shigella spp.* were exclusively associated with drainage water.



Figure I: The premises and practices at the Zaria abattoir, Kaduna State. A – open-space meat processing on the floor; B – indiscriminate waste disposal; C – washing of tripe at the borehole; D – food vending close to slaughter areas

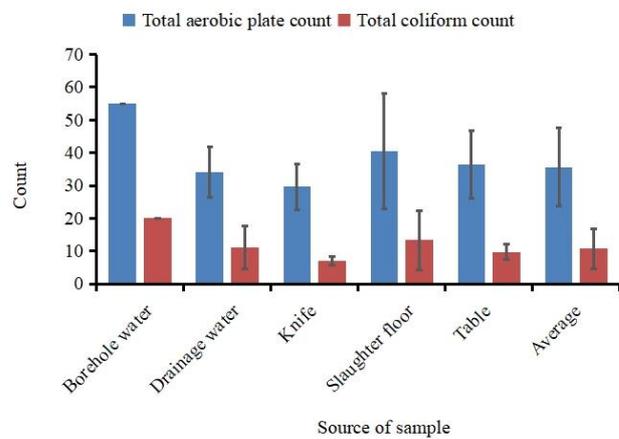


Figure II: Mean ± SD aerobic plate and coliform counts in samples from the Zango abattoir, Sabon-Gari, Zaria, Kaduna State, Nigeria

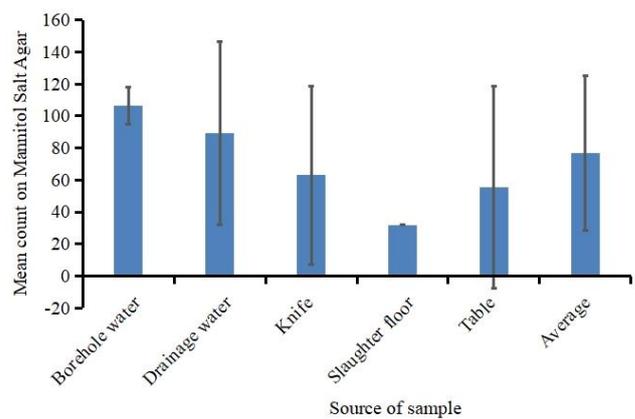


Figure III: Mean ± SD microbial counts, on Mannitol Salt Agar, in samples from the Zango abattoir, Sabon-Gari, Zaria, Kaduna State, Nigeria

Table I: Occurrence of bacteria in samples from the Zango abattoir

Source of sample	<i>Citrobacter</i> spp (%)	<i>Escherichia coli</i> (%)	<i>Enterobacter</i> spp (%)	<i>Proteus</i> spp (%)	<i>Salmonella</i> spp (%)	<i>Shigella</i> spp (%)
Borehole water	0 (0.0)	3 (11.1)	3 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)
Drainage water	3 (50.0)	3 (11.1)	3 (50.0)	0 (0.0)	0 (0.0)	6 (100.0)
Knife	0 (0.0)	9 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Slaughter floor	3 (50.0)	3 (11.1)	0 (0.0)	6 (66.7)	0 (0.0)	0 (0.0)
Table	0 (0.0)	9 (33.3)	0 (0.0)	3 (33.3)	3 (100.0)	0 (0.0)
Total	6 (10.5)	27 (47.4)	6 (10.5)	9 (15.8)	3 (5.3)	6 (10.5)

$\chi^2 = 50.278$, $p < 0.05$

DISCUSSION

The present study demonstrated that the Zango abattoir in Zaria was operating under conditions that pose substantial risks to food safety and public health. The practices observed contravene international hygienic standards, particularly those outlined in the Codex Code of Hygienic Practice for Meat and WHO/FAO food safety guidelines, which emphasize separation of clean and dirty operations, use of potable water, and proper effluent disposal (Codex, 2022). These findings highlight systemic lapses in infrastructure and hygiene enforcement, consistent with previous reports of Nigerian abattoirs and those in other low- and middle-income countries (LMICs), where similar structural and operational deficiencies are widespread (Olawuyi *et al.*, 2020; Edet, 2022; Ovuru *et al.*, 2023; Nigussie *et al.*, 2025).

Microbial counts recorded further emphasise the unsanitary status of the facility. High aerobic and coliform counts across sample types indicate widespread environmental contamination, with borehole water exhibiting highest microbial load. This suggests that water used for slaughter and washing is a critical vehicle for bacterial spread, a finding consistent with studies that demonstrate untreated abattoir water as a significant contamination route for carcasses and utensils (Eze & Phil-Eze, 2020; Ogbeibu & Erhirhi, 2021). While statistical comparisons did not reveal significant differences across sources, the consistently elevated counts could indicate a general breakdown of sanitation that transcends specific contamination points. In food safety risk assessment, such system-wide contamination is often more alarming than localized hotspots, as it suggests that no part of the processing chain is safe from microbial infiltration.

The detection of *Staphylococcus* spp. on Mannitol Salt Agar highlights human handling as another important contributor to contamination. The highest counts in borehole and drainage water suggest environmental persistence, but recovery from knives and tables points strongly to cross-contamination mediated by butchers and meat handlers. Similar findings have been reported in Tanzania (Mlimbila *et al.*, 2018), Kenya (Obanda *et al.*, 2022), and Ghana (Suuk *et al.*, 2025), where

Staphylococcus aureus was linked to poor worker hygiene and lack of protective equipment in slaughterhouses. Although statistical differences were not significant, the trends observed here reinforce the importance of handler-focused interventions, such as provision of hand washing facilities, training, and use of personal protective equipment.

The bacterial isolates identified, in this study, reflect both faecal contamination and potential zoonotic threats. *Escherichia coli* was the most prevalent, and this is consistent with previous reports that identified it as the dominant contaminant in Nigerian and sub-Saharan abattoirs (Ajuwon *et al.*, 2021; Aworh *et al.*, 2022; Wada *et al.*, 2025). Its ubiquity across all sample types highlights faecal material as a major contamination source, whether via animal hides, intestinal contents, or handler contact. The presence of *Salmonella* and *Shigella* is of particular concern, as these pathogens are linked to severe foodborne outbreaks and have been documented in meat products traced back to abattoir contamination (Bawa *et al.*, 2020; Sosah & Donkor, 2025).

The significant association between bacterial occurrence and sample sources may suggest that certain niches, such as knives and drainage water, act as reservoirs and amplification points for specific pathogens. For instance, restriction of *Shigella* to drainage water emphasises the role of waste effluents in harboring enteric pathogens, which can easily contaminate community water supplies if untreated. This aligns with One Health perspectives that abattoir effluents are not only food safety hazards but also environmental and public health threats, contributing to diarrhoeal disease burdens in surrounding populations (Aworh *et al.*, 2022; Anele *et al.*, 2023; Ogwu *et al.*, 2024).

Comparisons of the abattoir in this study with abattoirs in other LMICs reveal similarities. Investigations in Ethiopia, Ghana, and India reported similar patterns of poor infrastructure, high microbial loads, and frequent isolation of enteric pathogens (Rajpal *et al.*, 2022; Suuk *et al.*, 2025; Zaba *et al.*, 2025). On the other hand, countries that have implemented structured hazard analysis and critical control point (HACCP) systems, such as Brazil and South Africa,

report lower microbial contamination and reduced prevalence of pathogens in slaughterhouses (Rodrigues *et al.*, 2019; Costa *et al.*, 2020). This contrast emphasises the effectiveness of structural and procedural interventions in mitigating contamination.

From a public health perspective, there are significant implications of these findings. Abattoir workers, meat vendors, and consumers are directly at risk of foodborne infections. Beyond acute gastroenteritis, long-term consequences include nutritional losses, economic burdens, and exacerbation of antimicrobial resistance (Gebeyehu & Tsegaye, 2022). The proximity of food vendors to slaughter operations further magnifies risk by facilitating direct transmission of pathogens from meat processing activities to ready-to-eat foods. To address these challenges, there is need for a multifaceted approach including structural and behavioural interventions. Also of importance are policy reform and enforcement. While Nigeria has launched the National Policy on Food Safety (Codex, 2023), implementation at the abattoir level remains weak. Hence, there is need to align local practices with international standards through the strengthening of regulatory oversight, investment in facility modernization, and instituting of HACCP-based systems.

Furthermore, the One Health paradigm provides the most appropriate framework for addressing the interconnected risks highlighted in this study. Abattoirs are critical points where human, animal, and environmental health intersect. Effective interventions must therefore go beyond working in isolation, bringing together veterinary services, environmental health, and public health agencies in coordinated action.

This study contributes valuable evidence on the sanitary and microbiological status of a major Nigerian abattoir. While limited to one site and without molecular identification of isolates, its findings highlight urgent intervention points for reducing microbial contamination and protecting public health. Future studies should incorporate longitudinal sampling, molecular characterization of isolates, and antimicrobial resistance profiling to deepen understanding of risk pathways and inform targeted interventions.

CONCLUSION

The Zango abattoir, Zaria Nigeria represents a critical point of exposure to foodborne and environmental pathogens. The combination of poor hygiene, unsafe water use, and high microbial contamination underscores the urgent need for investment in abattoir modernization, regulatory enforcement, and One Health-based surveillance. Addressing these gaps will not only improve meat safety in Zaria but also contribute to Nigeria's broader efforts to strengthen food safety systems and combat antimicrobial resistance.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this article.

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